T.C.
BAHÇEŞEHİR ÜNİVERİTESİ

THE SELECTION OF THE PROCESS OF WASTE ELECTRIC AND ELECTRONICAL EQUIPMENT MANAGEMENT

Graduate Thesis

ÇAĞRI ÖZGÜN

İSTANBUL,2008

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SUPERVISOR: ASISTANT PROF. F. TUNÇ BOZBURA

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I certify that this thesis meets all the requirements as a thesis for the degree of Master of Science.

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This is to certify that we have read this thesis and that we find it fully adequate in scope, quality and content, as a thesis for the degree of Master of Science.

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ABSTRACT

SELECTION OF THE PROCESS OF WASTE ELECTRIC AND ELECTRONICAL EQUIPMENT MANAGEMENT

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Supervisor: Yard. Doç. F. Tunç BOZBURA

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Being a consumption society; avoiding its responsibilities is the handicap of today's world. During last decades, according to the mass of human population and its demands, rapid urbanization, technological innovations, shorten product life and market expansion of electrical electronic equipments; a new type of problem challenge the world biologically, physically and socially which define as Waste of Electrical Electronical Equipment. It's becoming larger quantities of waste stream around the world which threats the human health and poses risks to the environment. To handle these consequences, the process of waste management has to be drawn clearly from the production to the disposal, but the requirements, capabilities and process of management differ relatively to existing methods, status and economy of country.

This paper provides a general overview of WEEE data and management practices employed in the world and Turkey. In Turkey, adequate legal and legislative arrangement, lack of social and governmental responsible and weak capabilities of industry to implement and enforce the waste management create a conflict typical for developing countries and constrain the right and useful application possibilities to manage WEEE as reuse or recycling.

In this paper, WEEE's data taken from the fabric Oyak Renault is operated with the processes different which are modeled according to reuse and recycling methods and are compared by cooperation of some expertise firms, civic governments and ministry of environment. The target is analyzing the effectiveness in perspective of environmental impact, recovery quantity and economic benefit. The study is realized by two multi criteria decision making practices: one of the multi objective decision making, Fuzzy Goal Programming and one of the multi criteria decision making, Fuzzy AHP focused on the selection of the right model. Thus the comparison of the processes becomes the comparison of two practices. The problems are solved by Lindo and according to the direction of the results the selection of processes and choices are criticized.

According to results, it is observed the proposed models are preferable and effective than existing. Although a proposed, developed model for WEEE management need more investments and provisions; their economic, quantitative, environmental recovery and social impact achieve more advantages over the long terms.

Keywords: Waste Electric and Electronic Equipment (WEEE), Recovery, Recycling/Reuse, Decision Making, Fuzzy goal Programming, AHP

ÖZET

ELEKTRİKLİ VE ELEKTRONİK ATIKLARIN YÖNETİM SÜREÇLERİNİN SEÇİLMESİ

Çağrı Özgün

Endüstri Mühendisliği Yüksek Lisans Programı
Tez Danışmanı: Yard. Doç. F. Tunç BOZBURA

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Tüketim toplumu olmak ve bunun sorumluluklarını göz ardı etmek; bugün dünyanın karşı karşıya kaldığı handikaplardan biridir. Günümüzde artan insan nüfusu ve ihtiyaçları, hızlı kentleşme, inovasyon, kısalan ürün hayat döngüleri ve elektrik elektronik pazarındaki büyüme bizi yeni bir sorumlulukla tanıştırmıştır: Elektrikli ve elektronik aygıt atıkları (EEAA).

Çevre ve insan sağlığı açısından taşıdığı riskler düşünüldüğünde bu atıkların sonuçlarıyla baş edebilmek için üretiminden bertaraf edilmesine kadar planlanmış etkin bir atık yönetimi düzenlenmeli ve ülkelerin statüleri, ekonomileri, mevcut durumları hesaplanarak bu süreç ve onun ihtiyaçları ve yeterlilikleri tasarlanmalıdır.

Bu çalışmada dünyadaki ve Türkiye'deki EEAA verileri ve yönetimleri hakkında genel bir öngörü oluşturulmuş. Bu bilgiler ışığında Türkiye için olası süreçler tanımlanmış ve uygun bir yönetim modeli kurulmuştur. Oyak Renault Fabrikasından alınan veriler geri dönüşüm ve yeniden kullanma yöntemlerine göre işletilmiş ve ortaya çıkan modeller Doğa Entegre Geri Dönüşüm Endüstri A.Ş. firmasının danışmanlığı ile kıyaslanmıştır. Çalışmanın hedefi çevresel ve ekonomik faydalar ve geri dönüşümü sağlanan ürün miktarı açısından süreçleri değerlendirmek ve seçim yapabilmektir. Çalışma çok kriterli (amaçlı) karar verme yaklaşımlarından geliştirilen iki yöntem kullanılarak gerçekleşmektedir: Çok amaçlı karar verme (Bulanık Hedef Programlama) ve bulanık çok ölçütlü karar verme (Bulanık AHP). Modeller Lindo ile çözümlenmiş ve sonuçlar doğrultusunda süreç seçimleri yorumlanmıştır.

Elde edilen sonuçlara göre, uygulamada önerilen model mevcut modellere oranla daha fazla yatırıma ihtiyaç duymasına rağmen çevre ve yeniden kullanım sonuçları ile tercihe edilebilecek etkin bir yöntem olarak görülmüştür. Geri dönüşüm ve yeniden kullanım kavramı ele alındığında uzun dönemlere yayılmış avantajlar ölçüt olarak göz önünde bulundurulmalıdır; böylece üreticiler için yeni bir hammadde kaynağı, tüketiciler için alternatif ürün profili ve sanayi için de daha çevreci bir üretim sahası yaratılabilmektedir.

Anahtar Kelimeler: Elektrikli ve Elektronik Aygıt Atıkları (EEAA), Geri Dönüşüm/Yeniden Kullanım, Bulanık Hedef Programlama, AHP

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1. INTRODUCTION

The balance between production and consumption is critical line whish is have to drawn diligently. However the consumption supported by humankind and influenced by world population take an advantage situation whereas the resources of world exhausting rapidly. The humankind has to show attention to produce, create new values and discover new type of resource similarly to consume. Because the resources of world already limited for the next periods; we have to produce, consume then produce and use again the one consumed. Thus the recovery of used products which could be defined as waste management is becoming the critical. It is the major concern of industrialized and densely populated countries because of the huge amount of waste produced after manufacturing or consumption. (Fleischman,2001)

Product recovery has been considered as a logistic function besides an engineering function; but the direction of process is reverse. The process begins with the collection of products generally from consumers and finished at producers as a raw material or part. The logistics notion includes many activities as return to supplier, remanufacture, and sale at second hand market, recycle, etc.

Because of unsatisfied demand, rapid change in technology, increasing consumption and irresponsible human behaviors (like preference of brand, desire of acquiring the last product in market on the contrary preference of functionality); the diversity of waste is enormous. Paper, glass, household, metal, medical, industrial waste are the some first comers examples. In this study, we observe a specific example of waste: the waste electric and electronical equipment (WEEE).

The world is contending with larger quantities of electronics are coming into the waste stream without attention of societies. Managing the increasing volumes of e-waste effectively and efficiently–in cost and environmental impact–is a complex task. Collecting the e-waste, separating e-waste from its many hazardous substances which are extremely dangerous to human health and the environment and their disposal is evaluating with special logistic requirements and special treatment to prevent the leakage and dissipation of toxics into the environment. Besides these weakness, being a rich source by recovery create lucrative business in both developed as well as developing countries. While some countries have organized systems for the collection, recycling, disposal and monitoring, other countries are still to find a solution that ensures jobs while minimizing the negative environmental impacts of e-waste recycling. The research expresses the current situation of countries and Turkey briefly.

To perceive the WEEE as a value added services besides its own business sector (EEE) for the manufacturing, information technologies, energy industry and also for national economy and ecology; the management of WEEE have to be a national and civil strategy. All of the level in industry (hierarchical government to secondhand dealers and consumer) is organized considering the benefits to cycle of process.

The research focuses on the strategies of effective management of WEEE, the process of recovery of WEEE and selection of a process of WEEE management whose implementation achieve more higher revenue in different means. In this study; we choose a fabric to realize the process of WEEE management and observe the results according to movements of variables.

As we mentioned that the process contain variables; the management of WEEE include also, some constraints (like limited storage area, cost of investment's limit, environmental responsibilities, etc.) or some targets as higher revenue, lower damage level of human health of environment or entities as current companies working on recycling, collection, etc. and selection of each of them make the problem complex.

Multi criteria decision making is an approach which is identifying and choosing the best decision under the alternatives depend on values and preference of situation. This approach helps us to find a reasonable solution where the alternatives make the problem environment conflicting. The management of WEEE has to be chosen relatively to the company, government or country's most preferred targets. Thus the best approximation could be obtained by the help multi criteria decision making.

The methods used in the research are fuzzy goal programming (FGP) and fuzzy Analytical Hierarchy Process (AHP). The common parts of two different methods are that both are operation the approach of multi criteria decision making and both are fuzzy; since the area of study include uncertainty as randomness and risk as non-predictable variables. To handle such problem fuzzy extension of each decision could be helpful.

Both of the methods decide the feasible and better process of WEEE management. Although FGP introduce quantitative result according to information given and has a chance to evaluate the goals simultaneously; Fuzzy AHP introduce linguistic decisions by adding the expertise views to the problem and subsequently evaluate more criteria which couldn't be expresses quantitatively or by absolute numbers.

In the first part, we profoundly represent the definition, the process and management of WEEE by illustrating the current managements in the world. This part is concluded by the detailed portrait of WEEE system in Turkey. Second part is dedicated to the decision making and we introduce the methods which are realized the problem. The most important part of study is the application which could be the sample minimized of the process of WEEE. We confirm the most preferable type of process which could also be a compound of different types, but we try to minimize the complexity of problem to obtain more understandable results. The sample is the process of e-waste taken from an international automotive fabric, OYAK Renault A.Ş. The expertise used in the fuzzy AHP method and the approximate costs is provided by DOĞA Entegre Limited A.Ş. who is the first licensed recycler in Turkey. The research could be made broader by adding the revenues of product recovered.

In conclusion the study explicate the efficient process which could be the strategy of country to take an advantage in this developing business area, the weakness and strengths of the different processes and make a chance to compare the different multi criteria decision making methods.

2. THE DEFINITION AND THE PRESENTATION OF E-WASTE

Electronic waste (e-waste) or Waste Electrical and Electronical Equipment (WEEE) is a waste type consisting of any broken or unwanted electrical end electronical appliance. It is a point of concern considering that many components such equipment are considered toxic and are not bio-grabble.

E-waste for short - or Waste Electrical and Electronic Equipment (WEEE) - is the term used to describe old, end-of-life or discarded appliances using electricity. It includes computers, consumer electronics, fridges etc which have been disposed of by their original users. While there is no generally accepted definition of e-waste, often it is associated with relatively expensive and essentially durable products used for data processing, telecommunications or entertainment in private households and businesses. But the ever increasing digitalization of products blurs such a distinction from former electrical appliance such as a kettle, a boiler or an oven; all do or will soon contain electronic circuits and ultimately become e-waste.(Carroll, 2008)

2.1 What is E-Waste?

There has been also some conflict about the definition. Some activists define "Electronic waste" to include all secondary computers, entertainment devices electronics, mobile phones and other items, whether they have been sold, donated, or discarded by their original owner. This definition includes used electronics which are destined for reuse, resale, salvage, recycling or disposal. Others define the reusable (working and repairable electronics) and secondary scrap (copper, steel, plastic, etc.) to be "commodities", and reserve the use of the term "waste" for residue or material which was represented as working or repairable but which was discarded by the buyer.

Debate continues over the distinction between "commodity" and "waste" electronics definitions. Some exporters may deliberately leave obsolete or non-working equipment mixed in loads of working equipment (through ignorance, or to avoid more costly treatment processes for 'bad' equipment). On the other hand, some importing countries specifically seek to exclude working or repairable equipment in order to protect domestic manufacturing markets. "White box" computers ('off-brand' or 'no name' computers) are often assembled by smaller scale manufacturers utilizing refurbished components. These 'white box' sales accounted for approximately 45% of all computer sales worldwide by 2004, and are considered a threat to some large manufacturers, who therefore seek to classify used computers as 'waste'.

While protectionists may broaden the definition of "waste" electronics, the high value of working and reusable laptops, computers, and components (e.g. RAM), can help pay the cost of transportation for a large number of worthless "commodities". Broken monitors, obsolete circuit boards, short circuited transistors, and other junk are difficult to spot in a container load of used electronics.

Until such time as equipment no longer contains such hazardous substances, the disposal and recycling operations must be undertaken with great care to avoid damaging pollution and workplace hazards, and exports need to be monitored to avoid "toxics along for the ride". [16]The table below show the categories of e-waste used in European Union legislations.(wikipedia, 2008)

Table 2.1: The contents of EU legislations

EU WEEE Directive
Large Household Appliances Washing machines, Dryers, Refrigerators, Air-conditioners, etc.
Small Household Appliances Vacuum cleaners, Coffee Machines, Irons, Toasters, etc
Office, Information & Communication Equipment PCs, Laptops, Mobiles, Telephones, Fax Machines, Copiers, Printers etc.
Entertainment & Consumer Electronics Televisions, VCR/DVD/CD players, Hi-Fi sets, Radios, etc
Lighting Equipment Fluorescent tubes, sodium lamps etc. (Except: Bulbs, Halogen Bulbs)

Electric and Electronic Tools Drills, Electric saws, Sewing Machines, Lawn Mowers etc. (Except: large stationary tools/machines)
Toys, Leisure, Sports and Recreational Equipment Electric train sets, coin slot machines, treadmills etc.
Medical Instruments and Equipment
Surveillance and Control Equipment
Automatic Issuing Machines Legend: WEEE Directive implemented by Member States by August 2005 – 08

WEEE is non-homogenous and complex in terms of the materials and components. Many of the materials are highly toxic, such as chlorinated and brominated substances, toxic metals, photoactive and biologically active materials, acids, plastics and plastic additives. Major categories of hazardous materials and components of WEEE are listed in Table 2.2.

Table 2.2: Major hazardous components in waste electric and electronic equipment

Materials and components	Description
Batteries	Heavy metals such as lead, mercury and cadmium are present in batteries
Cathode ray tubes (CRTs)	Lead in the cone glass and fluorescent coating cover the inside of panel glass
Mercury containing components	Mercury is used in thermostats, sensors, relays and switches; it is also used in medical equipment, data transmission, telecommunication, and mobile phones
Asbestos waste	-
Toner cartridges, liquid and pasty, as well as color toner	-
Printed circuit boards (PCB's)	Cadmium occurs in certain components
Polychlorinated biphenyl containing	-

Capacitors	-
Liquid crystal displays (LCD’s)	-
Plastics containing halogenated flame	During incineration/combustion of the plastics
Retardants	Halogenated flame retardants can produce toxic components
Equipment containing CRC HCFC or HFC’s	HCFC or CFC’s are present in the foam and the refrigerating circuit
Gas discharge lamps	Mercury is present in them

With these hazardous elements, WEEE can cause serious environmental problems during disposal if not properly pretreated. For example, the cadmium from one mobile phone battery is sufficient to pollute 600.000 lt. of water. Growing attention is being given to the impacts of the hazardous components in WEEE on the environment.

Electronic waste is a valuable source for secondary raw materials, if treated properly, however if not treated properly it is a major source of toxins and carcinogens. Technical solutions are available but in most cases a legal framework, a collection system, logistics and other services need to be implemented before a technical solution can be applied. The Association of Plastics Manufactures in Europe released their statistics of material consumption in EEE in Western Europe in 1995. Relatively the composition was as follows: 38% ferrous, 28% non-ferrous, 19% plastics, 4% glass, 1% wood, and 10% others.

In general, printed circuit board (PCB) scrap contains approximately 40% metals, 30% plastics, and 30% ceramics. The typical metal scrap in PCB consists of copper (20%), iron (8%), tin (4%), nickel (2%), lead (2%), zinc (1%), silver (0.2%), gold (0.1%), and palladium (0.005%). Polyethylene, polypropylene, polyesters, polycarbonates and phenol formaldehyde are the typical plastic components. These materials are valuable and could be recycled by proper technologies. Besides, a significant amount of disposed equipment might be collected for reuse or remanufacturing. (Wenzhi et al. 2006)

Table 2.3: List of example applications of the elements and substances

Lead	Solder, CRT monitors (lead in glass), lead-acid batteries
Tin	Solder
Copper	Copper wire, printed circuit board tracks
Cadmium	Light-sensitive resistors, corrosion-resistant alloys for marine and aviation environments
Aluminum	Nearly all electronic goods using more than a few watts of power (heat sinks)
Iron	Steel chassis, cases and fixings
Silicon	Glass, transistors, ICs, printed circuit boards
Nickel and cadmium	Nickel-cadmium batteries
Lithium	Lithium-ion battery
Zinc	Plating for steel parts
Gold	Connector plating, primarily in computer equipment
Americium	Smoke alarms (radioactive source)
Germanium	1950s–1960s transistorized electronics (bipolar junction transistors)
Mercury	Fluorescent tubes (numerous applications), tilt switches (pinball games, mechanical doorbells, thermostats)
Sulphur	Lead-acid batteries
Carbon	Steel, plastics, resistors. In almost all electronic equipment

2.2 Waste Management: How Can We Deal With E-Waste?

We identified the components and the hazardous substances of this type of waste; but none of consumers or producers aren't enough aware of these information. Consumers and producers have focused on new properties, technologies, brands and innovation of equipment. They haven't realized the consequences yet: Environmental impact, Health care perspective, social impact internationally, capacities of the factor terrestrial.

According to Cui and Forssberg (2003), the production of electronic and electrical equipment (EEE) is one of the fastest growing areas. In the meantime, both technological innovation and market expansion of EEE are accelerating the replacement of outdated EEE, leading to a significant increase in waste of EEE (WEEE) that induces a new environmental challenge.

In West Europe, 6 million tones of WEEE were generated in 1998, and the amount of WEEE was expected to increase by at least 3–5% per annum (Poonam, Arvind 2007). In the USA, it was said that over 315 million computers would reach their date of expiration by 2004 (Kang, Schoenung 2005). In Australia, there are approximately 9 million computers, 5 million printers and 2 million scanners currently in households and businesses, and all of them will be replaced, most within the next couple of years. (Wenzhi et al. 2006)

From past records, it seems certain that new problems of physical, biological and social change, not now widely anticipated, will arise sooner than later. This is because our scientific knowledge of each of these systems is incomplete, the mass of human population and its demands are increasing relentlessly and the possible human adjustments and adaptations, including technology, are multiplying (White, 1996). Only a few years ago, some of the environmental issues of concern included the trio: acid rain, stratospheric ozone layer depletion and global warming.

Today, waste electrical and electronic equipment (WEEE) or electronic waste (e-waste) generation, trans-boundary movement and disposal are becoming issues of concern to solid waste management professionals, environmentalists, international agencies and governments around the world (Musson et al., 2000; Cui and Forssberg, 2003).

The useful life of consumer electronic products is relatively short, and decreasing as a result of rapid changes in equipment features and capabilities (Kang and Schoenung, 2004). This creates a large waste stream of obsolete electronic equipment. Due to their hazardous material contents, WEEE may cause environmental problems during the waste management phase if it is not properly pre-treated. As a result, many countries have drafted legislation to improve the reuse, recycling and other forms of recovery of such wastes in order to reduce disposal (Nnorom,Osibanjo 2007).

Electronic waste recycling is gaining currency around the world as larger quantities of electronics are coming into the waste stream. Managing the increasing volumes of e-waste effectively and efficiently–in cost and environmental impact–is a complex task. Firstly, special logistic requirements are necessary for collecting the e-waste.

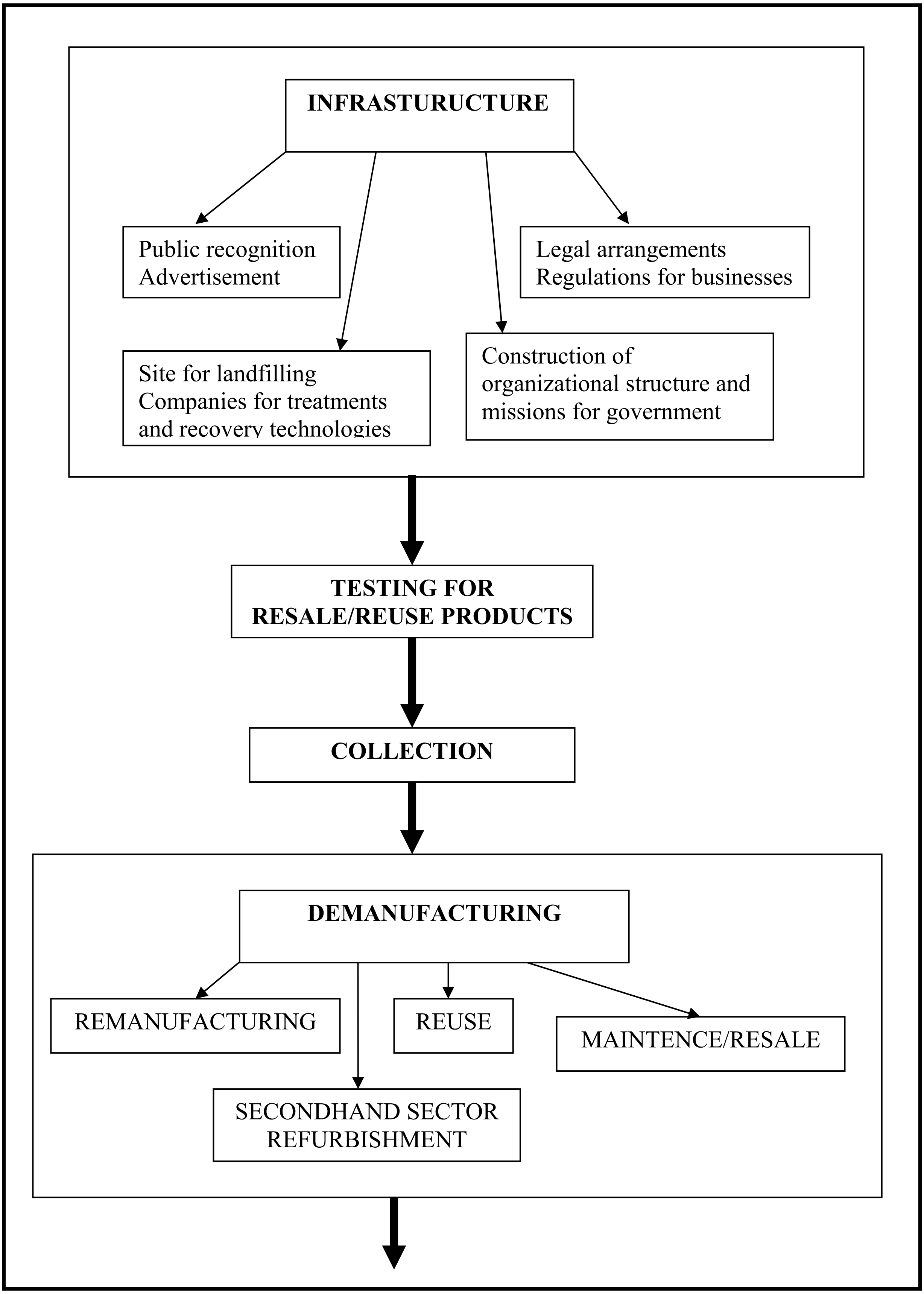
Secondly, e-waste contains many hazardous substances which are extremely dangerous to human health and the environment, and therefore disposal requires special treatment to prevent the leakage and dissipation of toxics into the environment.

At the same time, it is a rich source of metals such as gold, silver and copper, which can be recovered and brought back into the production cycle. This particular characteristic of e-waste has made e-waste recycling a lucrative business in both developed as well as developing countries. While some countries have organized systems for the collection, recycling, disposal and monitoring, other countries are still to find a solution that ensures jobs while minimizing the negative environmental impacts of e-waste recycling.

To perceive the WEEE as a source of raw materials and energy or as a products of recycling to reuse and resale or as a value added services besides its own business sector (EEE) for the manufacturing, information technologies, energy industry and also for national economy and ecology; the management of WEEE have to be a national and civil strategy. All of the level in industry (hierarchical government to secondhand dealers and consumer) is organized considering the benefits to cycle of process.

