ATILIM UNIVERSITY
GRADUATE SCHOOL OF SOCIAL SCIENCES
DEPARTMENT OF BUSINESS ADMINISTRATION
BUSINESS ADMINISTRATION MASTER'S PROGRAMME

ANALYSIS OF SOLID WASTE TRANSFER PROBLEM BY TRANSPORTATION MODEL: AN EMPIRICAL STUDY ON BAGHDAD MUNICIPALITY

MASTER'S THESIS

DERAA AL-DULAIMI

ANKARA, 2018

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SUPERVISION BY
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ANKARA, 2018

ACCEPTION AND APPROVAL

This is to certify that this thesis “ANALYSIS OF SOLID WASTE TRANSFER PROBLEM BY TRANSPORTATION, MODEL AN EMPIRICAL STUDY ON BAGHDAD MUNICIPALITY” prepared by DERAA ALDULAIMI meets with the committee’s approval unanimously/ by a majority vote as Master’s Thesis in the field of MBA following the successful defense of the thesis conducted in 19.01.2018.

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ETHICS DECLARATION

I hereby declare that;

- I prepared this thesis in accordance with Atılım University Graduate School of Social Sciences Thesis Writing Directive,
- I prepared this thesis within the framework of academic and ethics rules,
- I presented all information, documents, evaluations and findings in accordance with scientific ethical and moral principles,
- I cited all sources to which I made reference in my thesis,
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January 19, 2018

Deraa Al-Dulaimi

ÖZET

[Deraa ALdulaimi]. [Katı Atık Transfer Probleminin Taşıma Modeli ile Analizi. Bağdat Belediyesi Üzerine Ampirik Bir Çalışma], [Yüksek Lisans Tezi. Tez, Ankara, (2018)].

Katı atıkların imha edilmesi Bağdat şehri de dâhil olmak üzere birçok şehrin ve uygar topluluğun karşılaştığı en zorlayıcı sorunlardan biri olarak düşünülmektedir. Artan nüfus ve yaşam standartları bireylerin tüketim davranışlarının artmasına neden olmuş bunun sonucunda ise katı atık üretimi artmıştır. Bu sorun artık ihmal edilemeyecek ve geciktirilemeyecek bir noktaya gelmiştir. Birçok çevreci, ekonomist ve politikacı için bu sorun endişe kaynağı olmuş ve soruna bilimsel, hızlı ve radikal çözüm bulmaya çalışan birçok araştırmacı için öncelikli bir konu haline gelmiştir. Bağdat 'taki sivil toplum tarafından yıllık olarak üretilen büyük miktardaki katı atık su, hava ve toprak kirliliği gibi çeşitli kirlilik türlerine önemli ölçüde katkıda bulunmakta ve doğal kaynakların tükenmesine neden olmaktadır. Bu nedenle, katı atıkların toplanması, taşınması ve bertaraf edilmesi süreci bu tür atıkları üreten yerlerin ve faaliyet alanlarının çeşitliliği nedeniyle karmaşık olmasına rağmen, büyük önem taşımaktadır.

Bu tez dört bölümden oluşmaktadır. Birinci bölüm katı atık, çevre ve çevre kirliliği konularındaki teorik temelleri ve kavramları ele almaktadır. İlk kısımda katı atık kavramına odaklanılmış, ikincisi kısım çevre ve çevre kirliliği kavramlarını ele almış ve üçüncü kısımda ise katı atıkları toplama ve taşıma yöntemleri ele alınmıştır.

İkinci bölüm, doğrusal programlama yönteminin teorik temelini ve taşıma modellemesindeki uygulamalarını ele almakta ve üç kısımdan oluşmaktadır, ilk kısım doğrusal programlama kavramını ve hipotezini açıklamaktadır. İkinci kısım taşıma sürecinin genel bir modelini belirtirken, üçüncü kısım ise taşıma modelini çözmek için kullanılan yöntemleri ve en uygun çözümün yöntemlerini belirtmektedir. Üçüncü bölüm bu tezle ilgili çalışmaları içeren literatür taramasını içermektedir.

Dördüncü bölüm Vogel yöntemi, tam sayı yöntemi, ve önerilen yöntem olan dizi kapsama modeli olmak üzere üç yöntemi ve çalışmanın genel boyutlarını içermektedir.

Çalışmamız Bağdat belediyesine bağlı idari sınırlar içerisinde bulunan Bağdat şehrinde gerçekleştirilmiştir. Bağdat belediyesinden elde edilen verilerin analiz edilmesinden sonra, önerilen taşıma modeli uygulanmıştır. Taşıma modelinin kullanılmasının, katı atıkların toplama alanlarından sağlıklı katı atık depolama alanlarına taşınması için gereken maliyetleri düşürdüğü sonucuna varılmıştır. Böyle bir yaklaşımın uygulanması ile günde 3.026,705 Irak dinarı tasarruf edilebilmektedir. Bu rakamlar, taşıma modelleri uygulanarak tasarruf edilebilecekken mevcut taşıma yaklaşımı nedeniyle boşa harcanan maliyet miktarlarıı hakkında fikir vermektedir.

Anahtar Kelimeler: Katı atık, taşıma modeli, tamsayılı programlama, küme örtme modeli

ABSTRACT

[Deraa ALdulaimi]. [Analysis of solid waste transfer problem by transportation. Model an empirical study on Baghdad municipality], [M.Sc. Thesis, Ankara, (2018)].

The disposal of solid waste is considered one of the most challenging problems that face cities and civilized communities including Baghdad city. The increasing population and their standard of living has led to increased magnitude of consumptive behavior of individuals which in turn results in increased solid waste production. This problem has reached to a point that cannot be neglected or delayed any more. It has been the concern for many environmentalists, economists and politicians, and occupied the top priority for many researchers that tried to find scientific and fast radical solution to the problem. The huge amount of solid waste produced annually by civil community in Baghdad can contribute significantly to various types of pollution including water, air, and soil pollutions and also leads to exhaustion of natural resources. Therefore, the process of collecting, transporting, and disposal of solid waste has become of paramount importance despite being complicated by the diversity of activities places that generate such waste.

This thesis divided into four chapters. Chapter one handles the theoretical bases and concepts of solid waste and environment and environmental pollution. The first part focused on concept of solid waste, the second discussed the concepts of environment and environmental pollution where third part handled common methods of collection and transportation solid waste.

Second chapter handled theoretical basis of method of linear programming and their applications in transportation modeling that included three parts, the first part explained linear programming, its concept and hypothesis. The second part stated general model of transportation process, while the third part stated the used methods to solve transportation model and methods of optimal solution. The third chapter includes a review of literature on studies related to this thesis.

The fourth chapter includes the essential aspect of the study, distributed to three methods Vogel method, integer method and proposed model: set covering model.

Our study was performed in Baghdad city within the administrative borders that subject to Baghdad municipality. After analysis of the data obtained from Baghdad municipality we applied a suggested transportation model. We concluded that the use of transportation model led to reduction in costs of solid waste transportation from collection areas to areas of healthy landfill. The application of such an approach could save 3,026,705 Iraqi dinar per day. These numbers give insights about the amount of fund wasted because of the current transportation approach that could be saved by the application of transportation models.

Keywords: Solid waste, transportation model, integer programming, set covering model.

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CONTENTS

CHAPTER 3

LITERATURE REVIEW

CHAPTER 4

APPLICATION PART

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The solid waste issue has became a common global problem nowadays whether in developing or developed countries. Moreover, no country in today's world hasn't affected from this huge problem. For a clear environment a sufficient solutions must be settled. The problem has reached a stage that cannot be ignored or delay, but has become a daily problem occupies the minds of ecologists, economists and politicians and occupies center stage in the lists of priorities for the countries for finding scientific and radical solutions. And transport costs constitute an important component of total costs borne by the municipal districts in the process of disposal of solid waste, so any improvement in the transport system will lead to savings in transport costs.

The goal of appropriate management of solid waste represents a significant challenge to the developing countries over the last few decades. It has been estimated that municipalities in such countries spend an average of 20 – 50 % of their operational budget on the collection and transport of solid waste. Nevertheless, the collected solid waste represents only 40 – 60 % of all produced waste. Moreover, only about 80% of urban areas are covered with such services. Hence, it is imperative that any improvement in the system of collection and transport of solid waste will lead to reduction in this overly expensive cost which is the goal of this research by using transport models that minimize the overall cost of solid waste transport from collection areas to areas of healthy landfill.

CHAPTER 1

SOLID WASTE AND ENVIRONMENT

The problem of solid waste accumulation has become a global problem affecting most countries of the world, both developed and developing. It's now possible to say that almost every country of the world is suffering from this problem to a certain extent. This problem has reached to a point that cannot be neglected or delayed any more. It has become the concern for many environmentalists, economists and politicians, and occupied the top priority for many researchers that tried to find scientific and fast radical solution to the problem. One of the contributing factors to this problem is the rapid increase in population in the cities because of large development plans that created investment and employment opportunities and contributed to increased individual income and changed the consumption patterns toward more excessive nutritional consumption in terms of quantities and qualities. This generated increased demand on various services and products in general. The current produced amounts of solid waste necessitate carful studying of its rate of generation, volume accumulated, and its composition as well in order that governing and responsible bodies can be able to provide best service for handling it.