Consequently the process of waste management has to be drawn clearly. It's obvious that the requirements are differing according to status of countries (developing countries, developed countries, third world countries) , and status of existing methods for waste management (landfilling areas , collectors , recyclers in competition ,etc.).

We can design a process scheme which helps us to determine the steps of management as following (Figure 2.1).


INFRASTURUCTURE
Public recognition
Advertisement
Legal arrangements
Regulations for businesses
Site for landfilling
Companies for treatments
and recovery technologies
Construction of
organizational structure and
missions for government
TESTING FOR
RESALE/REUSE PRODUCTS
COLLECTION
DEMANUFACTURING
REMANUFACTURING
REUSE
MAINTENCE/RESALE
SECONDHAND SECTOR
REFURBISHMENT

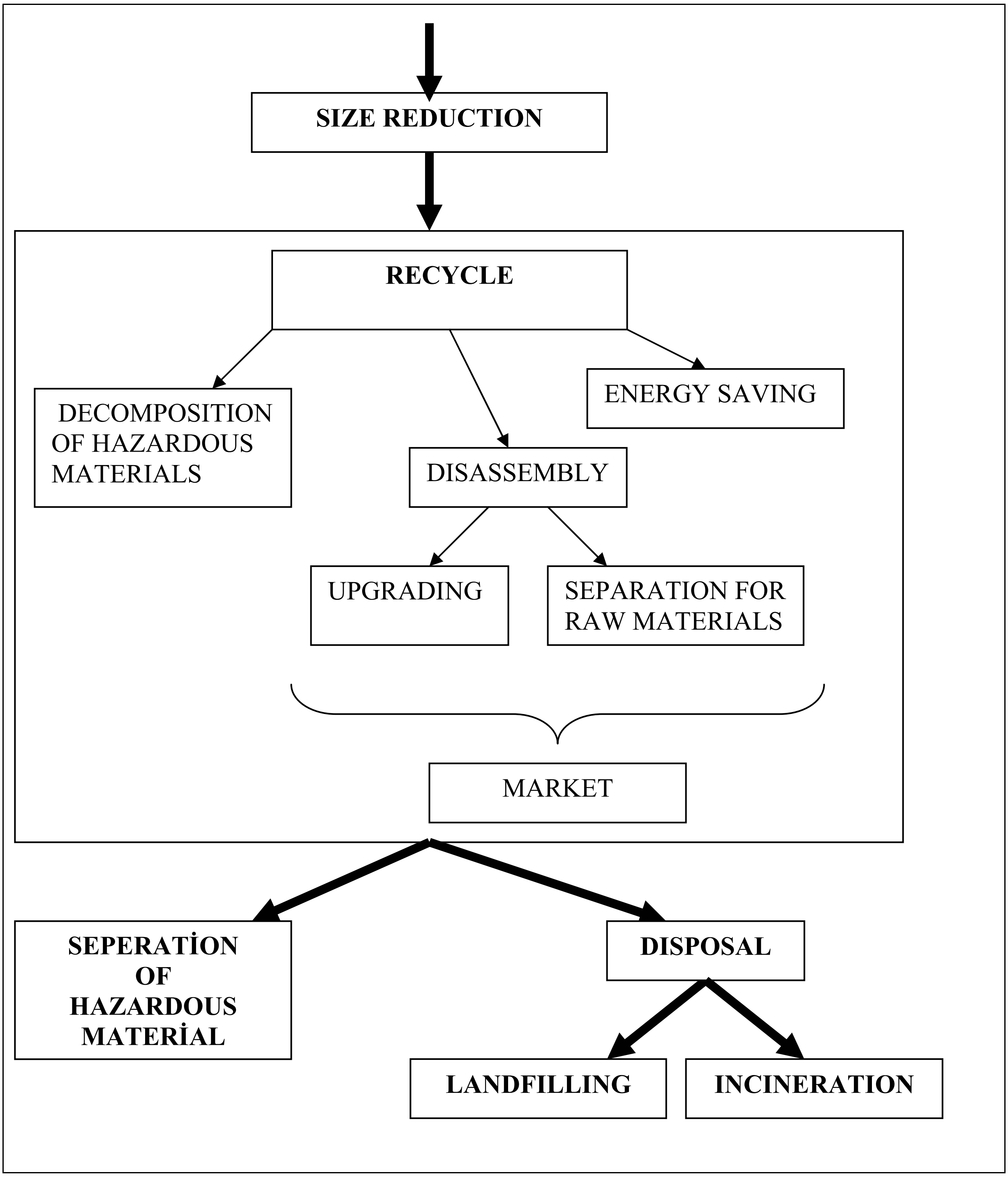


Figure 2.1: The steps of waste management's process

2.2.1 Infrastructure

Public Recognition & Advertisement: With the development of electronic technologies, the residual value of outdated electronic devices decreases rapidly. Both the recovery value of parts and the machine resale value drop rapidly with the age of the machines. For example, a computer's value approaches zero for machines with technologies more than two generations old. Furthermore, old equipment is more difficult to recycle than newer equipment. Because electronic recycling is in its infancy, consumer recognition of the need for recycling is a critical factor to the further expansion of this industry. Many consumers do not recycle their electronic products when they first become defunct or obsolete. Consequently the government has to make public conscious of the waste management programs. Effective electronics recycling requires that consumers both have access to recycling programs and have knowledge of such programs. This essentially means that consumers need to know where to take their electronic devices when they become obsolete or defunct (Kang, Schoenung 2004)

Legal Arrangement & Regulation for Companies: There have been some examples in the developed countries such as ARF (advanced recycle fees) and EPR (extended producers responsibilities) which is encouraged the businesses to join the cycle of waste management program. Also the arrangement state strictly the content of the hazardous substances and the equipments in which is containing them to inform producers. Regulations must control the production of EEE in industry and the level of capacities at the site of collection and land-filling.

For developing countries the process of waste recycling could become illegal as unregistered workers, child workers, unhealthy conditions, unrecorded income. Thus the directives construct a comprehensive, expanded and successful organization.

Site for Landfilling & Companies for Treatment and Recovery: One of the most important strategic decisions for any company is the location decision, since it affects long-term profits and costs. Changing a location decision is a very difficult and expensive process (Heizer and Render, 2001). Different models study the location decision problem using different location criteria. Models that first solved the location problem were based on quantitative criteria only, aiming at minimizing fixed costs and transportation costs between the production company and its clients. These models have become more complex and have been extended to companies with several products, or to networks of companies.

Additionally, uncertainties have been explicitly taken into account. Nevertheless, they do not consider non-monetary criteria (Queiruga et al. 2006).

Therefore, the numbers of applications of multi-criteria methods, which are able to take into account many objectives and quantitative as well as qualitative variables, has been increasing over the last few years. Using these methods, relevant criteria like quality and density of transportation and telecommunication networks, preferences of the entrepreneur, environmental influences, availability and quality of human capital, quality of life, provision of public services, and participation of the community can be considered.

Construction of Organizational Structure and Missions for Government: All of the waste program organization is related to government arrangements. The head of hierarchy is the government. The authority assigns the tasks to the departments or companies and controls their operations. Moreover it has to meet the requirements of the operations like land-filling areas, incineration plants, and experts on WEEE. There is some suggestion for government as following:

1. Ensure an effective system for monitoring of shipments, appropriate labeling and certification of the functionality of secondhand appliances
2. Implement economic policies such as ARF on new/second hand electrical electronic goods
3. Introduce value-added recovery (refurbishing and remanufacturing), material recovery (formal recycling technology) and energy recovery from the incineration of waste plastics.
4. Create a market of recovered components and modules
5. Assist with technology and funding for the formal recycling of e-waste and the disposal of hazardous components using appropriate disposal technology (Nnorom, Osibaji 2007).

2.2.2 Collection

The collection and transportation step is often the most costly step toward the reuse and recycling of electronic devices (Lonn and Stuart, 2002; IAER, 2003). It has been estimated that collection and transportation costs represent more than 80% of the total cost of recycling (Hainault and Smith, 2000). Table 2.4 shows a summary of collection options and transportation responsibilities.

Table 2.4: Summary of collection options and transportation responsibilities

Collection options	Responsible for transportation		Advantages	Disadvantages
	To collection site	To recycling site		
Curb side	-	Local government or recycler	Convenient, Resident participation	Potential theft and abandonment, Need extra sorting, High transportation cost
Special drop-off event	Consumer	Local government or recycler	Increase recycling awareness, Good for rural area	Irregular collection amount Need storage space
Permanent drop-off	Consumer	Local government or recycler	High sorting rate, Low transportation cost. Most cost-effective	Need regular checking, Not effective for all communities
Take-back	-	OEMs or recycler contract with OEMs	No collection site needed	High shipment cost, Need special packaging, Consumers visit shipping location
Point-of-purchase	Consumer	Retailer	Low cost, High visibility if promoted by retailer	Retailer commitment, Need storage space

Curbside collection consists of the collection of e-waste either on a periodic basis like a general municipal waste collection or by request. Co-existence of the e-waste collection with an existing curbside waste collection program can substantially reduce the operating costs. This collection model is the most convenient for residents. However, operating costs can be higher than for other collection options.

A special drop-off event is a 1 or 2 day event that is usually held over a weekend to maximize resident participation. In this collection option, the quantity of devices collected will depend on the extent of participation by consumers and the weather during the special event period. A special drop-off event is considered to be an ideal recycling program when experts from the repair industry work together with the program, because these experts can sort out the most valuable items for resale, repair, and reuse.

A permanent collection option is essentially a year-round collection event. The municipal solid waste collection site can be used for collection of e-waste, which results in negligible costs.

This type of program has been found to be the most cost-effective (IAER, 2003), however, this type of collection program is not desirable for every community size. This collection option requires that the quantity of collected devices be checked regularly and that the devices be transported to a recycler when certain quantities are collected.

In the point-of-purchase collection model, retailers of electronic products serve as the collection agency and consumers can bring old electronic equipment to a retailer when they purchase new electronic equipment. The active participation of the retailer is essential for this method of collection to be successful. Several original equipment manufacturers (OEM's) have established 'take-back' collection systems for collecting used electronic products from consumers. IBM, Dell, HP, and other computer manufacturers collect unwanted computer and related products regardless of the original manufacturer (Environmental and Plastics Industry Council, 2003) (Kang, Schoenung 2005).

2.2.3 De-manufacturing or Disassembly

Once the e- waste is collected, electronic waste is tested and sorted; because of the decision on strategies which is treated for reuse, repaired for resale or recycled. This step is the most critical in electronic waste management. The responsible have to classifier the wastes according to their circumstance of usage, their reason causing to become obsolete, their term of life, their components and whether they contain hazardous material. These acquirements guide the expert to choose the most appropriate strategy and process which e-waste will follow.

Collected equipment can be classified in a simple sense as reusable and recyclable. Thus target of reusable e-waste could be in

- Refurbishment system for secondary user or second hand market by repair or by detach malfunction part and add new part
- Remanufacturing system for secondary users and second hand market by adapting new properties or in new product as a specific part
- Component recovery system for same users as well by separating theirs parts as different usage options

In view of this perspective, the environmental problems and high residual value of WEEE, WEEE management system should be established to extend the life cycle of EEE. This management system comprises collection, classification, pre-treatment, etc., and five conventional end-of-life treatment strategies. In accordance with the potential economic and environmental efficiency, these strategies can be categorized as follows:

1. *Reuse:* the recovery and trade of used products or their components as originally designed;
2. *Servicing:* a strategy aimed at extending the usage stage of a product by repair or maintenance;
3. *Remanufacturing:* the process of removing specific parts of the waste product for further reuse in new products;

4. *Recycling (with or without disassembly):* including the treatment, recovery, and reprocessing of materials contained in the used products or components in order to replace the virgin materials in the production of new goods;
5. *Disposal:* the processes of incineration (with or without energy recovery) or landfill (Wenzhi et al. 2006)

Naturally the treatment of this step needs a specialized knowledge and experience. The economical value and demand is directly connected to success of these treatments. Also there are lots of researches about disassembly process like robotics. Still at successful and accurate conditions the parts ejected or products repaired wouldn't be preferred. The reason of preference would be cheap price, however these treatments end specialization increase the price and the substitute new product's price decrease in today economy and market conditions.

We mention that this step is based on the decision where the e-waste could be used and which strategy could be applied to extend its life cycle. Electronic products, like cars, are a combination of some valuable subcomponents and assemblies – such as the central microprocessor or hard drive – and those that have value only as materials, such as the printed circuit board or housing. The recovery options that are pursued must balance the costs of testing and disassembly, which tend to be labor intensive, with the incremental value of the components over their material value. The technological life cycle of a product has a profound interaction with this decision. For example, CRT's are a mature product for personal computers and have experienced rapid declines in prices in order to compete with liquid crystal displays (LCD's) that are penetrating the market. The resale value of recovered CRT's is, therefore, very low in their original markets. This discourages the testing and refurbishment of CRT's and increases the need to recover the leaded glass, metals, and plastics. However, as the market for CRT's declines, leaded glass itself will become obsolete and we will be faced with a disposal problem at a different level.

This problem is more complex for the computer itself, as whole systems, or subsystems can be reused and the obsolescence rate for chips and fixed drives has slowed, but prices for new components have continued to fall. A further complication is that testing, disassembly, and bulk recycling technologies scale in cost very differently with throughput. Thus, for small scale operations that have been adopted to deal with the historical flows of electronic products, disassembly has been possible, but as the volumes, variability, and age of systems increase, there will be a need to shift toward higher throughput, less manually intensive operations (Realff et al. 2004).

2.2.4 Recycling of WEEE

First we have to give a basic definition for recycling. As we mentioned before; Recycling is including the treatment, recovery, and reprocessing of materials contained in the used products or components in order to replace the virgin materials in the production of new goods. Recycling is significant step of the strategies for WEEE management; since the target quantity of waste is highest than the other steps. This means that the income of this step is higher.

First; the step begins with the separation of the hazardous substances. In the previous step, the de-manufacturing, the parts or units in the e-waste is saved for reuse or resale. Thus working systems, valuable components, and hazardous materials are removed from the e-waste, the materials recovery process begins. The primary goal of this process is to separate different types of materials that can be recovered and sold.

Prototypical examples of separation process are shown in figure 2.2 that the majority of the items collected consist of TVs, computers and monitors, and other appliances: Metals (49 wt. %), plastics (33 wt. %), and CRTs (12 wt. %) account for over 90 wt. % of collected e-waste (USEPA, 1999). According to research for residential electronic waste collection program in the U.S. when only computers are collected, the distribution is different: glass (25 wt. %), metals (48 wt. %), and plastics (23 wt. %) (Silicon Valley Toxics Coalition, 2004). When only TVs are considered, the distribution is glass (48 wt. %), plastic (15 wt. %), and metal (32 wt. %) (Materials for the Future Foundation, 1999b),(Khetriwal et al. 2005).

Table 2.5 shows a summary of the material types in de-manufactured TVs and computers. These results show that the major materials in electronic equipment are metals, plastics and glass.

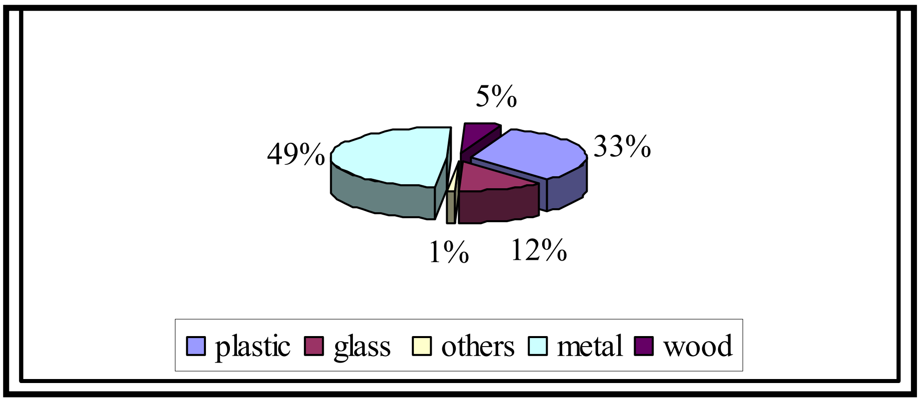


Fig. 2.2: Schematic of typical components of electronic waste

Table 2.5 : Summary of the material types in de-manufactured TV's and computers		
Materials	TV	Computer
Glass	47.6	24.8
Plastic	14.7	23.0
Printed wiring board	5.6	-
Precious metals	27.1	0.02
Iron	-	20.47
Lead	-	6.3
Aluminum	-	14.17
Copper	4.8	6.93
Others	-	4.3
Total	100	100

With the help of recycling technologies; WEEE become a source of raw materials and energy. To recover valuable materials from WEEE, the feed material initially needs to be liberated by mechanical processing so that the desirable fractions can be separated. Hammer mills and shredders are the most commonly used communication devices to reduce WEEE to finer fractions, thus, liberating the phases. Typical methods used to separate these liberated materials include manual sorting, magnetic separation, eddy current separation and air table sorting. (Scheafer et al., 2003) reported that these techniques have shown limited efficiency due to enormous loss of materials (Scheafer et al., 2003). For example, an eddy current separator would separate non-ferrous metals. However, other metals can also be influenced by the magnetic field and affect the purity of the end product. Since there is strict specification for the reuse and recycling of the materials, efficient sorting is of great importance (Bledzki et al., 2002), (Mohabuth, Miles 2004)

En general, the recycling could be composed of four parts: Mechanical/Physical Recycling, Chemical Processing, Thermal Processing and Biological Processing. The most appropriate and significant of them are mechanical and biological recycling.

2.2.4.1 Mechanical/Physical Recycling

The "mechanical" element is usually an automated mechanical sorting stage. This either removes recyclable elements from a mixed waste stream (such as metals, plastics, glass and paper) or processes them. It typically involves *factory style conveyors, industrial magnets, eddy current separators, trammels, shredders and other tailor made systems, or the sorting is made by hand*. (wikipedia 2008)

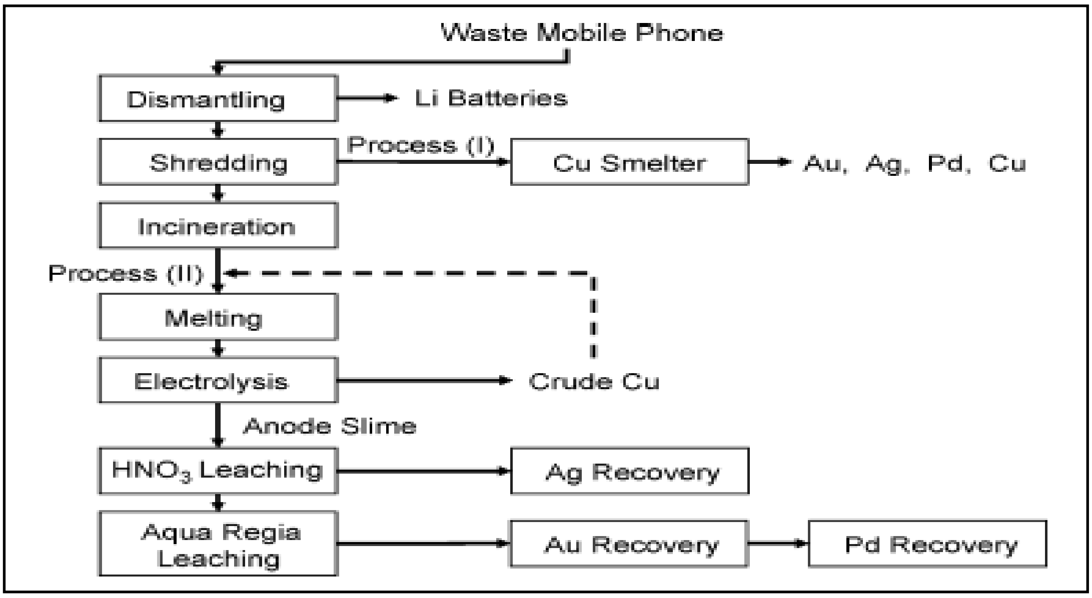


Fig. 2.3: Flow sheet for the recycling of metal values from waste mobile phones

With the steadily decreasing of the precious metal contents in EEE, the precious metal-oriented recovery techniques, such as hydrometallurgy and pyrometallurgy, are facing great challenges. On the other hand, mechanical/physical recycling of WEEE, due to its better environmental property and easier operability, is drawing more attention. Compared with hydrometallurgy and pyrometallurgy, mechanical/physical processes can achieve full material recovery including plastics.

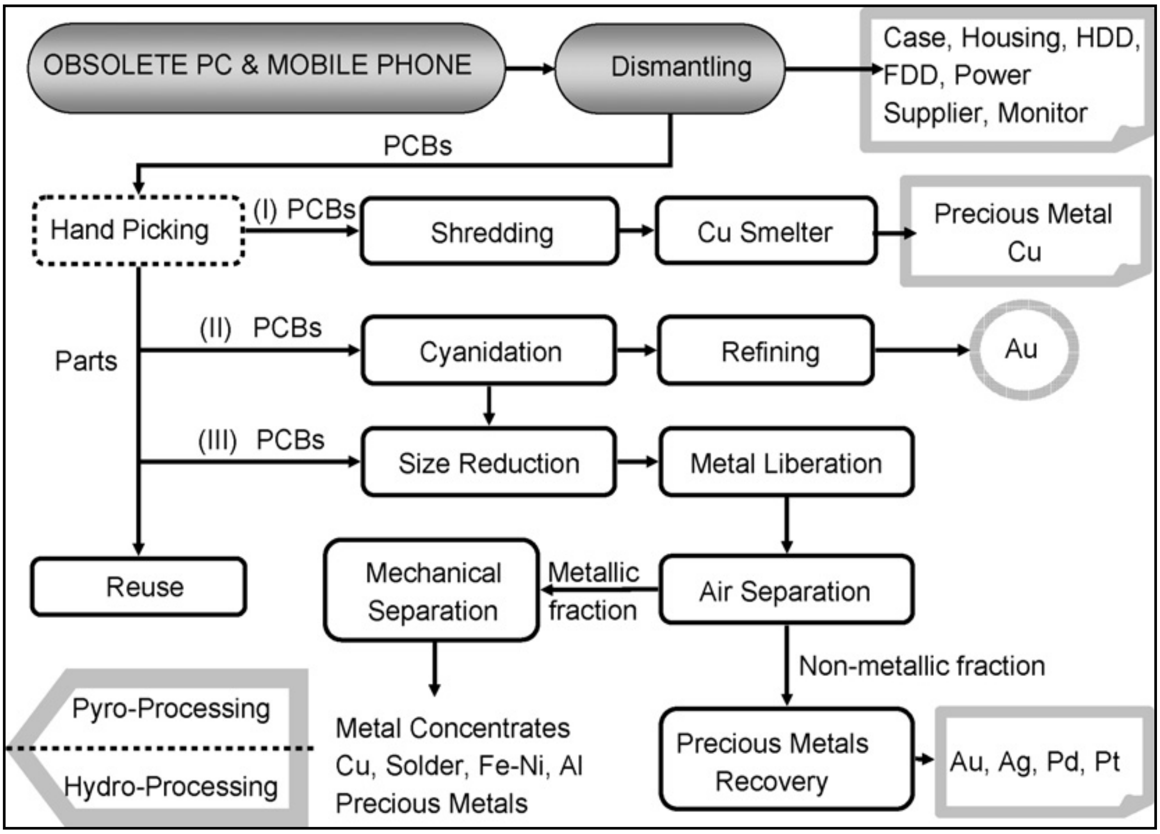


Fig. 2.4: Strategic processes for the recycling of waste PCBs

Mechanical recycling of WEEE can be broadly divided into three major stages.

- Disassembly (dismantling): targeting on singling out hazardous or valuable components.
- Upgrading: using mechanical/physical processing to upgrade desirable materials content, i.e. preparing materials for refining process

- Refining: in the last stage, recovered materials return to their life cycle. Disassembly and upgrading are two key processes of the mechanical recycling of WEEE.

Disassembly: Disassembly is a systematic process that removes a component or a part, or a group of parts or a subassembly from a product (i.e., partial disassembly); or splits a product into all of its parts (i.e., complete disassembly) for a given purpose. In WEEE recycling practice, selective disassembly (dismantling) is an indispensable process, since (1) the reuse of components is of the first priority, (2) dismantling the hazardous components is essential, and (3) it is important to dismantle highly valuable components and high grade materials such as PCBs, cables, and engineering plastics in order to simplify the subsequent recovery of materials (Wenzhi et al. 2006).