1.1. Historical Overview

The problem of solid waste is a humanity-aged problem where the old human threw his waste outside of his housing. As human beings were developing, they devoted special places for collection of wastes. However, when humans started living in communities and cities with unprecedented increase in population, the problem of solid waste accumulation appeared that required to be treated appropriately. Different cultures treated solid waste differently. For example, people during the Greek culture used open disposal for collecting waste instead of systematic landfill where some other cultures used to dispose waste in big earth cavities then covering with soil (Wilson, 1977). Open disposal first appeared in old roman culture where people of

Jerusalem threw their solid wastes in valleys to protect the surrounding environment from pollution and potential harm caused by inappropriate disposal (Schubel et al., 1978). After the industrial revolution in Europe, solid waste accumulation became a real challenge because of the increased population density in cities and elevated standards of living that lead to generation of large amounts of solid waste. The accumulation of such waste led to proliferation of insects and rodents that contributed to more rapid spread of many diseases in addition to the bad smell produced by solid waste collections. Consequently, people started to study this problem in trial to find suitable solutions and protect humanity from its danger (Al Hashemi et al., 1992).

In the past, throwing off solid waste was not a problem because of the vast amount of earth spaces available for disposal but in the modern era, the situation has changed. Solid waste is being produced in very large quantities because of the expanded human activities in all industrial, agricultural, commercial and social dimensions. Hence, this a problem is contingent with the life of the modern human's everyday life (Mawlood et al.: 1992: p192). Another important change is the increased economic level. Societies with low individual income tend to produce much less solid waste than those with higher average individual income. That explains why industrialized communities produce much more solid waste than that produced by developing countries. Different seasons of the year also affect the composition and amount of solid waste produced (Ahmed, 1996: p254).

1.2. Solid Waste

As mentioned before, solid waste is one of the modern-day problems that affect almost all countries worldwide. Although it is a human-aged phenomenon, its negative consequences became prominent with the start of industrial revolution and the technological advances in all fields.

Solid waste can be defined as "Any substance considered useless by a human in a specific place and specific time, despite its potential usability in other places and at other time" (Wilson, 1977).The term "solid waste" is used globally in the present time to refer to “Non-liquid waste produced as by-product of different household, professional, commercial, industrial, agricultural and mining activities”. The non-liquid term is a relative description because sludge, formed from several wastes, is considered solid waste despite being physically semi liquid in nature (Velntof, 1988).

On the other hand, solid waste is defined by English low as “Any substance containing leftovers, or unneeded materials in addition to production by-products or any broken or polluted substance, device or tool or any old unneeded dressings or corrupt substance” (Abd Algawwad: 1997: p34). All in all, we can conclude that solid waste is a by-product of human daily activities in all fields including industrial, agricultural, commercial, social activities in certain time and place. Nevertheless, may be usable in other time and place.

1.3. Types of Solid Waste

Solid waste can be classified into 5 different categories depending on chemical composition are as organic waste, inorganic waste plastic waste, paper waste, special waste.

1.3.1. Organic Waste

Organic waste is the waste that has an organic chemical composition. This type of waste is rapidly biodegradable especially in hot climates producing offensive smell and attracting insects and rodents. The proportion of this type of waste is high especially in areas of high population (Ahmed, 2006: p255). This category also includes the waste that public gardens generate such as grass and leaves. Moreover, it contains food waste such as food remains, spoiled food and kitchens’ waste along with wastes of commercial activities and all other food remains from other places such as restaurants.

1.3.2. Inorganic Waste

Inorganic waste is composed of non-biodegradable rubbish. It could be either combustible such as paper, plastic, fabric, wood, rubber or leather or non-combustible such as metals, glass or ceramics. This type is further explained as paper waste, plastic waste, metal waste, glass waste, textile waste, and ash and combustion remains waste (Edessa, 2044: p18-6).

1.3.2.1. Paper waste

Paper waste includes, but not limited to, newspapers and magazines, advertising papers, office paper, computer and printing paper, records paper and cardboards enveloped by wax or plastic. This type of waste represents the most abundant type of solid waste after organic waste in Baghdad city (Mosaed, 2010: p62).

1.3.2.2. Plastic waste

Plastic waste includes: transparent bottles like drinking bottles of different types, and cleanser bottles, colored bottles (PET) like drinking bottles and some cleanser bottles and food utensils, plastic colored and uncolored bottles (HDPE) colored and uncolored like dairy bottles and engine oil bottles and hair wash bottles and PVC plastic like cosmetics cans and some household cleanser bottles and several other types of plastic.