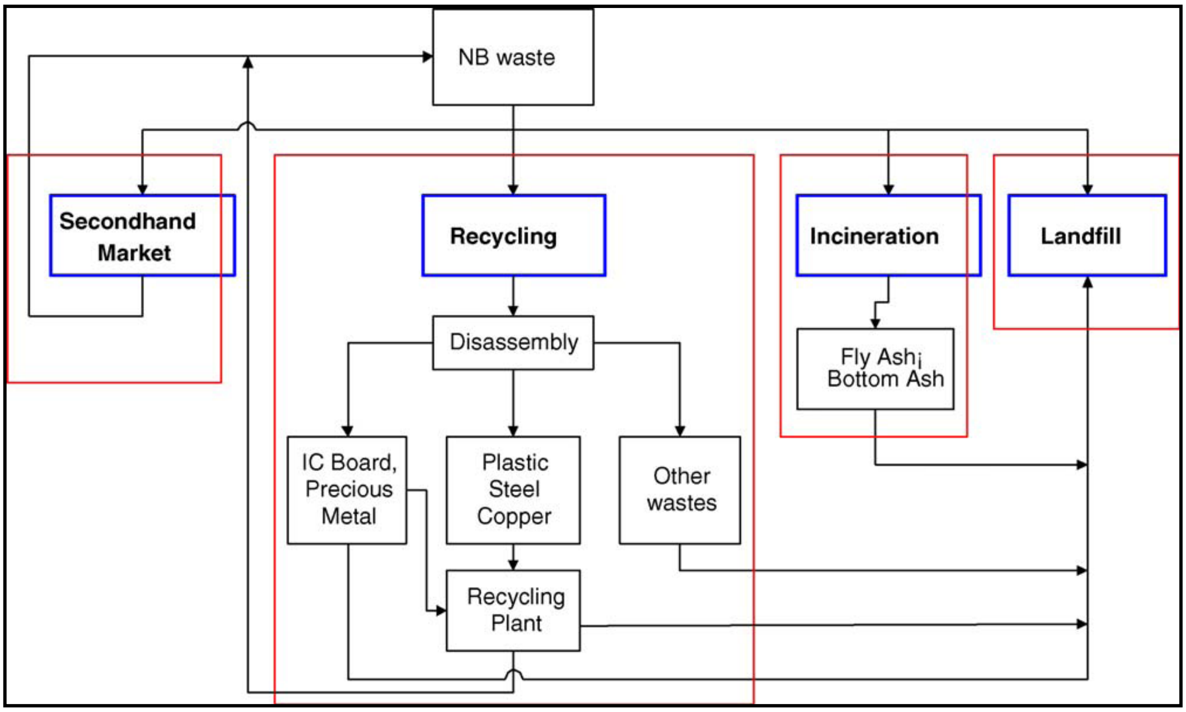


Fig. 2.5: An example of the schematic of disassembly of notebook

The implementation of disassembly needs highly efficient and flexible tools. The most attractive research on disassembly process is the use of robots. Unfortunately, full (semi) application of automation disassembly for recycling of EEE is full of frustration. Currently, there are only a few pilot projects for automated disassembly of keyboards, monitors and PCBs, and there is no (semi-) automated solution for the personal computer (PC) itself.

The manual disassembly aided by tools, due to its high flexibility, is currently the main dismantling process. A variety of tools are involved in the dismantling process for removing hazardous components and recovery of reusable or valuable components and materials. The disassembled cables, PCBs and metal/plastics mixture, being a mixture of various materials, should be further treated to upgrade the materials contents of them.

Upgrading: WEEE can be regarded as a resource of metals, such as copper, aluminum and gold, and non-metals. Effective separation of them, based on the differences in their physical characteristics, is another crucial process for recycling of WEEE. The upgrading usually includes two stages: comminuting and separating (Wenzhi et al. 2006).

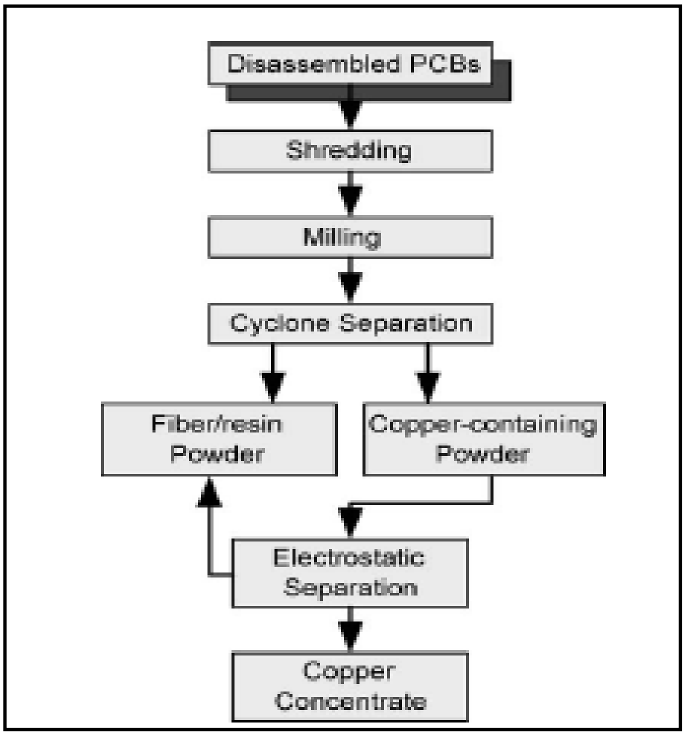


Fig. 2.6: PCB upgrading processing

- Comminuting is the first step of the physical upgrading process. Only when the disassembled WEEE is shredded to a proper granularity, can the materials of the WEEE be liberated one another, and then be separated effectively. Basically, the materials present in EEE are attached by fastening, inserting, welding, binding, wrapping and so forth. Therefore, it does not need much intensive energy to unlock the associated materials like ceramics, glass, and metals having distinctive mechanical properties. The optimized comminuting result is that every comminuted particle is made by sole material.

- After liberation of the materials in the disassembled WEEE through comminuting, the separation of them can then be performed by mechanical/physical methods. The differences on the physical characteristics of materials in non-homogeneous compounds, such as magnetism, electric conductivity and density, etc., are the bases of the mechanical/physical separation of them.

Mechanical/physical separation processes include electronic magnetic separation, electronic-conductivity-based separation, density-based separation and so forth. All of them have application instances in the WEEE recycling field. Magnetic separation is widely used for the recovery of ferromagnetic metals from non-ferrous metals and other nonmagnetic wastes. Over the past decade, the advances in the design and operation of high-intensity magnetic separators also make it possible to separate copper alloys from the waste matrix (Kang and Schoenung 2005).Electric conductivity-based separation is used to separate materials of different electric conductivity (or resistivity). There are three typical electric conductivity-based separation techniques: (1) eddy current separation, (2) corona electrostatic separation, and (3) tribo-electric separation.

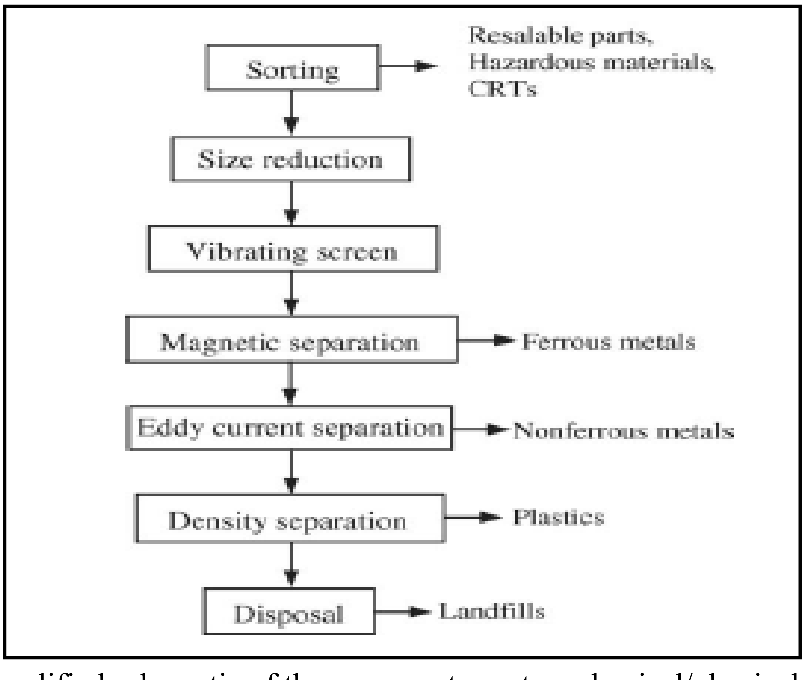


Fig 2.7: Simplified schematic of the process steps at mechanical/physical recycling

With the marked density difference between metals and nonmetals in WEEE powders, the heavier metal materials can be effectively separated from non-metal materials by the density based separation methods. In the practice of recycling WEEE, according to the requirements of the task, some of the above methods can be combined together to fulfill the separation of the materials present in WEEE (Kang and Schoenung 2005).

2.2.4.2 Biological Processing

The "biological" element refers to either: Anaerobic digestion , Composting , Bio-drying. Anaerobic digestion breaks down the biodegradable component of the waste to produce biogas and soil improver. The biogas can be used to generate electricity and heat. Biological can also refer to a composting stage. Here the organic component is treated with aerobic microorganisms. They break down the waste into carbon dioxide and compost. There is no green energy produced by systems employing only composting treatment for the biodegradable waste.

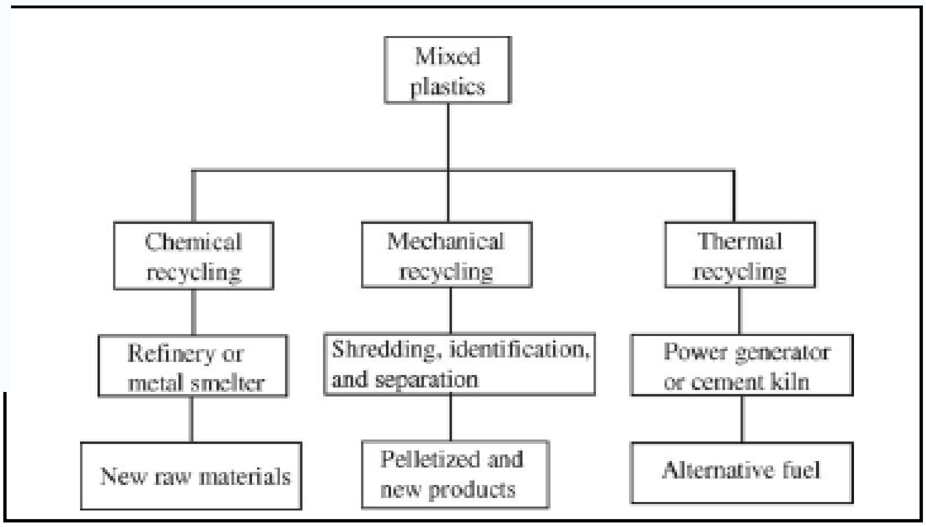


Fig. 2.8: Recycling option for managing plastics from e-waste

In the case of bio-drying, the waste material undergoes a period of rapid heating through the action of aerobic microbes. During this partial composting stage the heat generated by the microbes result in rapid drying of the waste. These systems are often configured to produce a refuse-derived fuel where a dry, light material is advantageous for later transport combustion. Products of this system could be recyclable materials such as metals, paper, plastics, glass etc.; unusable materials prepared for their harmless final deposit; carbon credits; high calorific fraction. The advantages of this type of process are that:

- The finally deposited waste is inert
- Reduction of the waste volume to be deposited to at least a half (density > 1.3 t/m³), thus the lifetime of the landfill is at least twice as long as usually
- Utilization of the leachate in the process
- No additional facilities for the collection and combustion of biogas as there is no biogas
- Daily covering not necessary, aftercare 3 to 5 years (wikipedia 2008)

The following figures are the examples of the complete process diagram for recycling technologies.

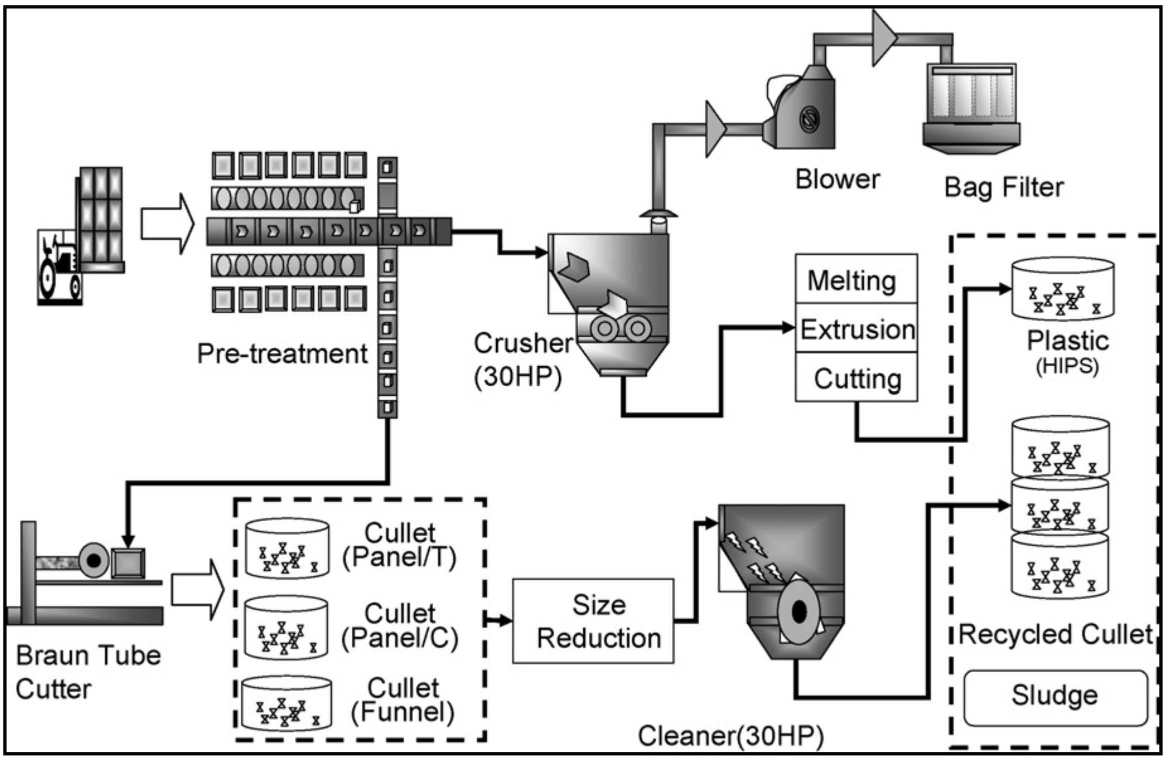


Fig. 2.9: Simplified flow diagram of waste televisions and CRT monitors recycling plant

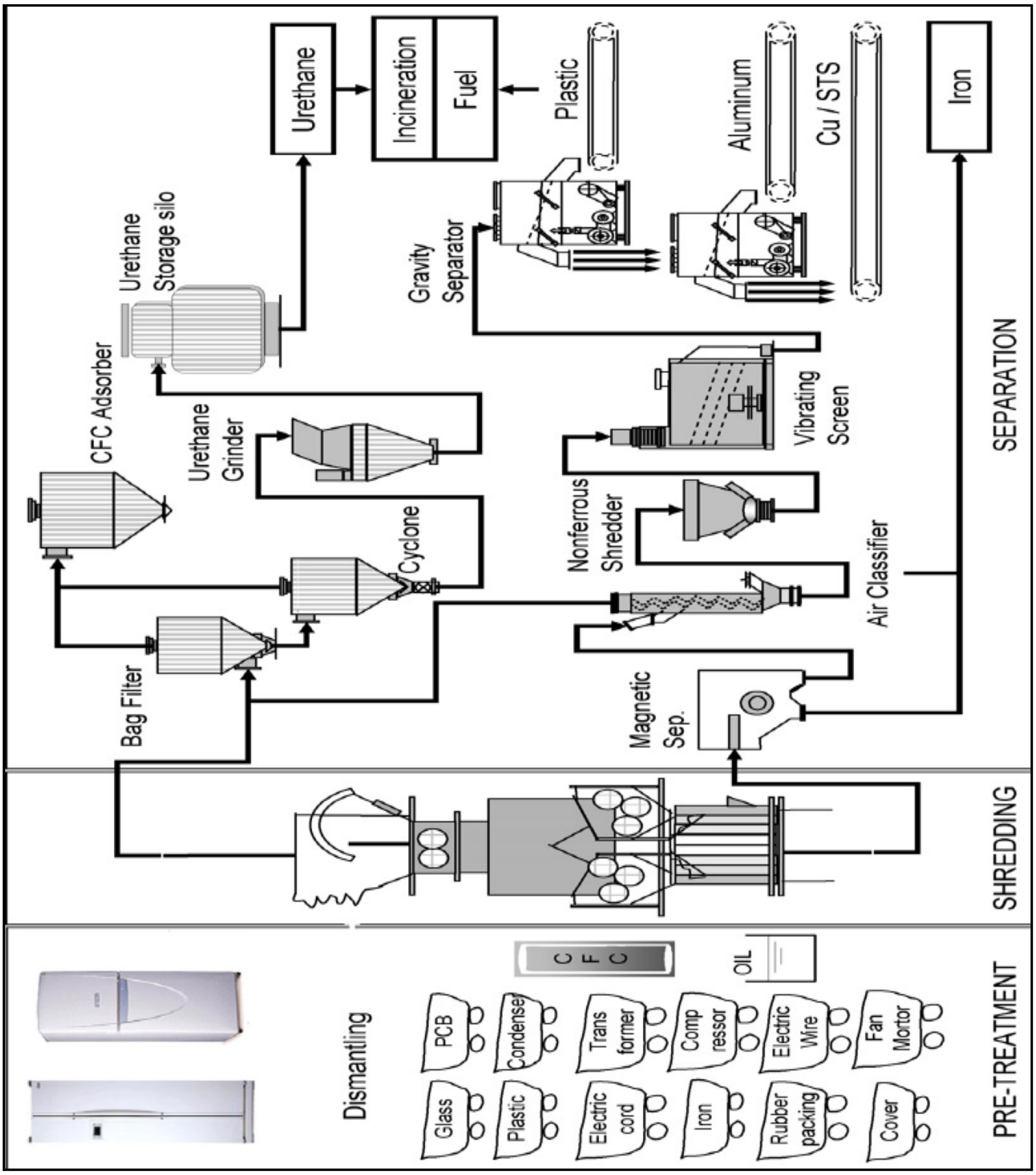


Fig. 2.10: Simplified flow diagram of waste refrigerators recycling plant

2.2.5. Disposal

Disposal is the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water, so that such solid waste or any constituent thereof may not enter the environment. That means that the final placement or destruction of toxic, radioactive, or other wastes; surplus or banned pesticides or other chemicals; polluted soils; and drums containing hazardous materials from removal actions or accidental releases. Disposal includes land-filling and incineration.

2.2.5.1 Land-filling

Disposing of waste in a landfill involves burying waste to dispose of it, and this remains a common practice in most countries. Historically, landfills were often established in disused quarries, mining voids or borrow pits. A properly-designed and well-managed landfill can be a hygienic and relatively inexpensive method of disposing of waste materials. Older, poorly-designed or poorly-managed landfills can create a number of adverse environmental impacts such as wind-blown litter, attraction of vermin, and generation of liquid leachate. Another common byproduct of landfills is gas (mostly composed of methane and carbon dioxide), which is produced as organic waste breaks down anaerobically. This gas can create odor problems, kill surface vegetation, and is a greenhouse gas.

Design characteristics of a modern landfill include methods to contain leachate such as clay or plastic lining material. Deposited waste is normally compacted to increase its density and stability, and covered to prevent attracting vermin (such as mice or rats). Many landfills also have landfill gas extraction systems installed to extract the landfill gas. Gas is pumped out of the landfill using perforated pipes and flared off or burnt in a gas engine to generate electricity (wikipedia 2008).

2.2.5.2 Incineration

Incineration is a disposal method that involves combustion of waste material. Incineration and other high temperature waste treatment systems are sometimes described as "thermal treatment". Incinerators convert waste materials into heat, gas, steam, and ash.

Incineration is carried out both on a small scale by individuals and on a large scale by industry. It is used to dispose of solid, liquid and gaseous waste. It is recognized as a practical method of disposing of certain hazardous waste materials (such as biological medical waste). Incineration is a controversial method of waste disposal due to issues such as emission of gaseous pollutants. Incineration is common in countries such as Japan where land is scarcer, as these facilities generally do not require as much area as landfills.

Waste-to-energy (WtE) or energy-from-waste (EfW) is broad terms for facilities that burn waste in a furnace or boiler to generate heat, steam and/or electricity. Modern combustion technologies maintain the advantages of incineration without its numerous disadvantages, while providing a clean energy source. Installation of a "boiler" such as the RCBC (rotary cascading bed combustor) allows the consumption of problem waste as fuels for the generation of electricity. Municipal solid waste, sewage, sludge, "dirty coals", and coal byproducts, are cleanly and efficiently consumed for energy production with emissions well within strict regulatory standards. The fly ash byproduct is inert, and can be mixed with compost(wikipedia 2008).

Through this section, we can create a modeling about recycling process of e-waste. We can find out the options which would be possible to recycle the electronic waste. Following figures show us the boundaries of a modeled WEEE recycling system and its disposal.

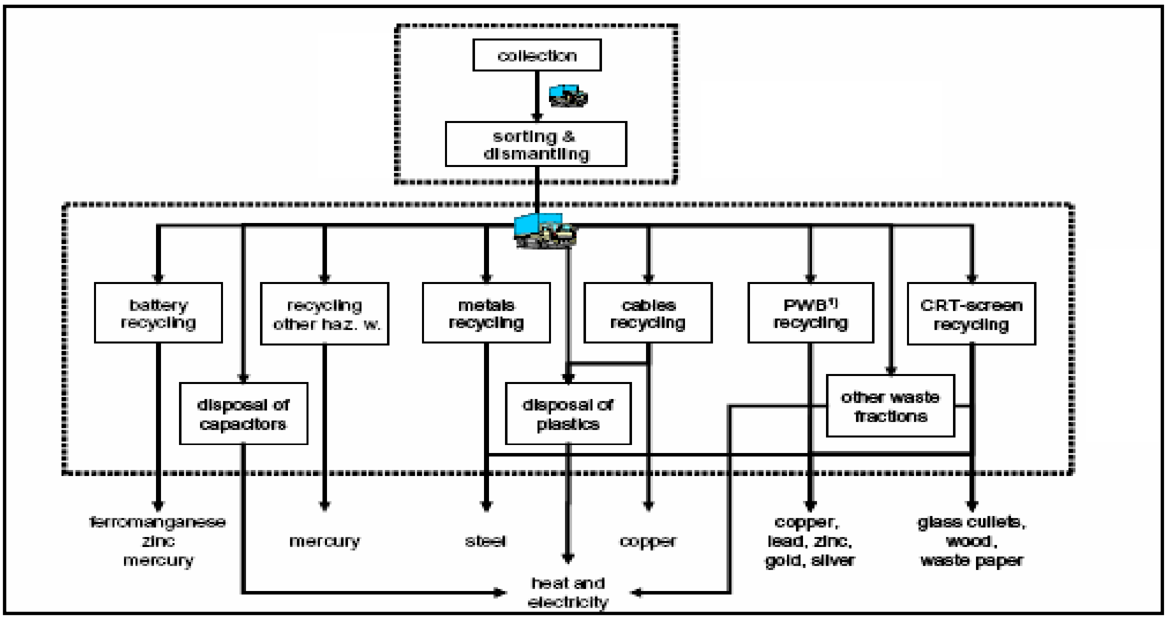


Fig. 2.11: WEEE recycling system including steps up to the production of secondary raw material

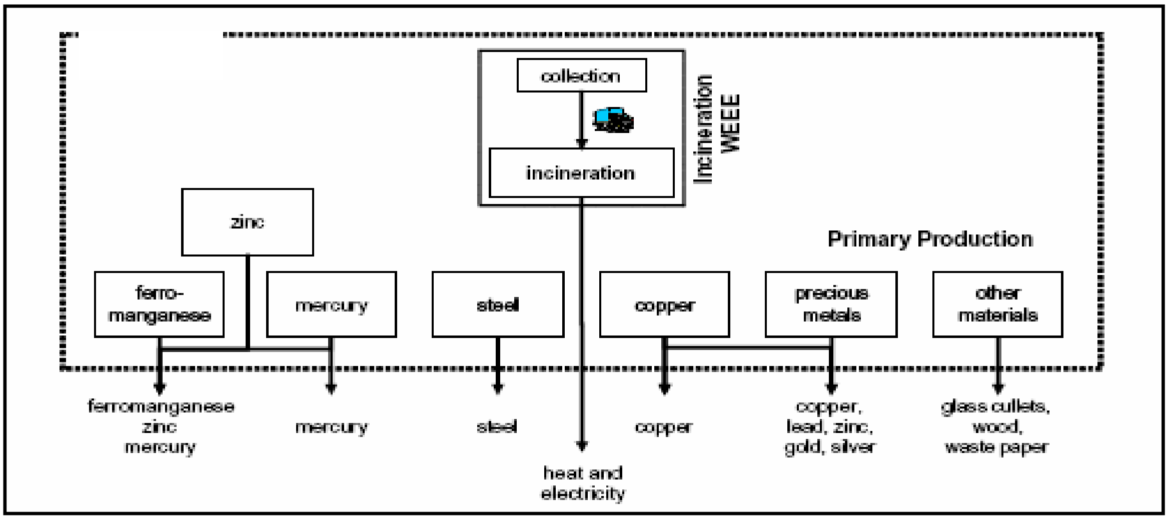


Fig. 2.12: WEEE recycling and disposal systems including production of primary raw materials and incineration.

2.3 The Perception of E-Waste by Societies

From the beginning of 1980's until today; with help of the induction of consumer oriented technologies, the electrical and electronic industry show an impulse trend economically, renovating and in sense of production unit.

The success of the industry have been creating a developing mass consumer market especially for computers, mobile phones and other personal or entertainment electronic equipment. World must find now ways for safely and economically recovering the materials that are embedded in these products. Furthermore, world is facing an ever growing stream of electronics waste as a result both of the rapidly increasing number of new applications for electronics and of the accelerating pace of technological development and ever shorter service and product life; thus world have to solve the capacity and health problems whose are the results of this consumption.

Through the time passed, some try to compensate the possible damage and threats and to bear responsibility against this mankind's impact. Nevertheless some try to bury theirs head in the sand in spite of the world's reactions. Legislations, directives, common contracts and civil organization were established and are advancing globally.

Certainly the first applications were enounced in Europe. European society requests global arrangements among the developed countries initially. Therefore Europeen Union implements the requirements of being responsible and exquisite and widely develops the system of waste management. The far eastern countries as Japan, China, Taiwan and Korea, according to their industrial progress and territory capacities had kept up with the technologies of waste management. But China and Taiwan are carrying the similar troubles with Asian and African countries which they are considered as developing countries or third world countries. They became the trash of other producer countries and themselves. Most of them aren't aware of the management of waste; at least officially. Even tough the citizens could join the process of the e-waste management accepting all harmful risks. For example it is normal to find an Indian man heating circuit boards over flame to extract metal or to meet a Pakistani child who is ripping out the metal parts of a mouse. Finally America is the most insensitive country against its own society and the world. In spite of its mass production and spreading marketing around the world, the cautions were taken, applied by state decisions and current at that state.

Through that duration; consumer products such as white goods (refrigerator, TV, washing machines, etc.) became similar and simplified to handle their results and recycle. On the contrary; brown goods (especially personal computer) which show rapid growth over the last decade become new challenging category to solve and make them beneficial.

In this section we present the situation of the world and comparatively Turkey.

2.3.1 The concern of the World

The advent of electrical and electronic equipment (EEE) with new functions and design time to time, stimulate consumers' purchasing desire towards the latest equipments. This leads the rapid increase in the sales of new facilitated models of EEE in the world (LaCoursiere, 2005). Due to the rapid replacement of old model by latest advanced model time to time causes short average lifespan of EEE and consequently leads to yield mass generation of waste electrical and electronic equipment (WEEE). The generation of tremendous amount of bulky WEEE containing variety of hazardous substances is a major social problem and threat to the environment (Brodersen et al., 1992; Lee, 2005).

It is estimated that, by 2005, one computer will become obsolete for every new one put on the market. Between 1997 and 2004, 315 million computers will become obsolete. This will result in the discard of 550 x 10^6 kg of Pb, 900000 kg of Cd, 180000 kg of Hg, and 0.5 x 10^6 kg of Cr VI. This will also yield additional waste in the form of 1800 x 10^6 kg of plastic and at least 159 x 106 kg of brominated flame-retardants from monitors. The disposal of consumer electronics accounts for 40% of Pb in landfills. Additionally, 22% of the yearly world consumption of Hg is used in electronics. The successful capture and reuse of these streams of materials will require a combination of government initiatives at local, regional, national, and supranational levels, as well as public willingness and innovations in materials, products, and recycling technologies. Above all, this is a systems problem, where innovations at different scales and levels must be tied together to achieve the maximum impact (Realff et al. 2004).

For example, several million tonnes of WEEE are being generated in the U.S., EU and Japan (Kang and Schoenung, 2005; Beck, 2004; Clean Japan Center, 2002). In 2001, the quantity of electronic wastes generated in the U.S. was estimated around 2.26 million tonnes and these were mainly: (1) video products such as TVs, VCR decks, camcorders and TV/VCR combinations, (2) audio products including compact disk players, rack audio system and compact audio system, and (3) information products like PC, computer monitors, telephones and fax machines.

In the case of EU, total electronic waste generation was found 5 million tonnes, simultaneously the average quantity of the generation of electronic wastes was observed 14 kg per person in the year 2004 (Beck, 2004). Despite of an enormous amount of WEEE is being generated every year in the U.S. and EU; their treatments are simply relying on incineration or landfill. In the EU, when the WEEE directives are successfully enforced, they can make much contribution towards the constitution of resources-recirculation society that will satisfy both the protection of environment and the conservation of resources (Europa, 2006; Fauve-Buresi, 2006).

An important part of the electronics recycling problem is the legislative framework that has or is being established in a particular region. There are 11 countries that currently have ‘mandatory’ electronics recovery laws on the books. They include Belgium, Denmark, Italy, Netherlands, Norway, Sweden, Switzerland, Portugal, Japan, Taiwan, and South Korea. There are extensive voluntary programs in a number of other countries, such as Germany, and draft take back bills in several more, including China.

The European Union (EU) enacted two directives in January 2003. The first, referred to as WEEE, requires industry to ensure recycling of any electronic product with a battery or a cord. A second, Restriction on Hazardous Substances (RoHS), phases out Hg, Cd, Pb, and Cr VI in all electronic items by July 2006, with a number of exemptions. In Asia, Taiwan and Japan have fee systems in place for take back of computers, large appliances, and air conditioners. Japan’s private collection system includes TVs, while Taiwan’s includes printers. South Korea enacted new take back laws for electronics in 2003, covering major electronic items, phasing in small products such as cell phones and cameras in 2005.

In the America, activity has been concentrated in the north. In Canada, provinces with authority to require take back of electronics cover about 95% of the population, most of which are expected to demand recycling plans from industry by 2005. In the US, the government initiated the National Electronic Product Stewardship Initiative, a series of talks in 2001 to set up a national recovery system for electronics. While no agreement had been finalized as of October 2003, there were 52 electronics waste (e-waste) bills introduced in 26 states in 2003. California enacted a fee on cathode ray tubes (CRTs) in October 2003, as well as a restriction on heavy metals that mirrors the EU RoHS requirements for CRTs over 4”. From this catalog of activity, it would appear that a worldwide consensus is emerging to regulate the disposal of electronic products and that legislation will be enacted over the next few years.

However, the specific tack being taken by regions varies and may lead to significant overheads for global manufacturers trying to comply with different regulations. In all cases, it will be important to establish economically efficient system designs that combine effective recycling technology with socially acceptable collection systems. (Realff et al. 2004).

2.3.2 The EU directives

As European society has grown wealthier it has created more and more rubbish. Each year in the European Union alone we throw away 1.3 billion tonnes of waste - some 40 million tonnes of it hazardous. This amounts to about 3.5 tonnes of solid waste for every man, woman and child, according to European Environment Agency statistics. Add to this total a further 700 million tonnes of agricultural waste and it is clear that treating and disposing of all this material - without harming the environment - becomes a major headache.

Between 1990 and 1995, the amount of waste generated in Europe was increased by 10 %.(Organization for Economic Cooperation and Development / OECD). Most of what we throw away is either burnt in incinerators, or dumped into landfill sites (67%). But both these methods create environmental damage. Landfilling not only takes up more and more valuable land space, it also causes air, water and soil pollution, discharging carbon dioxide (CO_2) and methane (CH_4) into the atmosphere and chemicals and pesticides into the earth and groundwater. This, in turn, is harmful to human health, as well as to plants and animals.

By 2020, the OECD estimates, we could be generating 45% more waste than we did in 1995. Obviously we must reverse this trend if we are to avoid being submerged in rubbish. But the picture is not all gloomy. The EU's Sixth Environment Action Program identifies waste prevention and management as one of four top priorities. Its primary objective is to decouple waste generation from economic activity, so that EU growth will no longer lead to more and more rubbish, and there are signs that this is beginning to happen. In Germany and the Netherlands, for example, municipal waste generation fell during the 1990s.

The EU is aiming for a significant cut in the amount of rubbish generated, through new waste prevention initiatives, better use of resources, and encouraging a shift to more sustainable consumption patterns.

The European Union's approach to waste management is based on three principles:

1. *Waste prevention*: This is a key factor in any waste management strategy. If we can reduce the amount of waste generated in the first place and reduce its hazardousness by reducing the presence of dangerous substances in products, then disposing of it will automatically become simpler. Waste prevention is closely linked with improving manufacturing methods and influencing consumers to demand greener products and less packaging.

2. *Recycling and reuse*: If waste cannot be prevented, as many of the materials as possible should be recovered, preferably by recycling. The European Commission has defined several specific 'waste streams' for priority attention, the aim being to reduce their overall environmental impact. This includes packaging waste, end-of-life vehicles, batteries, electrical and electronic waste. EU directives now require Member States to introduce legislation on waste collection, reuse, recycling and disposal of these waste streams. Several EU countries are already managing to recycle over 50% of packaging waste.

3. *Improving final disposal and monitoring*: Where possible, waste that cannot be recycled or reused should be safely incinerated, with landfill only used as a last resort. Both these methods need close monitoring because of their potential for causing severe environmental damage.

The EU has recently approved a directive setting strict guidelines for landfill management. It bans certain types of waste, such as used tires, and sets targets for reducing quantities of biodegradable rubbish. Another recent directive lays down tough limits on emission levels from incinerators. The Union also wants to reduce emissions of dioxins and acid gases such as nitrogen oxides, sulphur dioxides and hydrogen chlorides, which can be harmful to human health (Europa 2006).

2.3.2.1 Waste electrical and electronic equipment directives

The *Waste Electrical and Electronic Equipment Directive (WEEE Directive)* is the European Community directive 2002/96/EC on waste electrical and electronic equipment which, together with the *RoHS Directive* 2002/95/EC, became European Law in February 2003, setting collection, recycling and recovery targets for all types of electrical goods.

The directive imposes the responsibility for the disposal of waste electrical and electronic equipment (WEEE) on the manufacturers of such equipment. Those companies should establish an infrastructure for collecting WEEE, in such a way that "Users of electrical and electronic equipment from private households should have the possibility of returning WEEE at least free of charge". Also, the companies are compelled to use the collected waste in an ecological-friendly manner, either by ecological disposal or by reuse/refurbishment of the collected WEEE.

The WEEE Directive obliged the twenty-five EU member states to transpose its provisions into national law by 13 August 2004. Only Cyprus met this deadline. On 13 August 2005, one year after the deadline, all member states except for Malta and the UK had transposed at least framework regulations. As the national transposition of the WEEE Directive varies between the member states, a patchwork of requirements and compliance solutions is emerging across Europe.

2.3.2.2 Restriction of hazardous substance directive

The Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment 2002/95/EC (commonly referred to as the Restriction of Hazardous Substances Directive or RoHS) was adopted in February 2003 by the European Union. The RoHS directive took effect on 1 July 2006, and is required to be enforced and become law in each member state. This directive restricts the use of six hazardous materials in the manufacture of various types of electronic and electrical equipment.

RoHS is often referred to as the lead-free directive, but it restricts the use of the following six substances: Lead, Mercury, Cadmium, Hexavalent chromium, Polybrominated biphenyls (PBB), Polybrominated diphenyl ether (PBDE). PBB and PBDE are flame retardants used in several plastics.The maximum concentrations are 0.1% or 1000 ppm (except for cadmium, which is limited to 0.01% or 100 ppm)

In an effort to close RoHS loopholes, in May 2006 the European Commission was asked to review two currently excluded product categories (monitoring and control equipment, and medical devices) for future inclusion in the products that must fall into RoHS compliance. In addition the commission entertains requests for deadline extensions or for exclusions by substance categories, substance location or weight.

Note that batteries are not included within the scope of RoHS. However, in Europe, batteries are under the European Commission's 1991 Battery Directive (91/157/EEC), which was recently increased in scope and approved in the form of the new battery directive, version 2003/0282 COD, which will be official when submitted to and published in the EU's Official Journal.

The directive applies to equipment as defined by a section of the WEEE directive. The following numeric categories apply:

- Large and small household appliances.
- IT equipment.
- Telecommunications equipment (although infrastructure equipment is exempt in some countries)
- Consumer equipment.
- Lighting equipment—including light bulbs.
- Electronic and electrical tools.
- Toys, leisure, and sports equipment.
- Medical devices (currently exempt)
- Monitoring and control instruments (currently exempt)
- Automatic dispensers.

It does not apply to fixed industrial plant and tools. Compliance is the responsibility of the company that puts the product on the market, as defined in the Directive; components and sub-assemblies are not responsible for product compliance. Of course, given the fact that the regulation is applied at the homogeneous material level, data on substance concentrations needs to be transferred through the supply chain to the final producer. An

IPC standard has recently been developed and published to facilitate this data exchange, IPC-1752.

RoHS applies to these products in the EU whether made within the EU or imported. Certain exemptions apply, and these are updated on occasion by the EU.

2.3.2.3 Similar directives of RoHS in other regions

China establishes similar restriction, but it in fact takes a very different approach. Often known as China RoHS is announced as Electronic Information Products, or EIP's. Initially, products that fall under the covered scope must provide markings and disclosure as to the presence of certain substances, while the substances themselves are not (yet) prohibited. There are some products that are EIP's, which are not in scope for EU RoHS, e.g. radar systems, semiconductor-manufacturing equipment, photo masks, etc. The list of EIP's is available in Chinese and English. The marking and disclosure aspects of the regulation were intended to take effect on July 1, 2006, but were postponed twice to March 1, 2007. There is no timeline for the catalogue yet.

Japan does not have any direct legislation dealing with the RoHS substances, but its recycling laws have spurred Japanese manufacturers to move to a lead-free process in accordance with RoHS guidelines. A ministerial ordinance Japanese industrial standard for Marking Of Specific Chemical Substances (J-MOSS), effective from July 1, 2006, directs that some electronic products exceeding a specified amount of the nominated toxic substances must carry a warning label.

South Korea promulgated the Act for Resource Recycling of Electrical and Electronic Equipment and Vehicles on April 2, 2007. This regulation has aspects of RoHS, WEEE, and ELV.

California has passed SB 20: Electronic Waste Recycling Act of 2003, or EWRA. This law prohibits the sale of electronic devices after January 1, 2007, that are prohibited from being sold under the EU RoHS directive, but across a much narrower scope that includes LCD's, CRTs, and the like and only covers the four heavy metals restricted by RoHS. EWRA also has a restricted material disclosure requirement.

RoHS is not the only environmental standard of which electronic product developers should be aware. Manufacturers will find that it is cheaper to have only a single bill of materials for a product that is distributed worldwide, instead of customizing the product to fit each country's specific environmental laws. Therefore, they develop their own standards, which allow only the lowest common denominator of all allowable substances.

For example, IBM forces each of their suppliers to complete a Product Content Declaration form to document compliance to their environmental standard Baseline Environmental Requirements for Materials, Parts and Products for IBM Logo Hardware Products. So for example, IBM bans DecaBDE, even though there is a RoHS exception for this material. Similarly, here is Hewlett-Packard's environmental standard: General specification for the environment (GSE). The literature review on the directives announced for e-waste is as following:

Table 2.6: The Historical advances of directives concerning e-waste	
1970	US EPA's e'cycling program
1989-1992	Basel Convention
1994	SWICO
1995	BAN's
1998	SENS
1999	EPR
2001	Greenpeace Electronic Waste Campaign
2001	OEEC (Organization European Economic Cooperation)
2002	Silicon Valley Toxic Coalition
2003	EWRA (American Electronic Waste Recycling
2003	EU RoHS
2003	EU WEEE Directives

2005	California Electronic Waste Recycling Fee
2006	EIP
2006	J-MOSS

2.3.3 The concern of the Turkey

To express the conditions in turkey briefly; the situation of Turkish industry, its status economically, the progress of consumption of electrical and electronical equipments (especially the electric & electronic sector) must be represented.

Electronics industry is one of the most important manufacturing industry by the value of its 1.85 trillion USD trade volume in the world. Turkish electronics industry experienced a good growth performance in last few years.

In Turkey according to statistics of DPT at 2000, approximately 30 million TV and at 2003, more than 26 million cell phone exists in the market. Furthermore at 2003, the number of subscriber of home phone is approximately 19 million. According to the statistics given from the Community of Turkey Household Appliances Industry; through the previous years the manufacturing of household appliances including refrigerators, washing machines, oven, etc. is realized with an increasing rate %0, 91. The higher rates are determined when it is about exporting. Through the last period (January- June) the manufacturing of refrigerator is3.690.739; the manufacturing of washing machines is 2.293.242; the manufacturing of dish washer 427.319; finally the manufacturing of oven is 878.260. This community is constituted of the firms: Arçelik, BSH, Indesit Company BES, Türk Demirdöküm, Teba, Vestel (Anadolu Ajansı 2005).

Consequently; in our country the manufacturing is followed by the constitution of the e-waste rapidly, therefore the need of the projects for recycling are becoming a reality.

The current situation about the e- waste management in Turkey can not be defined as brilliant. The foundations of combusting, storage, incineration and the areas of disposal are established by government and the municipalities are interested in the control of waste process. Nevertheless there is no-precise attention about the expertise of special subtitles of solid waste or waste. Relevant to this expertise, organization of paper waste management is popular by the help of TEMA. Consequently we have to define electric and electronical waste following the information about solid waste statistics.

First of all, a general framework on solid waste recovery and recycling can be represented. Solid waste recovery and recycling has been a long-standing commercial activity in Turkey. Glass and paper recycling have been conducted at industrial scales since the 1950s (Neyim et al and Banar et al, 2001). With the recent investments in the recycling industry, almost all types plastic materials, glass, paper and metals can be recycled at industrial levels in Turkey.

Turkey, as one of the biggest steel scrap importers of the world, recycles more than 2 million tons of steel scrap annually. Recycling of nonferrous metals is also widespread and conducted at industrial scale, including aluminum, copper, lead and silver. The scrap metal recycling industry essentially is built on small and medium scale scrap dealers spread around the country. This type of operation is also valid for most of collection and recovery of recyclable MSW (Electronica.ca 2005).

Recovery of plastics, paper, glass and metal from municipal solid waste is mostly conducted, as indicated above, by the scrap dealers and individual collectors (scavengers etc.). These individual collectors and scrap dealers purchase the used packaging (mostly paper and cardboard) from commercial units, markets and business centers and reprocess (sort and bale) these materials to sell directly to the industrial recycling facilities. In addition, scavenging and collection from the waste bins is a widespread activity. Since this type of collection and recovery process is a part of “unregistered” economic activity, it is difficult to specify figures reflecting actual collection and recovery. This is essentially a widespread collection and recovery method utilized in Turkey (Atık Yönetimi 2003). However, estimates made by experienced individuals working in this field indicates that total amount of MSW recovered in Turkey is probably over 1.0 million tons/year. This estimation, together with the data showing the amount of packaging and recyclable materials placed into market, is shown Table 2.7.

	Placed into market (tons/year)	Amount recovered (tons)	% Recycling
Paper and board	1.850.000	700.000	36
Glass	350.000	80.000	25
Plastics	550.000	170.000	30
Metal	150.000	50.000	30
Total	2.900.000	1.000.000	35

Table 2.7: Amounts of packaging waste (tons/year) placed in to market, and estimated recovery and recycling figures for Turkey in 2000

As shown in table 2.7, packaging waste recycling in Turkey is well above 30%. However, most of these activities operate within the hands of private entrepreneurs and waste collectors working on streets and in waste yards.

This obviously is driven by the fact that a strong used material market operates in Turkey as well as by the limited economic conditions in the country that provide an employment opportunity for this sector. Separate/curbside collection of the recyclable materials has started within the last ten years in Turkey.

Currently more than 60 municipal recovery programs are operational nationwide. These pilot programs have been a useful tool to develop relevant statistical basis for solid waste recovery activities in Turkey; the data has been summarized elsewhere (Neyim et al, Banar et al and Metin and Yigit, 1997).

In Table 2.8, a list of municipal recovery programs being implemented in Turkey is given. This list also supplies the data on the amount of used packaging material recovered and recycled through these programs. Data on collection frequency is also given in this table, which refers to a fairly long period of time, and therefore represents a relatively high statistical significance.

Number of municipalities	31
Number of households	186,311
Number of hotels	320
Number of schools	237
Number of commercials	179
Total waste collection (kg/month)	1,090,000

Table 2.8: Scope and source of separate collection data used in this study (operated in cooperation with ÇEVKO and local municipalities)

The collection scheme is similar in all of the municipal separate collection programs and is based on the weekly, commingled collection by plastic bags. Commingled recyclable waste materials include plastic, glass, metal, and paper. The collected packaging waste is either transported to Material Recovery Facilities (MRF) or is being handled by the individual private waste contractors.

Public participation and awareness in municipal recovery programs has been an important issue in all curbside/separate collection programs. Several types of tests and opinion poles have been conducted in order to gain an insight to the role of public awareness in these types of environmental programs (Banar et al and Metin et al 2003). A good example of such comprehensive programs has been implemented by a joint effort of UNDP-CEVKO—local municipalities as a part of a program in the earthquake-affected regions of Turkey (CEVKO, 2000). Furthermore, a detailed survey in Bursa Municipal Recovery Program, which covered 10,869 residents, has shown that 66.4% are aware of the separate collection and recovery program and 51.8% are claiming regular and active participation. Similar participation measurement polls have shown that the overall participation rate varies between 30 and 35% in other programs in Turkey (IGCM 2000).

Cost data on solid waste management in Turkey is usually highly controversial and complicated due to the nature of the subject. The cost data is further complicated by the specifics of the Municipal Region and the cost accounting methodology employed. However, here we attempt to simplify some of the factors involved (by separating out some cost build up operations) in order to gain an overall assessment of MSW management cost factors. In this section, two separate Municipal cost analyses have been conducted. The first one covered Municipal collection and transport costs whereas the other one is essentially an economic performance analysis of two small-medium scale material recovery facilities.

The first set of data was collected from 24 selected Municipalities from the Aegean Coast of Turkey. The survey includes only the collection and transport costs of municipal solid waste (Banar et al. 2001). This data is provided in Table 2. 9, which was compared with the data collected from other Municipal Authorities.

	Population	Waste collected ton/year	Total USD	Budget		Distribution		Cost*	
				Personnel USD	Maintenance USD	Operation USD	Others USD	USD/capita -Year	USD/ton -Year
Çanakkale	76.000	31.280	378.840	42%	40%	18%	0%	4.98	12.14
Manisa	214.000	153.000	1.533.790					7.17	10.02
Bandırma-balikesir	130.990	43.880	809.552					6.64	18.35
Modla	43.000	15.840	566.287	58%	0%	42%	0%	13.17	35.75
Aydin	145.000	52.280	1.208.677	33%	25%	67%	15%	8.34	23.17
Average (of 24 towns in Aegean Coast)	66%	18%	14%	2%	14	27			

Table 2.9: Cost data for municipal solid waste collection and disposal, for some selected cities full scope of this survey comprises 24 cities

In order to make comparative assessment and gain some commercial insight towards the separate collection programs, cost data has been gathered from separate collection programs in Turkey.