1.3.2.3. Metals waste

Metal waste includes aluminum drinking containers, aluminum papers, aluminum sheets, chairs, iron food containers and other types of iron, magnetic steal waste included in some industrial, commercial and household waste such as clothes hangers, metal sheets products, tubes and pipes, metal pieces and non-magnetic metals such as copper waste.

1.3.2.4. Glass waste

Glass waste includes transparent uncolored containers of foods and drinks, colored containers for food and drinks and other types of glass such as glass sheets, kitchen tools, ashtrays, mirrors … etc. Glass in solid waste can be used again through the recycling process*.

1.3.2.5. Textile

Textiles are mainly formed of thrown clothes but also include furniture, carpets, and footwear along with floppy materials such as bed sheets, towels, curtains, blankets … etc.

1.3.2.6. Ash and Combustion Remains

Combustion remains includes substances that remain after burning wood and charcoal that are generated in homes, bakeries or factories that are being burnt for cooking or heating purposes. It also includes burning waste to decrease its volume (Algameely, 1998: p8). This type of waste is present as powder of very small particle size containing the combustion remains.

1.3.3. Special Waste

Special waste is generated from the street sweeps and some dead animals like rodents … etc. in addition to waste from collection containers present in different streets (Shemshir: 2001:p25). It also includes hospital waste and anatomical waste or chemicals … etc.

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* Recycling involves treatment and re-construction of thrown waste. So returning it to lifecycle by making it usable for the same purpose or other purposes. For instance, recycling cardboard paper. On the other hand, reuse means using waste for the same purpose or other purposes without any treatment like using plastic and glass bottles for refilling after cleansing and sterilization.

1.3.4. Treatment Plants Waste

Treatment plants waste may be solid like that produced from the initial treatment phases or semisolid as sludge that are produced from drinking water and sewage treatment plants and also from industrial water treatment plants. Sludge can be used after it is separated and precipitated as organic fertilizer for agricultural purposes as a safer alternative to chemical fertilizers specially to the environment (Environmental studies and research center, 2000: p45).

1.4. Sources of Solid Waste

Solid wastes are generated wherever there is a human activity and its nature varies with different stages of human development. As solid waste is composed from a wide variety of substances, it is aggregated from wide variety of sources (Alghamry et al., 2009: p4-6). Sources of solid waste can be classified as: domestic wastes, commercial solid waste, and industrial waste.

1.4.1. Domestic Waste

Domestic waste is the waste produced by inhabitants of residential areas of different types. It is composed of wastes of unneeded materials produced on daily, weekly or monthly bases. Sometimes they are not produced periodically but dependent on how the individual organizes his activities and life events within his home and his surroundings.

Domestic wastes represent the largest proportion of solid waste collected in cities, in Baghdad for instance, they represent 55 - 65 % of the total produced amounts of solid wastes as in Table 1.1. Wastes falling in this category contain organic and inorganic waste that includes (food remains in addition to cardboards, paper, plastic, glass, rubber, leather, textiles, wood, metal, electronic devices and household tools). These wastes are produced by single or multiple housings with the amount produced variable according to the number of inhabitants in each residential unit. They get collected periodically or during specific time points. Unfortunately, those wastes are not being collected completely due to the deficiency in resources required for collection such as containers and trucks. In developing countries, part of these wastes remains in the streets represents a significant health risk due to offensive smell and attraction of insects and rodents that spread diseases rapidly (www.holroyd.news.org.na , visited on 15/3/2017).

Table 1.1. Percentage of waste types collected in Baghdad

Solid waste source	Percentage
Domestic waste	55 – 65
Industrial waste	10 – 5
Commercial waste	15 – 10
Institutional waste	5 - 2
Medical waste	7 – 4
Municipality waste	5 – 3
Rubble waste	10 – 40
Others	5 – 1

Source: (Naem Abob Mosaed, Designing a System to Manage Solid Waste within the Boundaries of Baghdad City, Unpublished Master's thesis, San Clements University. 2010: p81).

Table 1.1. shows that domestic waste dominates the sources of solid waste (55 – 65 %) which is attributable to the dominance of residential areas in Baghdad over commercial or industrial areas. The population explosion has a major role in the unprecedented increase in the amount of solid waste produced especially domestic waste. The increased population is associated with increased resources consumption which requires increased production and also increased resources consumption. Eventually, this increased generation of solid waste which will pollute our

environment and exhaust the next generations' resources. In order to decrease these negative consequences, we have to rationalize our consumption and encourage citizens to sort wastes at home.