The data on cost of collection and sorting has been summarized in Table 2.10 and Table 2.11, for a medium-to-large city. An average population is estimated to be 1.0 million. Based on the detailed waste analysis, a cost/revenue analysis for a city wide recycling program is made (Çevre ve Orman Bakanlığı 2006)

Table 2.10: Cost estimation for a medium sized city wide recycling program for Turkey, with difficult collection methodology (Assumptions: Population: 1.0 million, MSW: 1000 tons/day, % recyclable waste: 20% amount recyclable waste: 200 tons/day, participation rate: 45%, material recovery: 90 tons/day.)

Cost item/collection method	Bring centers	Plastic Bins	Door to door, plastic bags
Investment cost (US$)			
Cost period	Invest.	Invest.	Invest.
Collection bins/units	1.500.000	980.000	0
Municipal trucks	560.000	750.000	750.000
MRF	650.000	650.000	650.000
Total	2.710.000	2.380.000	1.400.000
Operation costs (US$)			
Cost period	Monthly	Monthly	Monthly
Collection costs	26.000	34.000	28.000
Operational costs	38.500	25.500	78.000
MRF operation	60.000	60.000	60.000
Total	124.500	119.500	166.000

Table 2.11: Sales value of sorted material with different collection source

Material source	Paper and board	Plastics	Metal	Glass	Average revenue $/ton	Total revenues $/month
Sales value $/ton	80[a]	150[a]	120[a]	35[a]	96.25	
Residential	38%	21%	9%	32%	83.9	170.000
Commercial	72%	26%	2%	[b]	99	200.000
Composite	70%	18%	3%	9%	89.75	182.000

The analysis given in 2.11 indicates that revenues are sufficient to cover the general operational costs of material recovery facilities if it's operated at full capacities. Depending on the source composition or depending on the collection method employed, a relatively acceptable commercial profit can be retained. In table 2.11, costs items are categorized with different types of collection methodology. Collections through bring-centers yields relatively high investment costs and low operational costs, whereas door-to-door collection of recyclable materials by plastic bags has the lowest investment cost. However the continuing consumption of plastic bags yields relatively higher operational costs. (Banar et al. 2001).

These analyses are found to be consistent with the data published by (Coopers and Lybrand, 2000) and seem to be in line with similar studies (Lund, 1993, EPA, 1997 and White et al 1996). Obviously, the cost of separate collection, purely on financial terms will be misleading since environmental costs and benefits are not accounted for in simple financial evaluations. The results indicate that at large scales of collection and sorting, market gains of the sold material are usually sufficient to support the operational costs of material recovery facilities. Additional costs due to separate collection and public training processes are usually considered to be compensated as an environmental benefit.

These costs and benefits must be studied through a life cycle approach, which has been a topic of various publications. A good summary of environmental benefits of material recycling has been recently published by (White et al 1996). Intensive efforts are being made by the European Commission and European Countries in order to assess the "value" of material recycling versus other methods of waste management, such as land filling, incineration, composting, etc (Coopers and Lybrand, 2000 and ECOTEC, 2000. ECOTEC Research and Consulting, 2000. Beyond the Bin; The Economics of Waste Management Options. Final Report to UK Waste and Waste Watch.ECOTEC, 2000). The results indicate that material recycling has the highest environmental benefit. Therefore, the recent legislative proposals in the European Union Packaging Waste Directive targets have higher recycling rates.

Secondly, according to the Survey of Municipality Solid Waste Statistics by TÜİK in 2004, separated as at the summer season 12,3 million ton and at the winter season 11,9 million ton ,totally 24,2 million ton solid waste is collected. According to this results; the daily average solid waste quantity per capita is 1,34kg. %46 of this quantity of solid waste collected is disposed to municipality waste yard; %29,8 of waste is disposed to storage area; %15,6 is to municipality waste yard of metro pole; %1,6 is disposed by burying; %1,4 is disposed to foundations of combusting; %0,3 is disposed by open incineration; %0,4 is disposed by dropping out of river or lake. These information means that %30 of solid waste are stored regularly (Neyim 2001),(Metin et al. 2001).

The amount of e-waste in solid waste is estimated approximately %1, 7; but this rate will be doubled in the next five years period. So we conclude that in Turkey there is 0,41ton solid waste and only 0, 12 ton is stored or have a chance for recovery.

Also; we have to mention that for the industrial waste the information in Turkey is very limited. In this area, the source of information is again a survey of manufacturing industry by TÜİK. The survey at 2004 represent that in a year 1.196.000 ton waste is produced; %8 of them is recovered; %45 is sold or donated; %47 of them is disposed. To be sold or donated means waste could be given to junk dealer or could be given to municipality.

The current situation of Turkey shows us that we are not able to manage the e-waste opportunities and market. Also meaning of this lack is that the human and environment welfare could contend with the dangerous consequences of e-waste in the future.

At the same time; the ministry of environment published some regulations or laws and a calendar about waste management to adapt the country relatively with European Union.

Table 2.12: The legislations published by the ministry of environment

Name of EU Legislation	Number	Estimated Calendar of Adaptation	Estimation of Application / Obligation Date
Directive of Dangerous Waste	91/689/EEC	2005	2005
Directives of Packaging and waste of Packaging	94/62/EC	2004	2005
Directives about disposal of waste oils	75/439/EEC	2004	2004
Directives related to accumulators and batteries containing some dangerous elements	91/157/EEC	2004	2004
Catalog of European waste	2000/532	2006	2006
Directive of regular storage of waste	99/31/EC	2006	2006
Directive of transmission of waste	259/93/EEC	2008	Related to

			membership
Directive of incineration of waste	2000/76/EC	2006	2006
Directive of PCB/PCT	96/59/EC	2007	2008
Directive of junk conveyance	2000/53/EC	2007	2008
Directive of management of mine waste	2006/21/EC	2008	2008
ROHs	2002/95/EC	2007	2008
Directives related to WEEE	2002/96/EC	2007	2008

In the table 2.13; the costs of these legislation of directives are calculated and are published by the strategy of EU integration of environment adaptation. Nevermore these costs contain only some pre-calculation; thus the costs have to revise considering the technology need according to the condition of country. The costs related to waste management could be classified as: closing the old waste yard, establishing of new regular storage areas, establishing the system of collection for recycling/recovery, establishing the combusting systems, the recovery of heterogeneous waste and establishing the transmission systems for dangerous wastes.

Table 2.13: The investments need related to directives of waste management

	TOTAL	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Regular Storage	5435	345	345	345	400	425	475	500	500	500	500	550
Packaging	491	41	40	41	41	41	41	41	41	41	41	41
Incineration	987		89	89	89	90	90	90	90	90	90	90
Dangerous Waste	56		4	4	4	5	5	5	5	6	6	6
TOTAL	6969	386	478	479	534	561	611	636	636	637	637	687

In respect of report of task of e- waste recovery in 2005-June Business Communication Company Inc.; throughout the world the average growth rate of the market of e-waste at 2004 which is 7.2 billion $ will be increased rapidly %8.8 at 2009 which will be 11 billion

$. The sale of the recycled metals at e-waste market between the years 2004 – 2009; is improved at %8.1 increasing rate whereas it's 4236 million $ at 2004 and will be 6245 million $ at 2009. The sale of the recycled plastics between the years 2004 – 2009; is improved at %10.2 increasing rate whereas it's 2552 million $ at 2004 and will be 4157 million $ at 2009. The sale of the recycled glass/silica between the years 2004 – 2009; is improved at %7.5 increasing rate whereas it's 41 million $ at 2004 and will be 59 million $ at 2009. The e-waste markets that generally arise after the use of consumer become more powerful in five years. (Business Com. Company 2005)

After the steps following as we mentioned above, the raw materials without potential of dangerous waste and environment-friendly nature in electric and electronical manufacturing are the important expectations from the industry and the government.

In conclusion, e-waste could be defined as an opportunity for new allocation areas, investments and economic development or could be a threat for human health, future of environment or could be a prejudge which represent the industry and country as unrespectable, irresponsible and the products as dangerous and the market as unfavorable or could be a priority for effective usage of all kind of resources. So Turkey has to make an expensive plan to reorganize its system of waste management and develop different types and methods of e-waste process because of their revenue quantitative and qualitative.

3. RESEARCH TECHNIQUES

3.1 Decision Making

We all make decision of varying importance every day; so the idea of decision making can be a rather sophisticated art may at first seem strange. However, studies have shown that in the real life most people are much poorer at decision making than they think. We are faced with difficult choices emanating from the diversity of the factors which influence the decision. 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.

Decision making is the study of identifying and choosing alternatives based on the values and preferences of the decision maker or is the process of sufficiently uncertainty and doubt about alternatives to allow a reasonable choice to be made form among them. This definition stresses the information gathering function of decision making. It should be noted here that uncertainty is reduced rather than eliminated. Very few decisions are made with absolute certainty because complete knowledge about all the alternatives is seldom possible. Thus, every decision involves a certain amount of risk (Harris 1998). A critical factor that decision theorists sometimes neglect to emphasize is that the decision making is a non-linear, recursive process. Most decisions are made by moving back and forth between the choice of criteria and the identification of alternatives. The historical development of the decision making studies is shown as following.

Table 3.1: The historical development of the decision making studies

At the end of 1990's	Pareto (Multi Criteria Problem)	In the concept of economy, group made of several agents with different preferences
1970 – 1978	Marquis de Caritat de Condorcet	Analysis of the probability of the decision taken by different judgments
1733-1799	Chevalier de Borda	The method of Borda; analyzed the social choice which mentioned before by Concordet

After the second war	Hicks, Bergson and Samuelson founders of 'the new economics of welfare"	The general framework of micro economy which is about the theory of multi criteria analysis.
1938	Samuelson	The theory of the revealed preferences along the all of the criteria
1954 – 1960	Savage and Debreu	Theoretical contributions of multi criteria analyses
1961	Charnes and Cooper	Goal Programming
1968	Roy	The concept of outclassing The method of discrete multi criteria decision, ELECTRE
1970	The Hague (Netherlands)	The framework of the seventh mathematical congress of programming The first scientific meeting devoted to the multi criteria
1947– 1960- 1965	Leontief- Debreu- Fishbum	Multi-attribute utility technique (MAUT)
1976	Keeney and Rafa	Multi-attribute utility technique
1985		The multi criteria methods knew world diffusion
The Eighties Cent.		The introduction of data processing into the reflection on the multi criteria decision.

Many normative decision models assume that a firm pursues the single objective of stockholder wealth maximization. However, a modern enterprise is a complex organization in which various stakeholders interact with one another, each with its own possible interpretation of wealth maximization, subject to concerns about risk, liquidity, social responsibilities, environmental protection, employee welfare, and so forth. Consequently it may well be appropriate to pursue a multiple objective approach to many decision making problems.

3.1.1 Elements of Multi Criteria Decision Making Methods

In this part we focus on multi criteria decision making. MCDM problems involve a set of alternatives that are evaluated on the basis of conflicting and incommensurate criteria.

Criteria is considered a generic term that includes both the concepts of the attribute and objective. Accordingly two broad classes of MCDM can be distinguished: MADM (multi attribute decision making), MODM (multi objective decision making). Both MADM and MODM problems are further categorized into a single decision maker problem and group decision problems. These two categories are, in turn, subdivided into deterministic, probabilistic and fuzzy decision.

Deterministic decision problems assume that the required data and information are known with certainty and that there is a known deterministic relationship between every decision and the corresponding decision consequence. Probabilistic analysis deals with a decision situation under uncertainty about the state of problem's environment and about the relationship between the decision and its consequences. Whereas the probabilistic analysis treats uncertainty as randomness, it is also appropriate to consider inherent imprecision of information involved in decision making: fuzzy decision analysis deals with this type of uncertainty.

A number of approaches to structuring MCMD problems have been suggested in the decision analysis literature (Keeney and Raiffa – 1976; Saaty – 1980; Chankong and Haimes – 1983; Kleindorfer et al. – 1993). In General, MCDM problems involve six components:

1. A goal or a set of goals the decision maker attempts to achieve

2. The decision maker or group of decision makers involved in the decision making process along with the preferences with respect to evaluation criteria

3. A set of evaluation criteria (objectives and/or attributes) on the basis of which the decision makers evaluate alternative courses of action

4. A set of decision alternatives, that is, the decision or action variables

5. The set of un controllable variables or states of nature (decision environment)

6. The set of outcomes or consequences associated with each alternative - attribute pair (Keeney and Raiffa 1976; Pitz and Mckillip 1984)

The relationships between the elements of MCDM are shown in the following figure. The central element of this structure is a decision matrix consisting a set of columns and rows (Pitz and McKillip 1984). The matrix represents the decision outcomes for a set of alternatives and a set of evaluation criteria.

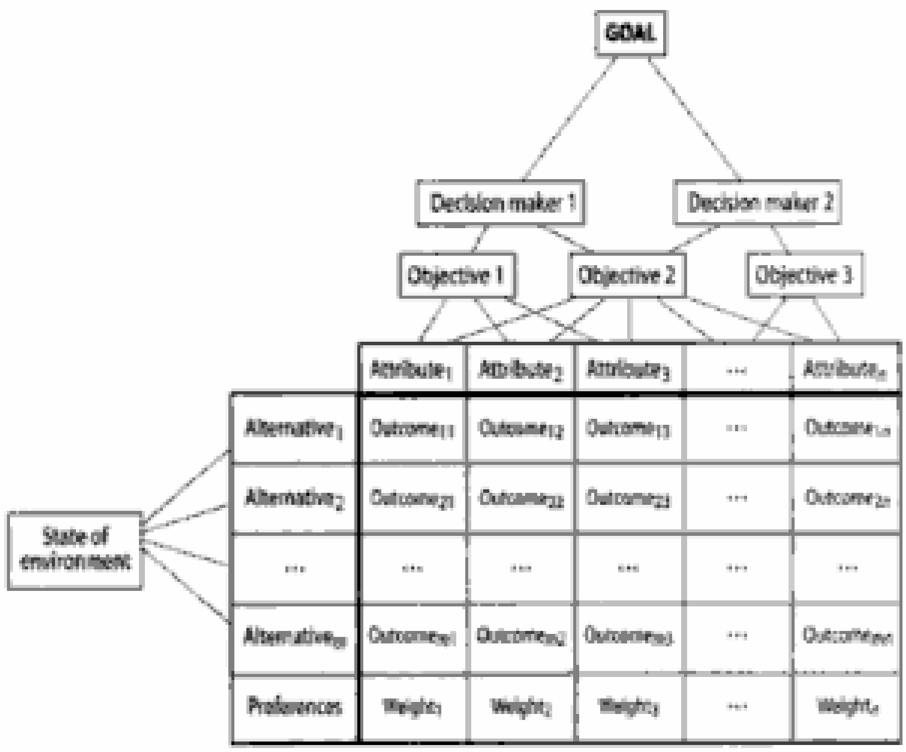


FIGURE 3.1 Framework for multicriteria decision analysis.

Fig. 3.1: Framework for multi criteria decision analysis

The structure of the columns consists of the levels representing the decision makers, their preferences, and evaluation criteria. These elements are organized in a hierarchical structure. The most general level is a goal. At this level a desired end state resulting from decision-making activity is specified. For example, in the context of land-use planning, the goal may be to improve quality of life in a particular region. Complex decision problems typically involve a number of decision makers (interest groups). A decision maker may consist of a single person or a group of people, such as government or corporate organizations. The decisions require analysis of the values of persons affected by the decision, who are often characterized by unique preferences with the respect to the relative importance of criteria on the basis of which alternative decisions are evaluated (Multiple Criteria Decision Analysis: State of the Art Surveys 2005).

The preferences are typically operationalized in terms of weights assigned to the evaluation criteria. A criterion is a standard of judgment or a rule to test the desirability of alternative decisions (Hwang and Yoon 1981). It is a generic term that includes both objectives and attributes. Any multiple criteria decision problem involves a set of objectives, a set of attributes, or both. Although in real-world problems the objectives and attributes are often involved in a mixed fashion, the distinction between these two concepts is a crucial importance for understanding of the nature and essence of MCDM approaches. The objectives are made operational by assigned them to one or more attributes.

The rows of the decision matrix represent decision alternatives. All decisions are made in some kind of environmental context and therefore involve many factors beyond the control of decision maker. These uncontrollable factors are referred to as states of nature or states of environment. The term nature as used here refers to the general unpredictability of the decision making environment. A state of nature can be a state of economy (e.g., recession, inflation), a weather condition (rain, drought, frost), an action of a competitor or other situations over which the decision maker has little or no control, and therefore they must be included in the unpredictability of nature. Each state is assumed to be independent of other states of immune to manipulation by the decision maker; that is, the decision environment is neutral. Also, it is assumed that a finite number of possible states of nature can occur. The states of nature reflect the degree of uncertainty about decision outcomes (Multiple Criteria Decision Analysis: State of the Art Surveys 2005).

Therefore; for each alternative there is a set of possible outcomes. Which outcomes will actually follow a decision depend on the state of nature. If only one state of nature is considered, only one decision outcome is associated with a given alternative.

The decision outcomes depend on the set of attributes for evaluating alternatives. Consequently, an entry in the intersection of each row and each columns of decision matrix is the decision outcome associated with a particular alternative and attribute. The matrix cells contain a single entry if a single state of nature is considered, and they contain a number of outcomes if the decision situation requires consideration of more than one states of nature. Thus the decision outcomes in each row of the matrix are represented as the attribute levels, which measure the degree of achievement or performance of a decision alternative. The decision problems require that the set of outcomes are ordered so that the best alternative can be identified (Multiple Criteria Decision Making Methods 2000).

Although the methods of multi-criteria decision making are largely varied, they have certain common aspects as we represented below like the concept of alternatives and the concept of attributes (Multiple Criteria Decision Making Methods 2000):

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 (Multiple Criteria Decision Making Methods 2000).

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 (Multiple Criteria Decision Making Methods 2000).

The Conflict between Criteria: Since the various criteria represent various dimensions of the alternatives, they can be in conflict with each other (Multiple Criteria Decision Making Methods 2000).

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 (Multiple Criteria Decision Making Methods 2000).

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 (Multiple Criteria Decision Making Methods 2000).

- *The Decision Matrix:* A multi criteria problem of decision can be easily represented in a matrix form.

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 (Jhanshahloo 2006).

In multiple criteria decision making (MCDM) problems, there does not necessarily exist the solution that optimizes ail 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:

	C_1	C_2	....	C_n
A_1	x_{11}	x_{12}	……	x_{1n}
A_2	x_{21}	x_{22}	……	x_{2n}
:	:	:	…….	:
A_m	x_{m1}	x_{m2}	……	x_{mn}

$W= [w_1, w_2, \ldots, w_3]$

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 .

3.1.2 Classification of Multi Criteria Decision Making

MCDM methodologies are classified differently according to different point of views. The first classification divided into three sections relatively the knowledge, certainty and risk.

MCDM problems can be classified on the basis of the major components of multi criteria decision analysis. Three type of differentiation can be distinguished:

1. Multi objective decision making (MODM) versus multi attribute decision making (MADM)
2. Individual versus group decision makers problems
3. Decision under certainty versus decision under uncertainty

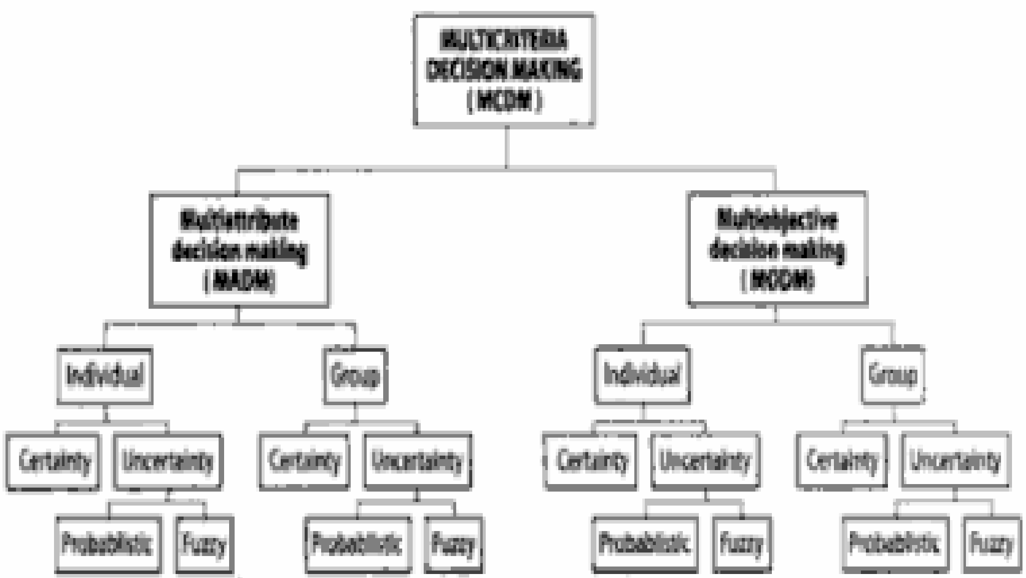


FIGURE 3.2 Classification of multicriteria decision problems.

Fig. 3.2: Classification of multi criteria decision problems

The distinction between MADM and MODM is based on the classification of evaluation criteria into attributes and objectives. These two approaches can be further subdivided into two categories depending on the goal preference structure of the decision maker. If there is a single goal preference, the problem is referred to as individual decision making; regardless of the number of decision makers actually involved. On the other hand, if the individuals are characterized by different goal-preference structures, the problem becomes that of group decision making. The subdivision of decision problems into individual and group decision making applies to both MADM and MODM.

Finally, decision problems can be categorized into decisions under certainty and decision under uncertainty, depending on the amount of information about the decision situation that is available to the decision maker and analyst. If the decision maker has perfect knowledge of the decision environment, the decision is made under conditions of certainty. Most real-world decisions involve some aspects that are unknowable or very difficult to predict. This type of decision making is referred to as decisions under conditions of uncertainty. We have to recognize, however, that uncertainty may come from various sources. To this end, the decision under uncertainty may be further subdivided into two categories: probabilistic and fuzzy decision making.

3.1.2.1 Multi-Objective Decision Making and Multi-Attribute Decision Making

As mentioned earlier, criteria are the standards of judgments or rules on the basis of which the alternative decision are ranked according to their desirability. Criterion is a generic term including the concepts of attribute and objective. Thus MCDM is used as the blanket term, which includes both multi-objective and multi-attribute decision making (Multiple Criteria Decision Analysis: State of the Art Surveys 2005).

Attributes are the proprieties of elements of a real-world geographical system. More specifically, an attribute is a measurable quantity or quality of a geographical entity or a relationship between geographical entities. In the context of a decision making problem, the entities and the relationships are referred to as the objects of decisions. We assume that decisions are made to change or leave unchanged the state of a system that is the state of entities and the relationships among them. The concept of attribute is synonymous with the often-used concept of the measurement of system performance. An attribute is used to measure performance in relation to an objective. It can be thought of as the means or information sources available to the decision makers for formulating and achieving the decision maker's objectives (Starr and Zeleny 1977).

An objective is a statement about the desired state of the system under consideration. It indicates the directions of improvement of one or more attributes. Objectives are functionally related to, or derived from, a set attributes. For any given objective, several different attributes might be necessary to provide complete assessment of the degree to which the objective might be achieved.

For example, if we have the objective "minizing the population exposure to air pollution", we may use the attribute "number of people exposed to sulfur oxides above a specified standard" (e.g. 80 $\mu g/m^3$ not to be exceed more than once per year), and "number of people exposed to carbon monoxide above a specified standard" (e.g., 100 mg/ m^3 not to be exceed more than once per year). (Multiple Criteria Decision Analysis: State of the Art Surveys 2005).

Some of the examples of these two types of MCDM developed in literature are shown as following:

MOP	Mathematical Optimization Programming	John von Neumann	1947
GP	Goal Programming	Charnes and Cooper(1961)	1955
MOL	Mathematical Optimization Linear Programming With Fuzzy Coefficients		

FP	Fuzzy Programming	Zimmerman	1965
ELECTRE	Elimination and Choice Translating Reality English	Bernard Roy	1965
AHP	Analytical Hierarchy Process	Thomas L. Saaty	1970
MACBETH	Measuring Attractiveness by a Categorical Based Evaluation Technique		
MAQİC	Multi-Attribute Global Inference of Quality	James D. McCaffrey	
DRSA	Dominance-based Rough Set Approach	Greco, Matarazzo and Słowiński	
VCDRSA	Variable-Consistency Dominance-based Rough Set Approach		
MAUT	Multi-Attribute Utility Technique	Keeny and Raiffa	1976
DEA	Data Enveloppement Analysis	Farrell Charnes; Cooper & Rhodes	1957-1978
VIG	A Visual Interactive Support System for Multiple Criteria Decision Making	Korhonen and Wallenius	1978
FGP	Fuzzy Goal Programming	Narasimhan	1980
PROMETHE	Preference Ranking Organization Method For Enrichement Evaluations	Brans	1982
UTA	Utility Additives Methods	Éric Jacquet-Lagrèze and	1982
ANP	analytical network process	Thomas L. Saaty	1986
VIMDA	Visual Multiple-Criteria Decision Support System for Discrete Alternatives	Kor honen, P.	1988

Table 3.2: Examples of these two types of MCDM developed in literature

3.2.2.2 Decision Making Under Certainty versus 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 (Holloway 1979). 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 (Kalu 1999).

There are two sources of uncertainty involved in making a decision. The first concerns the validity of information (Keeny and Raiffa 1976). The decision maker may be unsure whether the information about the problem is error-free and appropriate for predicting the outcome of any decision made. The second source of uncertainty concerns future events that might lead to differentially preferred outcomes for particular decision alternatives. In a sense, the former is a special case of the latter. For example, in the context of a farmer's decision, the uncertainty may be related to the question where and what kinds of agricultural production should be practice on the farm. Since the yield is influenced by weather conditions, which may be unpredictable; the farmer faces a decision under uncertainty. The limited information about the future weather conditions makes any prediction prone to error. Similarly, decisions concerning location or relocation of a retail facility are surrounded by uncertainty because of the unpredictability of the local decisions of competitors. Each competitor has its own local strategy, which may be difficult to predict because of imperfect information about the decision situation.

Although uncertainty exists in many decision situations, the amount of uncertainty (or the amount of information about the decision problem) varies greatly. To this end, it is useful to locate a decision problem on a continuum ranging from a predictable situation to one that is extremely difficult to predict. The former is referred to as a deterministic situation; the latter is referred to as a decision problem under uncertainty. Accordingly, MCDM problems can be classified into two categories: MCDM under certainty and MCDM under uncertainty. In a decision under certainty it is assumed that all relevant information about the decision situation is known and that there is a known deterministic connection between every decision and the corresponding outcome. This means that under conditions of certainty only one state of nature is possible or, alternatively, any variation that is possible will not affect the consequences of choosing a particular option. Either way, the decision is judged to be insensitive to any uncontrollable factors present.

Some decision situations come close to the case of certainty; that is, the uncertainty is so remote that it can be disregarded as a factor. Indeed; many problem formulations assume that the future state of nature is known with certainty. Such secondary attention to uncertainty (risk) factors is often a necessity because of data availability or costs. Thus, even when uncertainty is recognized, it may have to be ignored because of insufficient data for evaluation would require too much time or money. Moreover, a decision maker can deliberately choose to model a decision as occurring under a condition of certainty if it is believed that modeling it in a probabilistic manner will add nothing to the analysis of the problem. It may be perfectly legitimate ploy to assume, for example, that population figures by region will have a certain value and to assume that the investments costs of establishing a facility in alternative locations will take a certain level, even though we know that these figures are merely best guesses (Yang and Hung 2007). This does not imply, however, deterministic decision problems may be particularly easy or straightforward. The problems may be complex because a multitude of alternative strategies may be present, which may be evaluated on the basis of incommensurate and conflicting criteria by a number of interest groups or decision makers. Furthermore, to deal with uncertainty involved in a deterministic problem formulation, sensitivity analysis can be performed to demonstrate the possible outcomes under different scenarios.

Two basic types of uncertainty may be presented in a decision situation:

1. uncertainty associated with limited information about decision situations

2. uncertainty associated with fuzziness (imprecision) concerning the description of the semantic meaning of the events, phenomena, or statements themselves

Consequently both MADM and MODM problems under uncertainty can be subdivided further into probabilistic (stochastic) and fuzzy decision making problems, depending on the type of uncertainty involved. The probabilistic decision has a stochastic character. They are handled by probabilistic theory and statistics. The concept of uncertainty can be treated as secondary to that of probability. Once the probability of the event concerned is known, the quantitative aspect of the uncertainty is determined. The precise nature of the link will depend on the view actually taken.

In many cases the uncertainty is not due to randomness but to some imprecision whose formal treatment cannot be handled by probability theory. Note that the outcome of a stochastic event is either true or false. However, in a situation where the event itself is ambiguous, the outcome may be given by a quantity other than true (1) or false (0). The problem of ambiguity can be structured as the degree to which an event "more or less belongs" to a class. This type of situation is handled by the fuzzy set theory. Specifically, the theory of fuzzy sets provides a natural basis for the theory of possibility, playing a role similar to that of measure theory in relation to the theory of probability (Zadeh 1965). It is important to realize that possibility theory is an alternative information theory to that based on probability. 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 proposed fuzzy set theory to handle this imprecision (Zadeh 1965,1968). Fuzziness is a type of imprecision which may be associated with sets in which there is no sharp transition from membership to non membership claimed Zadeh and Bellman (Bellman and Zadeh 1970).

The management of e-waste 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.

3.2 The Multi Criteria Decision Making Techniques Used In the Application

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 (Rinquest 1995).

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 (Schniederjans 1995).

Applications of decision analysis with multiple objectives have been summarized in several publications. Comer 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 Winterfeidt and Edwards (1986), Beil, Raiffa and Tversky (1988), and Edwards (1992) (Keeney and Raiffa 2003).

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, Rornero 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 (Keeney and Raiffa 2003).

3.2.1. Goal Programming & Fuzzy Goal Programming Literature Review

Goal programming is a branch of multi-objective optimization, which in turn is a branch of multi-criteria decision analysis (MCDA), also known as multiple-criteria decision making (MCDM). It can be thought of as an extension or generalization of linear programming to handle multiple, normally conflicting objective measures. Each of these measures is given a goal or target value to be achieved. Unwanted deviations from this set of target values are then minimized in an achievement function. This can be a vector or a weighted sum dependent on the goal programming variant used. As satisfaction of the target is deemed to satisfy the decision maker(s), an underlying satisfying philosophy is assumed (Wikipedia 2008).

Goal programming (GP) has been a widely discussed (Hannan, 1985; Gass, 1987; Min and Storbeck, 1991) and applied (Jones and Tamiz, 2002) technique for solving decision problems with multiple criteria. In classical GP models, unwanted deviations from target values defined by the decision maker are minimized in order to reach an acceptable solution (Steuer, 1986). The unwanted deviations are measured using positive and negative deviation variables that are defined for each goal and they represent over achievement and underachievement of the goal, respectively.

GP models have been classified based on the achievement function that is used to combine the unwanted deviations (Romero, 2004):

1. Weighted GP (also known as 'non-preemptive GP') where the weighted sum of deviations from the targets are minimized
2. Preemptive priority GP (also known as 'Lexicographic GP'), where a deviation from a higher priority level goal is considered to be infinitely more important than a deviation from a lower priority goal
3. MinMax GP (also known as 'Chebyshev GP'), where minimization of the maximum weighted deviation from the target values is sought.

Recently, some extensions, which are formed by hybridizing the above main approaches in order to obtain more general achievement function structures, have been proposed (Romero, 2004). However, from the modeling goal priorities point of view weighted GP and preemptive priority GP have been the two most widely used approaches (Jones and Tamiz, 2002; Romero, 2004).

In the weighted GP, a GP formulation is expressed as a mathematical programming model with a single objective function to be minimized (Steuer, 1986; Romero, 2004). The objective function is defined as a weighted sum of the deviation variables. The relative importance of the goals is represented by weights associated with the corresponding deviations. This type of GP is used when it is possible to quantify relative importance of goals. In the case of weighted GP, determination of the weights remains a difficult problem. Generally it depends on several factors such as the preference structure of the decision maker, the decision space and correlations between the objectives (Steuer, 1986; Mohanty and Vijayaraghavan, 1995).

Preemptive priority GP is based on associations of preemptive priorities among the goals (Steuer, 1986; Romero, 2004). In this case, each goal is set to a certain predefined priority level. A series of mathematical programming problems are solved sequentially, first considering highest priority goals only, and then continuing with lower priority ones, under the constraints imposed by the alternative optimal solutions of the problems that included the higher priority goals. The use of preemptive priority GP implies that there are infinite trade-offs between goals placed in different levels of priority. Consequently, this approach may generate solutions with high achievements obtained for the higher priority level goals only. Different arguments in favor or against the use of these two GP models have been presented in the literature. For example, Gass (1987) argues that modeling a multiple objective problem using the preemptive structure may be unrealistic for the decision maker for the following reasons.

First, it may be very difficult for the decision maker to set absolute goal hierarchy levels because this assumes infinite trade-offs between different levels. Second, the sequential solution technique may cut-off some parts of the solution space, which might be of interest to the decision maker. On the other hand, a decision maker may find determining absolute goal priority levels in some situations more straightforward than determining precise weights for the goals; this might make weighted GP less favorable compared to the preemptive priority GP (Jones and Tamiz, 2002; Romero, 2004). However, when the multi-criteria problem at hand does not naturally meet the assumptions implied by the preemptive priority GP, this may lead to unsatisfactory results. For that reason, Hannan (1985) argues that the use of preemptive priority GP instead of the weighted GP for the sake of its convenience in determining relative priorities should be avoided, even when specification of the weights is difficult and time consuming.

Bellman and Zadeh (1970) set the basic principles of decision making in fuzzy environments, which have been used as building blocks of fuzzy linear programming (Zimmermann, 2001). Since early 1980s, fuzzy sets have been used in GP models to represent uncertain knowledge about a certain parameter (Mohandas et al., 1990; Chanas and Kuchta, 2002), and to represent a satisfaction degree of the decision maker with respect to his/ her preference structure (Narasimhan, 1980; Hannan, 1981a; Tiwari et al., 1987; Mohamed, 1997; Wang and Fu, 1997; Chen and Tsai, 2001). Chanas and Kuchta (2002) provided a survey of various fuzzy goal programming (FGP) models reported in the literature.

Various approaches to treating relative importance of goals in FGP models have been developed. Narasimhan (1980) used a combination of linguistically defined weights, such as ‘very important’, ‘moderately important’ and achievement degrees of the goals. The weights and achievement degrees are combined by defining a membership function for each linguistic weight, where desirable achievement degrees are specified to represent goal importance. Hannan (1981b) showed that the above composite approach may lead to some contradictory results and suggested the use of explicitly defined weights to represent relative importance of goals. Hannan (1981a) proposed a fuzzy logic based methodology that employs piecewise linear functions, which represent decision maker satisfaction with attaining goal values. A target achievement degree is determined for each goal and the problem is converted to a standard GP formulation, where deviations from these target values are minimized using standard preemptive, weighted or MinMax achievement functions.

A different approach is proposed by Tiwari et al. (1987). The authors considered an additive FGP model with relative importance of commensurable goals. The model included a single objective function defined as the weighted sum of achievement degrees of the goals with respect to their target values. The authors also proposed a sequential method similar to classical lexicographic GP, where the problem under consideration is decomposed into n sub problems to be solved, where n is the number of preemptive priority levels. First, the highest priority level goals are considered by using the additive model. In each sub problem, the previously obtained achievement degrees of the goals are fixed and represented by additional constraints, and, subsequently, the achievement degrees of the goals that belong to the corresponding level are obtained. Chen and Tsai (2001) proposed an extension of the additive model to consider goals of different importance and preemptive priorities, where relative importance of goals is modeled by corresponding desirable achievement degrees. Mohandas et al. (1990) included linguistically defined weights in a scalarized objective function with fuzzy arithmetic operations. Wang and Fu (1997) used different types of membership functions to represent goal priorities, which are obtained by using fuzzy sets operations, such as dilation and contraction.

In practice, when real life multi-objective decision problems are considered, providing crisp definition of goal priorities is not an easy task. Uncertainty may be inherent in relative importance relations among the goals, or alternatively the perception of the relative importance relations among the goals may be vague from the decision maker's point of view. The decision space and correlation between objectives may also have effects on the definition of importance relations among the goals. Hence, there is a need to develop a FGP model which takes into account these uncertainties and provides a flexible decision making tool.

3.2.2. The formulations of Goal Programming & Fuzzy Goal Programming

Consider the linear multi objective model

$$\begin{aligned} &\text{Opt. } Z = C.X \\ &\text{s.t. } AX \le B \end{aligned} \tag{1}$$

where $Z = (z_1, z_2, z_3, \ldots.. z_n)'$ is the vector of objectives, C is a KxN matrix of constants, X is an Nx1 vector of decision variables, A is an MxN matrix of constants, and b is an Mx1 vector of constants. The model (1) has been applied to solve many real-world problems. Transportation problem with multiple objective functions, production planning with multiple efficiency criteria, input-output model for resource allocation, and operation scheduling are only examples of these applications (Mohammed 1996).

To solve (1), one can distinguish between 4 main approaches:

(i) Reducing the multi objective problem to a single objective one by using some real-valued function H $(z_1, z_2, z_3, \ldots.. z_n)$ which may take one of the following (or other) forms:

$$(a) H(z_1, z_2, z_3, \ldots, z_n) = \min z_k$$

$$(b) H(z_1, z_2, z_3, \ldots, z_n) = \sum_{k=1}^{K} \alpha_k (z_k)^{\beta_k}, \alpha_k \succ 0, \beta_k \succ 0$$

$(c) H(z_1, z_2, z_3, ..., z_n) = \prod_{k=1}^{K} z_k$

$(d) H(z_1, z_2, z_3, ..., z_n) = \max(z_k - z_k^*)$

where z* is the optimal value of Z_k subject to the constraints of (1)

(ii) Reducing the multi objective problem to a single objective one by means of utility functions. The methods of this area are based on the decision maker's preference. This preference is translated to mathematical expression by using either the value function or the utility function (Mohammed 1996).

(iii) The GP approach

(iv) The FP approach

These two approaches will be discussed in the following parts, respectively. A comparison between GP and FP to present the similarities and dissimilarities between them will be stated also.

3.2.2.1 Goal Programming

This approach was first introduced by Charnes and Cooper, and then developed by Ijiri, Lee, Ignizio, and others. The main idea behind GP is to minimize the distance between Z (as defined in (1)) and an aspiration level vector Z. The aspiration level Z is either determined by the decision maker or equals Z* where Z* = (z_1*, z_2*, z_3*,...., z_n*) with z_k* as defined before.

In GP the distance between Z_k and $\check{Z}_k$, d($Z_{k,}$ $\check{Z}_k$), is expressed by the deviational variables n_k and p_k (k = 1,2, ... , K) where n_k is the negative deviational variable,

(1.1)

$$n_k = \max(0, z_k - z_k^*) = \sqrt{\left[z_k - z_k^* + \left|z_k - z_k^*\right|\right]}$$

and p_k is the positive deviational variable,

(1.2)

$$p_k = \max(0, z_k^* - z_k) = \sqrt{\left[z_k - z_k^* + \left|z_k - z_k^{**}\right|\right]}$$

Minimizing the distance between Z_k and $\check{Z}_k$ means minimizing either n_k or p_k or $n_k + p_k$. We minimize n_k when we need Z_k and $\check{Z}_k \geq \check{Z}_k$ (maximization problem); minimize p_k when we need $Z_k \leq \check{Z}_k$ (minimization problem; and minimize $n_k + p_k$ when we need $Z_k=\check{Z}_k$. Accordingly, the model (1) is converted by GP to a minimization problem of the deviational variables and it may take any of the following forms:

(i) The Min-Max form:

$$\begin{aligned}
&\min\max g_k(p_k, n_k) \\
&st. \\
&(1.3) A..X \leq B, \\
&(1.4) C_k.X + n_k - p_k = z_k^*, k = 1,2,...,K \\
&(1.5) n_k \geq 0, p_k \geq 0, n_k.p_k = 0, k = 1,2,...,K
\end{aligned} \tag{2}$$

where g_k (p_k, n_k) in the case of maximizing z_k, g_k (p_k, n_k) = p_k in the case of minimizing z_k, and g_k (p_k, n_k)) = $n_k + p_k$ when we need $z_k = \check{z}_k$, C_k is the k'th row of the matrix C. The model (2) is converted to a linear program as following:

$$\begin{aligned}
&\min \tau \\
&st. \\
&constraints(1.3)-(1.5), \\
&\tau \geq g_k(p_k, n_k), k = 1,2,...,K
\end{aligned} \tag{3}$$

The model (3) can be solved by the simplex method.

(ii) The minimization of the sum of deviations form:

$$\begin{aligned}
&\min \sum_{k=1}^{K} g_k(p_k, n_k) \\
&st. \\
&constraints(1.3)-(1.5)
\end{aligned} \tag{4}$$

where all the parameters and variables are as defined in (1) and (2). (4) is a linear program which can be solved using the simplex method.

(iii) The minimization of the weighted sum of deviations form:

$$\min \sum_{k=1}^{K} w_k g_k \left(p_k n_k\right)$$
$$st.$$
$$constra\,\text{int}\, s(1.3)-(1.5) \tag{5}$$

where w_k (k = 1, 2, . . . , K) are determined by the decision maker. The equation (5) is a linear program like (3) and (4) and can be solved using the simplex method.

(iv) The preemptive priority form: If the decision maker can rank the K objectives according to their priority, then the lexicographical form of goal programming can be used. In this form the K objectives are rearranged according to their priority levels, the highest priority goal is considered first, then the second and so on (Mohammed 1996). The general lexicographical goal program is:

$$\min a = \left\{ \sum_{k \in P_i} w_k . g_k \left(p_k n_k\right) : i = 1,2,...I \right\}$$
$$s.t.$$
$$constra\,\text{int}\, s(1.3)-(1.5) \tag{6}$$

where i is the number of priority levels and $k \in P_i$ means that the k'th goal is in the i'th priority level. (6) is a linear goal program which can be solved using the multiphase simplex method or the sequential simplex method.

3.2.2.2. Fuzzy Programming

The FP approach for handling the multi objective problems was firstly introduced by Zimmermann. Narasimhan, and Ignizio had investigated and developed the use of fuzzy set theory in solving problems with multiple goals. The approach of Zimmermann is the basis and the best of all these and other works (Mohammed 1996). We will concentrate on presenting this renewed approach by Mohammed (1996) in this area which will be presented later.

Fuzzy linear programming using the min-operator form: Starting from the model (1) the adopted fuzzy version due to Zimmermann is

$$\begin{aligned} & CX \gtrsim Z \\ \text{s.t.} \quad & AX \lesssim b, \end{aligned} \tag{7}$$

where > and < are the fuzzification of ≥ and ≤, respectively. >~ (<~) means "essentially greater (less) than". To solve (7) Zimmermann suggested using a linear membership function for each goal $\mu_{1k}(C_kX)$, where

(1.6.)

$$\mu_{1k}(C_k.X) = \begin{cases} 1 & \text{if } (C_k.X) \geq \tilde{z}_k \\ 1 - (z_k^* - C_k.X) / d_{1k} & \text{if } \tilde{z}_k - d_{1k} \leq (C_k.X) \leq \tilde{z}_k \\ 0 & \text{if } (C_k.X) \leq \tilde{z}_k - d_{1k}, k = 1,2,...K \end{cases}$$

and another linear membership function $\mu_{2k}(a_iX)$ for the i'th constraint in the system constraints AX < b, where

(1.7.)

$$\mu_{2i}(a_i.X) = \begin{cases} 1 & \text{if } (a_i.X) \leq b_i \\ 1 - (a_i.X - b_i) / d_{2i} & \text{if } b_i \leq (a_i.X) \leq b_i + d_{2i} \\ 0 & \text{if } (a_i.X) \geq b_i + d_{2i}, k = 1,2,...K \end{cases}$$

where d_{1k} (k = 1, 2 . . . . . K) and d_{2i} (i = 1, 2 . . . . ,M) are the subjectively chosen constants of admissible violations, and a_i is the i'th row of the matrix A.

Since $\mu_{1k}(C_kX)$ and $\mu_{2i}(a_iX)$ express the satisfaction of the decision maker with the solution, they must be maximized, i.e. the problem is:

$$(1.8.)\quad \max_x\left(\mu_{11}(C_1.X),....,\mu_{1k}(C_k.X),\mu_{21}(a_1.X),...,\mu_{2i}(a_i.X)\right)$$

In one of the fuzzy set theorems, the membership function of the intersection of any two (or more) sets is the minimum membership function of these sets.

By applying this theorem the problem is converted to:

$$(1.9.)\quad \max_x \min\left(\mu_{11}(C_1.X),....,\mu_{1k}(C_k.X),\mu_{21}(a_1.X),...,\mu_{2i}(a_i.X)\right)$$

From (1.6.), (1.7.), and (1.9.) the fuzzy program can be rewritten as the following program; The program (8) is a linear program that can be solved using the simplex method:

$$\begin{aligned}
&\max y\\
&st\\
&y \le \frac{1-(\tilde{z}_k - C_k.X)}{d_{1k}}, k = 1,2,...,K,\\
&y \le \frac{1-(a_i.X - b_i)}{d_{2i}}, i = 1,2,...,I,\\
&y \ge 0, X \ge 0
\end{aligned} \qquad (8)$$

3.2.2.3. 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 (Ramik 2000). 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 Beliman 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 (Dubois and Prade 2000).

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 (Aköz and Petroviç 2007).

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 (2). 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 bad for solving the FGP problem (Kumar, Vrat and Shankar 2004).

We developed a new approach for transforming (7) to a linear goal program. This approach depends on the fact that the maximum value of any membership function is 1; hence maximizing any of them is equivalent to making them as close as possible to 1 by minimizing its negative deviational variable from 1(Mohammed 1996).

In this sense the problem is converted to a GP that can take any of the forms (3), (4), (5), or (6). By applying the form (3) to the fuzzy program (7) using the definitions of $\mu_{1k}(C_kX)$) and $\mu_{2i}(a_iX)$ in (1.6.) and (1.7.), the following program can be obtained:

$$\min \phi$$

$$s.t$$

$$(1.10)$$

$$\frac{1-\left(z_k^* - C_k.X\right)}{d_{1k}} + n_{1k} + p_{1k} = 1$$

$$(1.11)$$

$$\frac{1-\left(a_i.X - b_i\right)}{d_{2i}} + n_{2i} + p_{2i} = 1$$

$$(1.12)$$

$$\phi \geq n_{1k}$$

$$(1.13)$$

$$\phi \geq n_{2i}$$

$$(1.14)$$

$$X \geq 0, n_{1k} \geq 0, p_{1k} \geq 0, n_{2i} \geq 0, p_{2i} \geq 0,$$

$$n_{1k}.p_{1k} = 0, n_{2i}.p_{2i} = 0,$$

$$k = 1,2,...,K, i = 1,2,...,I$$

(9)

The model (9) is a linear program that can be solved using the simplex method. Also, by applying (4) to (7) we can get the following linear program:

$$\min\left(\sum_{k=1}^{K} n_{1k} + \sum_{i=1}^{I} n_{2i}\right)$$

$$s.t.$$

$$constra\text{int}\, s(1.10),(1.11),(1.14)$$

(10)

To transform (7) to a GP by using (5) one can get the following program:

$$\min\left(\sum_{k=!}^{K} w_{1k}.n_{1k} + \sum_{i=1}^{I} w_{2i} n_{2i}\right)$$
$$s.t.$$
$$constra\text{int}\, s(1.10),(1.11),(1.14)$$

(11)

Finally, if the decision maker can assign priority ranking for each goal then (7) can be rewritten as a GP by using the formula (6) as follows:

$$\min a = \left\{\sum_{k=!}^{K} w_{1k}.n_{1k} + \sum_{i=1}^{I} w_{2i} n_{2i}, k = 1,2,...,K, i = 1,2,...,I\right\}$$
$$s.t.$$
$$constra\text{int}\, s(1.10),(1.11),(1.14)$$

(12)

The forms (8), (9), (10), (11), and (12) represent the different types of fuzzy programs in the case of having linear membership function and the fuzziness is in the right-hand side of both the goals and constraints. The other cases of nonlinear membership functions or models with fuzzy numbers are out of our research.

3.2.2.4. The relationship between GP and FP

GP and FP are two approaches for solving the multi objective problem (1). Both of them need an aspiration level for each objective. These aspiration levels are determined either by the decision maker or the decision analyst. In addition to the aspiration levels of the goals, FP needs admissible violation constants d_{lk} for each goal. The larger d_{lk} indicates less important k'th goal (Mohammed 1996). Accordingly, the following theorem can be stated about the relationship between GP and FP.

Theorem: Every fuzzy linear program has an equivalent weighted linear goal program where the weights are the reciprocals of the admissible violation constants (i.e. w_k=l/ d_{lk}).

Proof: Without loss of generality we will assume that the fuzziness is in the aspiration levels of the goals and not in the system constraints (the goals and the constraints are treated in the same way in FP). We will prove that (8) is equivalent to (3) with weighted deviational variables where the weights are 1/ d_{1k},, (k = 1,2 . . . K). Starting from (8), it can be rewritten as

$$
\begin{aligned}
&\max y \\
&st \\
&y \leq \frac{1-\left(\tilde{z}_k - C_k.X\right)}{d_{1k}}, k = 1,2,\ldots,K, \\
&y \leq \frac{1-\left(a_i.X - b_i\right)}{d_{2i}}, i = 1,2,\ldots,I, \\
&y \geq 0, X \geq 0
\end{aligned}
$$

Since y is a transformed to membership function, y ≤ 1 which means that 1 - y ≥0. Let 1 - y = u, and the problem can be transformed to

$$
\begin{aligned}
&\min u \\
&st \\
&u \leq \frac{\left(\tilde{z}_k - C_k.X\right)}{d_{1k}}, \\
&A.X \leq b, \\
&u \geq 0, X \geq 0
\end{aligned}
\tag{13}
$$

From (13) u ≥ max(0,($\check{z}_k$ - C_kX)/ d_{1k})) and by using the definition of the negative deviational variables in (1.11) it can be obtained that u ≥ n_{1k}, where

$$
\begin{aligned}
&\frac{C_k.X}{d_{1k}} + n_{1k} - p_{1k} = \frac{\tilde{z}_k}{d_{1k}} \\
&i.e. \\
&C_k.X + d_{1k}.n_{1k} - d_{1k}.p_{1k} = \tilde{z}_k
\end{aligned}
$$

The full program (13) can be rewritten as

$$\begin{aligned}
&\min u \\
&s.t. \\
&A.X \leq b \\
&C_k.X + d_{1k}.n_{1k} - d_{1k}.p_{1k} = \tilde{z}_k \\
&u \geq n_{1k} \\
&X \geq 0, n_{1k} \geq 0, p_{1k} \geq 0, n_{1k}.p_{1k} = 0, \\
&k = 1,2,...,K
\end{aligned} \tag{14}$$

(14) is equivalent to (3) with $n_k = d_{1k}n_{1k}$ (i.e. $n_{1k} = n_k / d_{1k}$). Then (8) is equivalent to (3) with weighted deviational variables where the weights equal $1/ d_{1k}$. The proof is completed by considering the relationship between GP in its min-max form and the fuzzy linear program using the min-operator (Mohammed 1996).

In this study, we have to make a strategic process decision, we have to choose one of the recycling method.

3.2.1 Fuzzy AHP

We apply a novel methodology which integrates the MADM and MODM methods to solve mathematical programming problems including both qualitative and quantitative data. Fig.3.3 displays the outline of this new algorithm.

The main steps of this approach are described below.

(i) Formulate the model for environmental problems

Real world environmental management problems require the consideration of numerous factors. For example, to consider environmental, economical, social aspects etc., we can formulate a multi objective programming model that includes: decision variables, objective functions and constraints, concerning stakeholders. The stakeholders may consist of government, experts, NGOs, and business and so on

.

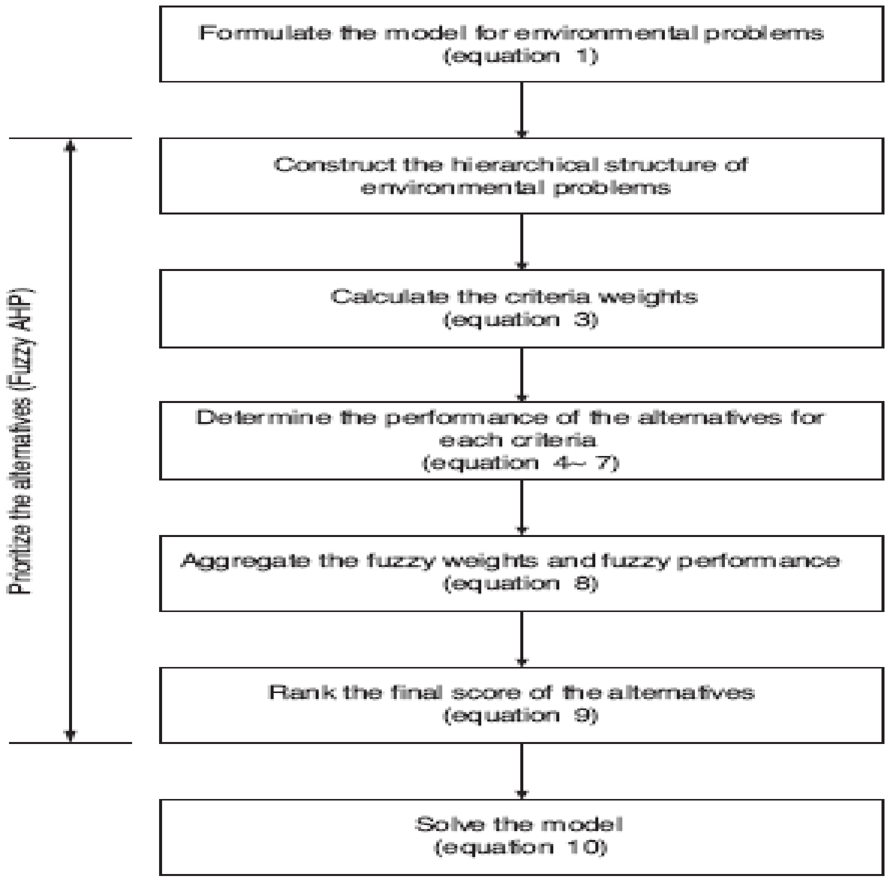


Fig. 3.3: The steps for formulation of a fuzzy AHP model

(ii) Prioritize the alternatives

Many MADM methods are used to prioritize the alternatives, such as ELECTRE (Roy, 1991), PROMETHEE (Brans and Vincke, 1985), TOPSIS (Hwang and Yoon, 1981), and the AHP methods (Saaty, 1980). The AHP method was developed by Saaty (1980). However, for real world environmental management problems that involve many stakeholders and conflicting viewpoints, the traditional AHP method is insufficient. Buckley (1985) applies the fuzzy theory to the AHP method to avoid neglecting extreme values. Applying the fuzzy AHP method involves five steps, as follows.

1. Construct the hierarchical structure of the waste management problems: In real MCDM problems, the process must be divided into distinct stages. First, based on a general problem statement, various stakeholders are defined and identified. They may include decision-makers, experts in relevant fields, and various interest groups affected by the decision. The overall objective is set during this stage.

Next, the alternatives/strategies for a discrete MCDM problem comprising of a finite set of alternatives/strategies are assessed in terms of multiple criteria (Hung et al. 2005).

2. Calculate the criteria weights: The criteria weights can be determined by the stakeholders. To include all the options of the stakeholders, this study used the fuzzy weighting method. The fuzzy weights of the criteria can be determined as follows:

$$
\begin{aligned}
\hat{w}_j &= \lfloor w_{jl}, w_{jm}, w_{jr} \rfloor, j = 1,2,...m \\
w_{jl} &= \min\{w_{jk}\}, \forall j, k = 1,2,...p \\
w_{jm} &= \begin{cases} geomean\{w_{jk}\}, \forall j, k \rightarrow if \forall w_k \neq 0 \\ average\{w_{jk}\}, \forall j, k \rightarrow otherwise \end{cases} \\
w_{jr} &= \max\{w_{jk}\}, \forall j, k
\end{aligned}
\quad (15)
$$

where m denotes number of criteria, p represents number of experts, w_{jk} is the weight of criteria j as judged by expert k, w_{jl} denotes the minimum weight of criteria j as judged by all of the experts, w_{jm} represents the geomean (or average) weight of criteria j as judged by all the experts, and w_{jr} is the maximum weight of criteria j as judged by all the experts

3. Determine the fuzzy performance of the alternatives for each criteria: The criteria can be divided into two categories: quantitative and qualitative, as noted earlier. The calculation of performance of the alternatives criteria can be calculated as follows.

3.1. Quantitative criteria: This investigation utilizes the triangular fuzzy number to express the performance of quantitative criteria. First, the original value of the quantitative criteria is normalized and expressed as follows:

$$x_{ij}^{norm} = \frac{\left(x_{ij}^{max} - x_{ij}^{0}\right)}{x_{ij}^{max} - x_{ij}^{min}}, i = 1 \approx n \text{ (positive criteria)}$$

$$x_{ij}^{norm} = \frac{\left(x_{ij}^{0} - x_{ij}^{min}\right)}{x_{ij}^{max} - x_{ij}^{min}}, i = 1 \approx n \text{ (negative criteria)}$$

(17)

where n denotes the number of alternatives, norm(x_{ij}) represents the normalized value of criteria j for alternative i, x^0 is the original value of criteria j for alternative i, x^{max} denotes the maximum value of criteria j for all alternatives, and represents the x^{min} minimum value of criteria j for all alternatives. The positive criteria means that those criteria positively affect environmental management, e.g. the social acceptability of the treatment technologies, and the negative criteria are the criteria that negatively affect environmental management, e.g. the cost of the treatment technologies (Hung et al. 2005).Second, the normalization value is fuzzified using the following equation:

Fuzzy performance of quantitative criteria x_{ij}*;

$$= \left(0{,}9.x_{ij}^{norm}, x_{ij}^{norm}, \min\left(1{,}1.x_{ij}^{norm}, 1\right)\right)$$

(17)

3.2.Qualitative criteria: The linguistic variables are designed to express the words or sentences in a natural or artificial language. The linguistic variables is composed of five variables (v, T, X, g, m), where: v denotes the name of the variable, T represents the set of linguistic terms of v that refers to a base variable whose values range over universal set X, g is a syntactic rule for generating linguistic terms, and m denotes a semantic rule that is assigned to each linguistic term (Zimmermann, 1987). The linguistic variables are utilized to calculate the performance of the qualitative criteria. Five levels are used to integrate the preference of the relative field experts, as shown in Fig. 3.2 The fuzzy performance of qualitative criteria is determined by using a fuzzy triangular number and is expressed as follows:

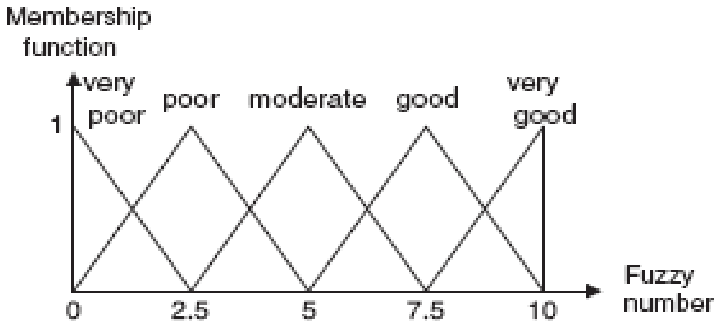


Fig. 3.4: Fuzzy membership function

Fuzzy performance of qualitative criteria x_{ij}*;

$$= \lfloor x_{ijl}, x_{ijm}, x_{ijr} \rfloor$$
$$x_{ijl} = \min\{x_{ijk}{}^{l}\}, \forall j, k$$
$$x_{ijm} = geomean\{x_{ijk}{}^{m}\}, \forall j, k$$
$$w_{ijr} = \max\{x_{ijk}{}^{r}\}, \forall j, k$$

(18)

where x_{ijl} denotes the left value of the fuzzy number of qualitative criteria j for the alternatives i, x_{ijm} represents the medium value of the fuzzy number of qualitative criteria j for the alternatives i, x_{ijr} is the right value of the fuzzy number of qualitative criteria j for the alternatives i, $x_{ijk}{}^{1}$ denotes the left value of the fuzzy number of qualitative criteria j as judged by expert k for the alternatives i, $x_{ijk}{}^{m}$ represents the medium value of the fuzzy number of qualitative criteria j as judged by expert k for the alternatives i, and $x_{ijk}{}^{r}$ denotes the right value of the fuzzy number of qualitative criteria j as judged by expert k for the alternatives i.

4. Aggregate the fuzzy weights and fuzzy performance: The simple additive method is utilized to aggregate the fuzzy weights and fuzzy performance, i.e.,

$$R^* = X^* \otimes W^{T*} = x_{ij}{}^* \otimes W^{T*}$$
$$= \begin{pmatrix} x_{11}{}^* \ldots\ldots x_{1m}{}^* \\ : \\ x_{n1}{}^* \ldots\ldots x_{nm}{}^* \end{pmatrix} \otimes \begin{pmatrix} w_1{}^* \\ : \\ w_m{}^* \end{pmatrix} \tag{19}$$

where R* denotes fuzzy evaluation matrix, X* presents fuzzy performance matrix, and W* is fuzzy weighting matrix.

5. Rank the final score of the alternatives: The centralized weight method (Yager, 1980) is the most commonly used defuzzification method (Opricovic and Tzeng, 2003) and is used in this study to defuzzify the fuzzy numbers to prioritize the alternatives. This method converts a fuzzy number into crisp value based on the concept of the center-of-gravity (Hung 2005). For the triangular fuzzy number $\widetilde{F} = (f_l, f_m, f_r)$ and the crisp value of the fuzzy number can be expressed as follows:

$$F_{crisp} = f_l + \frac{[(f_m - f_l) + (f_r - f_l)]}{3} \tag{20}$$

Next, the ranking results are utilized to solve the original mathematical programming problems. The best alternatives will be set as maximum as possible.

The original problem then is transformed to the following model:

$$\begin{aligned}
&Step(1) \\
&\max x_r \\
&s.t. X \in S \\
&Step(2) \\
&\max x_r \\
&s.t. X \in S \\
&x_1^r = x_1^{r*} \\
&:
\end{aligned}$$

$$
\begin{aligned}
&Step(n)\\
&\max x_r\\
&s.t. X \in S\\
&x_1^r = x_1^{r*}\\
&x_2^r = x_{21}^{r*}\\
&:\\
&x_{n-1}^r = x_{n-1}^{r*}
\end{aligned}
\tag{21}
$$

where x_1^r denotes the decision variable which is ranked first in the previous procedure, x_2^r represents the decision variable which is ranked second, . . ., x_n^r denotes the decision variable which is ranked nth. x_1^{r*} is the optimal solution for x^{r*} in Step (1), x_2^{r*} is the optimal solution for x^{r*} in Step (2) and so on. Finally, the model can be solved simply.

3.4 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 (Yang and Hung 2007). Each rank is assigned to a membership function.

A transformation table is below. The linguistic variables are classified from equal to absolute strong. For example, the fuzzy variable Weak to Strong is associated with triangular fuzzy number (2/3, 1, 3/2); where 0,66 is the minimum, 1 is the mode and 1,5 is the maximum. Table 3.2 illustrates the fuzzy membership functions.

Table 3.2: Linguistic Variables of fuzzy membership function

Equal(E)	(1, 1, 1)
Weak(W)	(2/3, 1, 3/2)
Strong (S)	(3/2, 2, 5/2)
Very Strong(VS)	(5/2, 3, 7/2)
Absolute Strong (AS)	(7/2, 4, 9/2)

4. APPLICATION

Multiple conflicting objectives characterize the current solid waste management systems such that integrated planning becomes essential and significant. It is frequently emphasized that both socioeconomic and environmental considerations need to be included simultaneously in solid waste management programs in order to provide a set of 'total solution' regarding waste recycling, facilities site, and system operation. However, the inherent uncertainties in the perception of both priority and scale of those economic and environmental goals may generate additional difficulties in management decision making.

4.1 Introduction

Various deterministic multi objective programming models have been applied for planning solid waste management systems. For instance, Perlack and Willis (1985) considered the application of a multi objective programming model in a sludge disposal problem in the USA. Koo et al. (1991) accomplished the site planning of a regional hazardous waste treatment center by using a fuzzy multi objective programming technique in Korea. The efforts in combining the environmental objectives (i.e., air pollution, leachate, and noise and traffic congestion) into a location/allocation model for solid waste management planning were established by Chang et al. in the USA and Taiwan (Chang and Wang, 1994, 1996a, b; Chang et al., 1993, 1994). A relevant study was also carried out by Chang and Wang (1995) in which a deterministic compromise programming model, including both considerations of economic and environmental objectives, was established in search of the long term optimal management alternatives in a typical solid waste management system.

However, uncertainty plays an important role in most solid waste management problems. Fuzziness is one type of uncertainties especially embedded in those linguistic expressions in decision making, which is non-statistical in nature and generally cannot be described by traditional probability distribution. Such impreciseness refers to the absence of sharp boundaries in information. It is found that the application of fuzzy sets theory to solving real-world decision making problems is urgently needed. The fuzzy mathematical programming is therefore viewed as an alternative to the stochastic one, where the parameters or objectives are modeled as fuzzy sets. There have been very few studies in the literature involving the use of fuzzy mathematical programming models for tackling real-world solid waste management problems. This research, serving as a continuing study of Chang and Wang 1995 illustrates the use of the fuzzy goal programming (FGP) approach (Zimmermann, 1978; Tiwari et al., 1978, 1986) to facilitate the long term planning of the waste management systems for a specific type which is becoming more crucial socially, economically also around the world. The membership functions defined in fuzzy sets theory might provide one of the flexibility in the formulation of such uncertainty for the objective function and/or constraints to form the fuzzy mathematical programming model. It specifically demonstrates the fuzzy multi criteria decision making process, based on the considerations of economic and environmental impacts such as noise, traffic congestion, air pollution, and material recycling within the long term planning program for site landfills, incinerators, and transfer stations in a typical solid waste management system. Interactions among the effects of waste generation, source reduction, recycling, collection, transfer, processing, and disposal are tied together within such an analytical framework.

The proposed FGP method has been applied to the electric and electronic waste management system in Turkey for the purpose of demonstration. It shows that the fuzzy optimal outputs may generate a set of flexible management alternatives for handling real-world, complex solid waste management problems. From the long term perspective, the optimal strategies obtained in this analysis are especially helpful for the sustainable development in the country. This application will precise the strategies of e-waste management and their consequences according to Turkey's conditions. In this study the research area is applied as an automotive fabric because of its high percentage of e-waste in total waste. To observe the system, the data needed received from Oyak Renault Fabric in Bursa and the firm, who is in cooperation about recycling, Doğa Entegre Geri Dönüşüm Endüstri A.Ş. The problem that we will try to find out is the best appropriate strategy for the electronic waste recovery. This is important, because we will not select a recycling method. The strategy with multi objectives and constraints for a specific fabric is chosen at the end of the study. This research helps us to make a provision about benefits if the manufacturers and government support a well organized waste management.

Another purpose of this study is to develop a fuzzy AHP approach by integrating the multi attribute and multi objective decision-making methods to solve qualitative and quantitative objectives simultaneously for environmental management problems. The reason is that environmental management problems are very complex and require considering numerous factors. In environmental management problems, the decision-makers usually consider the environmental, economic, social and other factors (Morrissey and Browne, 2004). Some of these factors can be quantified, while others are qualitative at most. Multi objective decision making methodologies (MCDM) are the popular methods for solving problems with multiple considerations, such as locating sites, and choosing optimal environmental management alternatives/ strategies (Alidi, 1996; Chang and Hwang, 1996; Chang et al., 1996; Wen and Lee, 1998; Chang and Wei, 1999). However, MCDM techniques encounter difficulties in dealing with both qualitative and quantitative objectives in a decision problem. Therefore the application part of the study includes applying AHP to solve qualitative and quantitative objectives simultaneously.

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 reveals 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.

4.2 Formulation of FGP Model for WEEE Management

4.2.1 Notations

$X_{i:}$ the number of waste appropriate to reuse (1)

recycle for raw material (2)

recycle for semi-finished goods (3)

combusting for energy (4)

disposal (5)

i= {1, 2, 3, 4, 5}

S_j: the type of scenario which is realized

Management accompanied with Junk Collector (1)

Management accompanied with Governmental Firms (2)

Management accompanied with Recycler's Association (3)

j = {1, 2, 3}

NP_{ij} : the net profit of the management according to scenario type

P_{ij}: the total profit comes from different revenues of the different types of waste

C_j: the costs of the scenarios as transportation, logistic or charges, etc.

E_{ij} : the environmental effect of the operations applied to waste

e_{ij}: the rate of affect depend on the type of X_i

R_{ij}: the recovery quantity of the electric electronic waste

r_{ij}: the integer which is 1 if X_i type of waste is used; else 0

$(SUP)_j$: the capacity of supplier of scenario

(PRO): the constraints which is limited the cost of operation according to producer's company policy

4.2.2 Objectives

We have 3 objectives: cost objective for company which plans on maximum benefit by this investments; recovery or recycling material objective that the fabric wants to maximize the quantity of material continuing their product life cycle and the environmental impact of this type of management totally. The first data given by Oyak Renault is the each amount of waste type annually.

Table 4.1: E-waste in OR

Annually quantity of e-waste	1400
Annually quantity of obsolete robots, machine, etc.	900
Annually quantity of broken robots, machine or equipment, etc.	1200
Annually quantity of broken or obsolete office equipments	1800
Annually quantity of obsolete automotive equipments	1700
Total	7000 ton

The study will try to asses all of these waste according to world standards to achieve the objectives better. According to world's statistic research, there is a table which shows us the possible results of electronic waste management.

Table 4.2: Percentage of the recovery types for e-waste

Recovery for reuse	%6.8
Recovery for recycling	%17
Recovery for combusting	%8.4
Total material recovery	%32.1
Combusting for energy recovery	%13.6
Discards to landfill, other disposal	%54.3

So far we could reach the results for the e-waste of OR as following.

Table 4.3: The recovery of e-waste in OR by sorting type of recovery and their income

The type of recovery	Quantity of recovered material	Income from the recovery
Reuse	476	28000 ytl
Recycling	1190	55000 ytl
Combusting	588	12000 ytl
Energy recovery	952	10000 ytl
Total		108000 ytl

In the other hand if the junk dealer buy 7000 ton of waste, the price is approximately 70000 ytl and if the official recyclers buy, they pay 70000ytl. After we check the cost of these organizations; the results become as below.

Table 4.4: Cost items for 3 scenarios

(YTL)		Junk Dealer	Official recyclers	Governmental firms
Labor cost	collection	2500	5000	5000
	separation	-	6000	13000
Plant cost		2500	5000	22000
Other costs and taxes		-	8000	11000
Total		5000	240000	50000
The profit		64000	46000	58000

O_1: $64000\ S_1 + 46000\ S_2 + 58000\ S_3 \approx 50000$

According to data of Turkey, statistic global and the directives European, the methods that we mention before have a waste recovery percentage as %25, % 30 and %32.1 by order.

Since there is no official support to the manufacturing industry or also no the environmental organization like WEEE, we couldn't find an expected percentage for the next period. But the study will select a fuzzy number as an expected percentage for 2008: %30.

O_2: $0{,}25\ S_1 + 0{,}3\ S_2 + 0{,}321\ S_3 \approx 0{,}30$

This objective shows similarity with the environmental impact objective. While the expected value for 2008 is %32.5, the percentage of the benefit with the help of these types of management is as following: The junk dealer: %30, The official recyclers: %33, The self management: %34.5

O_3: $0{,}33\ S_1 + 0{,}345\ S_2 + 0{,}3\ S_3 \approx 0{,}325$

4.2.3 The Constraint of Model

Basic Equations:

$$NP_{ij} = \sum P_{ij} X_i + C_j$$

$$E_{ij} = \sum e_{ij} X_i$$

$$R_{ij} = \sum r_{ij} X_i; \quad r = \begin{cases} 1 \text{ if } X_i \text{ is assigned} \\ 0 \text{ else} \end{cases}$$

Capacity Availability:

$$\sum X_i \leq (SUP)_j$$

$$C_i \leq (PRO)$$

Non-negativity Constraints:

$$X_i \geq 0$$

$$r_{ij} \in \{0,1\}$$

4.2.4 Transformation of Fuzzy Goals

In fuzzy goal programming, the membership function corresponding to the *k*–th fuzzy goal of type $Z_k(x) \approx b_k$ is defined as

$$\mu_{Zk}(X) = \begin{cases} 1 & \text{if } Z_k(x) = b_k \\ 0 & \text{if } Z_k(x) \leq b_{k} - d_{1i} \\ (Z_k(x) - (b_k - d_{1i}) / d_{1i} & \text{if } b_k - d_{1i} \leq Z_k(x) \leq b_k \\ (b_k + d_{1i})/ - Z_k(x)/ d_{1i} & \text{if } b_k \leq Z_k(x) \leq b_k + d_{1i} \\ 0 & \text{if } Z_k(x) \geq b_k + d_{1i} \end{cases}$$

where $b_k - d_{1i}$ is the lower tolerance limit and correspondingly where $b_k + d_{1i}$ is the upper tolerance limit.

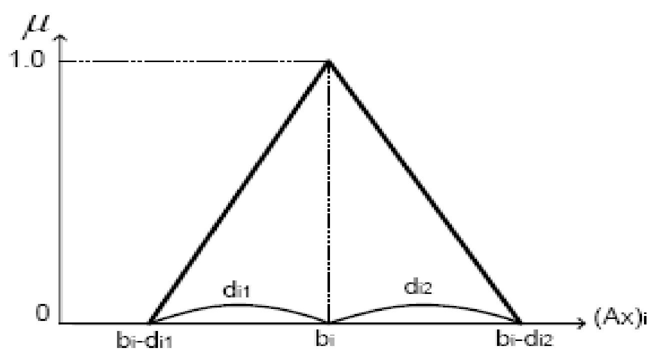


Figure 4.1: Triangular membership function

$\mu_{Zk}(X) \in [0,1]$, for all *k* represents the membership grade of achieving the goal with 0 and 1 representing the lowest and highest grade, respectively. The membership grade depends on the specified tolerance value given in the decision making context.

The problem of case, here is formulate as following:

	1	if $O_1 = 50000$
	0	if $O_1 \leq 40000$
$\mu_1(O_1) = \{$	$64000\ S_1 + 46000\ S_2 + 58000\ S_3 - 40000 / 10000$	if $40000 \leq O_1 \leq 50000$
	$60000 - 64000\ S_1 + 46000\ S_2 + 58000\ S_3 / 10000$	if $50000 \leq O_1 \leq 60000$
	0	if $O_1 \geq 60000$

Membership function : (40000, 50000, 60000)

	1	if $O_2 = 0{,}3$
	0	if $O_2 \leq 0{,}275$
$\mu_2(O_2) = \{$	$0{,}25\ S_1 + 0{,}3\ S_2 + 0{,}321 S_3 - 0{,}275 / 0{,}025$	if $0{,}275 \leq O_2 \leq 0{,}3$
	$0{,}325 - 0{,}\ 25\ S_1 + 0{,}\ 3\ S_2 + 0{,}321 S_3 / 0{,}025$	if $0{,}\ 3 \leq O_2 \leq 0{,}325$
	0	if $O_2 \geq 0{,}325$

Membership function : (0.275, 0.3, 0.325)

	1	if $O_3 = 0{,}325$
	0	if $O_3 \leq 0{,}3$
$\mu_2(O_3) = \{$	$0{,}33\ S_1 + 0{,}345\ S_2 + 0{,}3\ S_3 - 0{,}325 / 0{,}025$	if $0{,}3 \leq O_3 \leq 0{,}325$
	$0{,}\ 35 - 0{,}\ 33\ S_1 + 0{,}345\ S_2 + 0{,}\ 3\ S_3 / 0{,}025$	if $0{,}\ 325 \leq O_3 \leq 0{,}\ 35$
	0	if $O_3 \geq 0{,}\ 35$

Membership function : (0.325, 0.3, 0.5)

4.2.5 Final Form

The final LP form of the selection of strategy of waste management is obtained as follows:

$$\text{Max } \lambda_1$$

s.t.

$$64000\ S_1 + 46000\ S_2 + 58000\ S_3 - 40000 / 10000 \geq \lambda_1$$

$$60000 - 64000\ S_1 + 46000\ S_2 + 58000\ S_3 / 10000 \geq \lambda_1$$

$$0{,}25\ S_1 + 0{,}3\ S_2 + 0{,}321 S_3 - 0{,}275 / 0{,}025 \geq \lambda_2$$

$0,325 - 0,25 S_1 + 0,3 S_2 + 0,321 S_3 / 0,025 \geq \lambda_1$

$0,33 S_1 + 0,345 S_2 + 0,3 S_3 - 0,325 / 0,025 \geq \lambda_1$

$0,35 - 0,33 S_1 + 0,345 S_2 + 0,3 S_3 / 0,025 \geq \lambda_1$

$NP_{ij} = \sum P_{ij} X_i + C_j$

$E_{ij} = \sum e_{ij} X_i$

$R_{ij} = \sum r_{ij} X_i; \quad r = \begin{cases} 1 \text{ if } X_i \text{ is assigned} \\ 0 \text{ else} \end{cases}$

$\sum X_i \leq (SUP)_j$

$C_i \leq (PRO)$

$\lambda_1, \lambda_2, \lambda_3 \in \{0,1\}$

$X_i \geq 0$

$r_{ij} \in \{0,1\}$

The model is formulated using the above data and is executed using LINGO. Waste management and goal achievement values corresponding to two different weighting structures are presented in Table 4.5.

Table 4.5: Result obtained by LİNGO

RESULTS		
Sub problems	Optimum Membership Value	Management Strategy
1.	Infeasible	-
2.	0.9999	O3
3.	Infeasible	-
4.	0,9510	O3
5.	0,9810	O3
6.	Infeasible	-
7.	Infeasible	-
8.	0,9470	O3

The method is illustrated by the e-waste system selection in Turkey. This example demonstrated us that the current methods used in organizations are not the best suitable neither for the environment impact nor for the recovery rate. The expertise help for recycling is a better method with his effect environmental and high recovery rate.

4.3 Formulation of AHP Model for WEEE Management

The newly developed multi objective programming approach is used to evaluate a electric electronic waste management problem in Turkey. Some of the data used in this study are assumed, but some are based on real life situations.

Electric and electronic waste as defined here includes industrial waste, robotics, household electronic waste, and TV's or LCD's and other electronic equipments. The quantity of electronic waste is approximately 30% of the municipal solid waste (MSW) in Turkey. Total municipal solid waste generated in Turkey per capita is 1kg/day. If the e-waste is recycled, then the amount of MSW will decrease significantly (IGMC 2007).

The algorithm of finding the optimal e-waste management schemes is as follows:

4.3.1. Formulate the model for environmental problems

Decision variables: This study considers three different strategies related to the previous research, including management accompanied with Junk Collector (JC), management accompanied with Governmental Firms (GF), management accompanied with Recycler's Association (RA). The decision variables are:

X1(tons/day): the amount of e-waste treatment for reuse

X2(tons/day): the amount of e-waste treatment for recycle for raw material

X3(tons/day): the amount of e-waste treatment for recycle for semi-finished goods

X4(tons/day): the amount of e-waste treatment for combusting for energy

X5(tons/day): the amount of e-waste treatment for disposal.

Objective functions: This study considers four objectives, namely; environmental, economic, social, and technological factors. Environmental factors involve human health, resource consumption and ecological impacts. Economic factors include system costs, system benefits and the marketing potential of the by products. The social factors comprise of social justice, social welfare and social acceptability. The objective functions are defined as follows:

Z_1 : The objective function of human health (mPt/ton).
Z_2 : The objective function of resource consumption (mPt/ton).
Z_3 : The objective function of ecological impacts (mPt/ton).
Z_4 : The objective of land demand (mPt/ton).
Z_5 : The objective function of the system cost (NT$/ton).
Z_6 : The objective function of the system benefit (NT$/ton).
Z_7 : The objective function of the marketing potential.
Z_8 : The objective of proficiency of technology
Z_9 : The objective function of social justice.
Z_{10} : The objective function for social welfare.
Z_{11} : The objective function for social acceptability

The objectives can be divided into two categories: qualitative and quantitative, based on the property of the data of the objective functions. The quantitative part includes Z1~Z6, while the qualitative part consists of Z7~Z11. The environmental, economic, and physical data for e-waste management must be integrated together to complete the formulation of the quantitative objective function. The performance on environmental objective (Z1, Z2 and Z3) was determined by life cycle assessment. The performance on economic and technological objectives (Z4, Z5) was calculated using the data from the Fabric of "Ford Otosan A.Ş.".

The system cost contains the construction and operating cost for collection or separation of waste, and the system benefit is defined as the profit from the product obtained by recycling operations. The qualitative objectives cannot be determined using mathematical formula, and are discussed later; however, the quantitative objective functions can be determined as follows:

$$\min Z_i = C_{ij}.X_i, i = \{1,2,3,4\}$$
$$\max Z_i = C_{ij}.X_i, i = \{5\}$$

where C_{ij} denote the coefficients of the objective function.

Constraints: The constraints in this model are described as follows:

1. Mass balance constraint:

Since the sum of the five alternatives should equal the e-waste generation, it can be shown that

$$\sum_{j=1}^{5} X_j = X_{total}$$

2. Capacity constraint:

An alternative j can provide up to b_j units which should be equal or less than its capacity (Hung 2005). Marmara Region contains XXX incinerators and XXX landfill, and the capacity of all the incinerators is 4200 tons/day, while that of the landfill is 500 tons/day.

$$X_j \leq b_i, j = 5$$

3. Market demand constraint:

The byproducts identified in this study are the products transformed from the e-waste using the management strategies. For example, the byproduct of the reuse is a second-hand product or by combusting is energy respectively.

No marketing limitations exist for the byproducts of the management strategies. The market potential of the byproducts of management strategies is limited because of the innovation in the electric and electronic sector domain (Hung 2005).

$$T_{waste}.X_j \leq M_{waste}, j = \{1,2,3\}$$

where T_{waste} denotes the transforming rate of e-waste passing though the process reuse or recycle, M_{waste} represents the market demand of the byproduct of e-waste.

4. Separation rate constraint:

The separation rate is the ratio of the amount of e-waste collected divided by the amount of e-waste generated.

If waste is not separated and it would not be subject to the strategies (e.g. reuse, combusting). So separation rate is important. The separation rate is affected by environmental education, legislation, economic incentives, technological factors, and so on, and is assumed to be 12%.

$$\sum_{j=1}^{4} X_j \leq R.X \text{, } j = \{1,2,3,4\}$$

where R denotes the separation rate of e-waste.

5. Non-negative constraint:

$$\forall X_j \geq 0, \; j = \{1,2,3,4,5\}$$

4.2. Prioritize the alternatives

The fuzzy AHP approach was used to prioritize the alternatives and described as follows:

Build the hierarchical structure of the waste problems: The hierarchy of the problems can be established by classifying the objective functions mentioned before, as shown in Fig. 4.2.

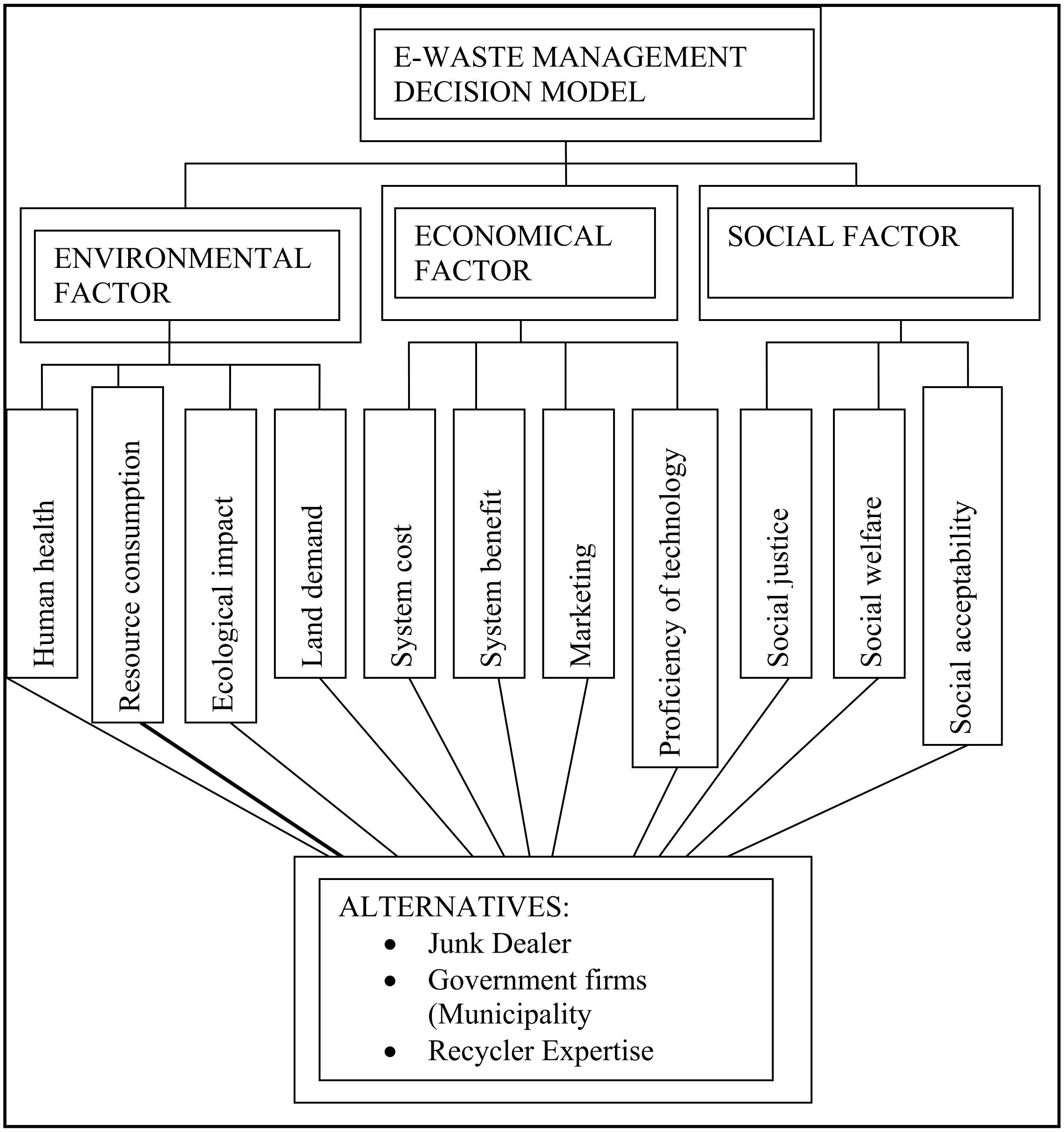


Figure 4.2: The hierarchical structure of the waste problems including all quantitative and qualitative criteria

Calculate the criteria weights: The criteria weights are determined by the questionnaires to reflect the opinion of the experts (including: government, stakeholders, NGOs and business) (Hung 2005). The priorities assigned to each criterion by these experts are integrated to develop the fuzzy criteria weights, as shown in Table 4.6.

Table 4.6: The fuzzy criteria weights

Criteria	JD
C1	(0.192, 0.265, 0.356)
C2	(0.190, 0.290, 0.316)
C3	(0.309, 0.350, 0.550)
C4	(0.065, 0095, 0.100)
C5	(0.150, 0.220, 0.240)
C6	(0.190, 0.210, 0.325)
C7	(0.120, 0,140, 0.201)
C8	(0.315, 0.431, 0.525)
C9	(0.324, 0.500, 0.737)
C10	(0.168, 0.250, 0.390)
C11	(0.168, 0.250, 0.390)

Determine the performance of the alternatives for each criterion: The performance of the alternatives for quantitative criteria is determined by Eq. (17). The triangular fuzzy number is utilized to express the performance of quantitative criteria (C1, C2, C3, C4 ,C5 and C6). The linguistic variables are used to calculate the performance of the qualitative criteria (C7, C8, C9, C10 and C11). Table 4.7 displays the fuzzy performance of all criteria.

Table 4.7: The fuzzy performance of all criteria

Criteria	JD	GR	RE
C1	(0.360, 0.500, 0.670)	(0.110, 0.140, 0.170)	(0.280, 0.370, 0.500)
C2	(0.140, 0.200, 0.280)	(0.149, 0.213, 0.319)	(0.430, 0.595, 0.800)
C3	(0.150, 0.215, 0.320)	(0.159, 0.230, 0.350)	(0.380, 0.550, 0.777)
C4	(0.164, 0.225, 0.318)	(0.378, 0.484, 0.603)	(0.224, 0.290, 0.384)
C5	(0.350, 0.484, 0.658)	(0.162, 0.225, 0.263)	(0.224, 0.290, 0.383)
C6	(0.000, 0.000, 0.000)	(0.900, 1.000, 1.000)	(0.809, 0.899, 0.988)
C7	(0.000, 0.000, 0.000)	(0.250, 0.623, 1.000)	(0.000, 0.354, 0.750)
C8	(0.000, 0.000, 0.000)	(0.900, 1.000, 1.000)	(0.025, 0.050, 0.075)
C9	(0.000, 0.250, 0.500)	(0.000, 0.433, 1.000)	(0.250, 0.612, 1.000)
C10	(0.500, 0.794, 1.000)	(0.000, 0.379, 0.750)	(0.500, 0.866, 1.000)
C11	(0.000, 0.433, 1.000)	(0.000, 0.125, 0.500)	(0.250, 0.707, 1.000)

Aggregate the fuzzy weights and fuzzy performance and ranking the final score of the alternatives: The fuzzy weighting and fuzzy performance can be aggregated to obtain the final score of the alternatives using Eq. (19).

Table4.8: The fuzzy weights hierarchically of process types

	SW	SJ	SA	
WEIGHTS	0,7	0,15	0,15	
ALTERNATİVES				
JD	0,66	0	0	0,46
GR	0	0	0	0,00
RE	0,34	1	1	0,54

	Eİ	HH	RC	LD	
WEIGHTS	0,19	0,04	0,77	0,00	
ALTERNATİVES					
JD	0	0,87	0	0,27	0,03
GR	0	0	0,31	0,18	0,24
RE	1	0,13	0,69	0,55	0,73

	M	SC	T	SB	
WEIGHTS	0,00	0,05	0,00	0,95	
ALTERNATİVES					
JD	1	0,05	0,72	0	0,003
GR	0	0,64	0	0	0,032
RE	0	0,31	0,28	1	0,965

	ENF	ECF	SOF	
WEIGHTS	0,43	0,37	0,20	
ALTERNATİVES				
JD	0,46	0,03	0,003	0,21
GR	0,00	0,24	0,032	0,10
RE	0,54	0,73	0,965	0,69

Figure 4.3 shows the final result of e-waste management. The e-waste management alternatives are ranked as follows:

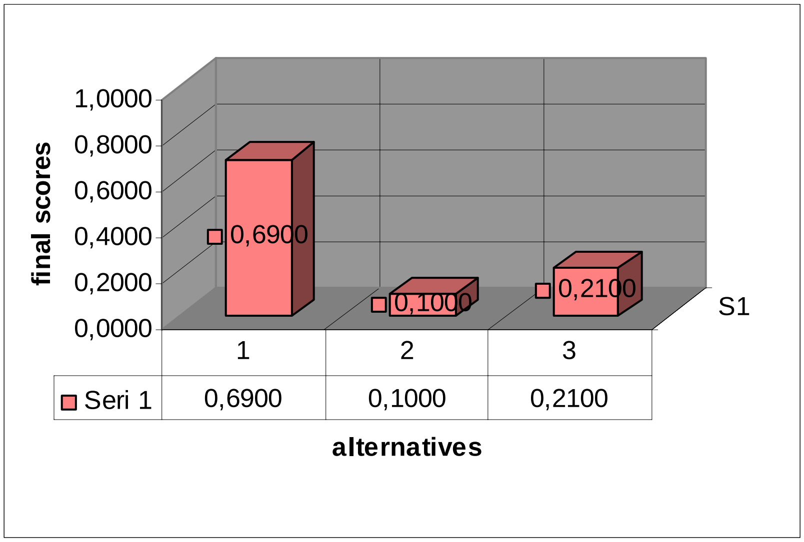


Figure 4.3: The ranking result of e-waste management criterions obtained by the help of fuzzy AHP, (RE > GR > JD)

Next, the multi objective model can be solved using Eq. (21) as:

$$\min Z_i = Cf_i.X_i, i = \{1,2,3,4\}$$
$$\max Z_i = Cf_{5i}.X_5$$
$$s.t.$$
$$\sum_{j=1}^{5} X_j = X$$
$$X_5 \leq b_5$$
$$T_{waste}.X_j \leq R.X, j = \{1,2,3,4\}$$
$$\sum_{j=1} X_j \leq R.X, j = \{1,2,3,4\}$$
$$\forall X_j \geq 0, j = \{1,2,3,4,5\}$$

Because RE is the best alternative in this study, the amount of ER is as maximal as possible until the limitation is reached. The GR is better than other technologies exception for ER. The best method selected in this application is compatible with the result of the fuzzy goal programming application.

5. CONCLUSION

Waste management process is complex systems where decision making is complicated by multi conflicting objectives and imprecision of data. 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 are the some of examples for the processes of waste management which are instrumental to recapture value or proper disposal. More precisely, waste management is the process of assessing the electric and electronic goods from their typical final destination for the purpose of capturing value, or proper disposal.

E-waste management is a new and emerging area consisted of many activities as collection, separation, reprocessing, disposal etc. The estimation of the size of waste recovery is hard because it is a recovery 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 ail activities rendering used products available and physically moving then to some point where further treatment is taken care of (Fleischman 2001). 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 management strategy by using two different decision making methods: fuzzy GP and fuzzy AHP. Fuzzy goal programming method (FGP) is a multi-objective decision making method effective in planning problem solving. The optimal selection process is a planning decision and the selection affects ultimately the recovery amount. FGP is a strong method for selection problem in presence of several objectives and imprecise data. In this study 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 (Rinquest 1992). 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.

AHP, developed by Saaty (1980), 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 AHP method is the need of an expert which interrupts and complicates the decision making process.

The two methods compromise at the same alternative: The Recycler Expertise. This is the waste management strategy adopted by many other country related to his human and environment consciousness. This example demonstrated us that the current methods in Turkey are not the best suitable neither for the environment target nor for the recovery rate. The recycler expertise is a better method with his lower environment effect and higher recovery rate. Furthermore the fuzzy AHP method requires us a ranking of all alternatives. This ranking does not only demonstrate that the current methods are not the best method. So we can conclude that the waste management system in Turkey needs serious revisions.

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APPENDİX

Appendix 1: Lindo Codes for Sub-Problem 4.

Max λ_1

Subject to

$64000\ S_1 + 46000\ S_2 + 58000\ S_3 - 40000 / 10000 \geq \lambda_1$

$60000 - 64000\ S_1 + 46000\ S_2 + 58000\ S_3 / 10000 \geq \lambda_1$

$0{,}25\ S_1 + 0{,}3\ S_2 + 0{,}321 S_3 - 0{,}275 / 0{,}025 \geq \lambda_2$

$0{,}325 - 0{,}\ 25\ S_1 + 0{,}\ 3\ S_2 + 0{,}321 S_3 / 0{,}025 \geq \lambda_1$

$0{,}33\ S_1 + 0{,}345\ S_2 + 0{,}3\ S_3 - 0{,}325 / 0{,}025 \geq \lambda_1$

$0{,}\ 35 - 0{,}\ 33\ S_1 + 0{,}345\ S_2 + 0{,}\ 3\ S_3 / 0{,}025 \geq \lambda_1$

$0 \geq \lambda_1 \geq 1$

$0 \geq \lambda_2 \geq 1$

$0 \geq \lambda_3 \geq 1$

$S_1 \geq 0$

$S_2 \geq 0$

$S_3 \geq 0$

Appendix 2: Lindo Results for Sub-Problem 4.

LP OPTIMUM FOUND AT STEP 2

OBJECTIVE FUNCTION VALUE

1) 0.9516841

VARIABLE	VALUE	REDUCED COST
X1	0.077333	0.000000
X2	0.000000	0.093480

X3	0.874352	0.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	0.000000	0.000003
3)	0.000000	3.114640
4)	0.042136	0.000000
5)	0.077333	0.000000
6)	0.000000	0.000000
7)	0.874352	0.000000
8)	0.922667	0.000000
9)	1.000000	0.000000
10)	0.125648	0.000000

NO. ITERATIONS= 2

RANGES IN WHICH THE BASIS IS UNCHANGED:

OBJ COEFFICIENT RANGES

VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
X1	1.000000	1102.448242	0.130121
X2	1.000000	0.093480	INFINITY
X3	1.000000	0.284000	0.249234

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
2	5000.000000	59009.031250	4945.793945
3	0.300000	0.022542	0.280469
4	0.600000	INFINITY	0.042136
5	0.000000	0.077333	INFINITY
6	0.000000	0.000000	INFINITY
7	0.000000	0.874352	INFINITY
8	1.000000	INFINITY	0.922667
9	1.000000	INFINITY	1.000000
10	1.000000	INFINITY	0.125648

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