1.4.2. Commercial Solid Waste

Commercial solid waste is the waste produced by commercial centers such as offices, restaurants, markets and hotels. It is very similar in composition and amounts to domestic wastes. Solid waste produced by offices include large quantities of paper while those produces by large warehouses are composed mainly of cartoons and packaging boxes. On the other hand, restaurants and markets mainly produce food remains. As mentioned in Table 1.1 the commercial wastes represent 10 – 15 % of the total amount of solid waste produced in Baghdad city. However, this percentage varies from area to another in Baghdad according to the classification of the area. Commercial waste can be a source of recyclable materials if those materials were sorted from the source to decrease the cost of managing their waste in addition to improving the process of recycling. Most commercial wastes are collected by specialized contractors that collect such wastes from commercial stores and offices for monthly fees that are determined by the amount produced and paid by its producer. The average cost is 4.55 USD for each cubic meter of solid waste in Huston city in the United States. Most special waste contractors have special parties that recycle materials from the collected waste and make deals with them to supply waste to extract recyclable materials (www.ci.austin.tx.us , visited on 20/3/2017).

1.4.3. Industrial Waste

Industrial waste is the waste produced from different manufacturing activities that are being ejected to the surrounding environment that could be solid, liquid or gas wastes. This type of waste is characterized by continuity and high variability as the wide variety of industries like chemicals, metals, leather, food industries… etc. The percentage of industrial waste represents 5 – 10% of total solid waste production in Baghdad city as seen in the Table 1.1.

It is important to note that some of these industries cause a potentially harmful pollution to the human health. Industrial waste can be classified into: harmless Industrial Waste and Harmful Industrial Waste.

1.4.3.1. Harmless industrial waste

Harmless industrial waste represents the industrial waste that does not represent any potential harm to the environment or public health like waste of food industries, textiles, packaging materials ... etc.

1.4.3.2. Harmful industrial waste

Harmful industrial waste is the industrial waste that represents a potential harm to the environment or public health like chemicals, pesticides, stains and solvents. The danger of such substance on the environment is significant both on the short and long terms. The disposal of such substances in sewage or other inappropriate methods of disposal leads to adverse effects on the environment. Therefore, industrial waste should be separated from domestic waste and treated independently.

1.4.4. Agriculture Waste

Agricultural waste is the waste produced from agricultural process in general like cutting trees, trimming plants, and fallen leaves of public & domestic gardens. Such waste can be used to produce fertilizers of high quality or cubes to be used as energy source in combustors.

The urban component of cities encompasses several agricultural processes at different levels in markets, streets, public gardens, public parks, and open green areas. The quantity and quality of solid waste differs according to the type of planting and the technique used. In heavy or vertical agriculture, commonly used in European countries and Jordan, every square meter is being used for planting or growing farm animals leading to production of large amounts of waste. This type of waste doesn't represent any risk to the environment if returned to its natural life cycle through reuse in fodder production or fertilizer production (www.islamonline.com,visited on 21/3/2017). Moreover, agricultural waste represents only small proportion of solid wastes in Baghdad city because agricultural area lie outside administrative borders of Baghdad Municipality.

1.4.5. Rubble

Rubble represents all substance produced by demolition and construction process and the wasted construction substances during these processes. Rubble is composed of several materials including stones, sand, iron of different types, other metals, ordinary or reinforced concrete, sanitation materials, plastic, wood, glass and several other substances depending on the type of the building. They don't represent a danger to the environment nor the public health but they spoil the general appearance of cities (Alsheikh Abbas, 2006: p15). Rubble constitutes large proportion of solid waste in Baghdad. Piles of rubble can be seen all over Baghdad especially in empty and demolished building. Based on its composition, rubble can be recycled as secondary construction materials and as infrastructure for roads. Rubble constitutes about 40 – 20 % of solid waste in Baghdad as per Table 1.1

1.4.6. Medical and Related Waste

Medical waste is the waste produced inside any health or medical facility like hospitals, specialized healthcare centers, dispensaries and health centers within cities public and private clinics, medical laboratories, pharmacies, veterinary laboratories, veterinary health centers. Medical waste is composed of general non-dangerous waste as well as dangerous infectious waste. Non-dangerous waste is any waste that has not been contaminated by blood or other body fluids like rubber gloves, paper, textile, glass and food remains. Non-dangerous waste is treat as other ordinary solid wastes.

On the other hand, solid waste constitutes significant pollutants as by-products of medical work because they contain body tissues and blood or bone.

Dangerous waste includes scrubs, bottles, plastic and glass containers, blood carrying tubes, remains of medications and expired drugs, animal materials, and medical activity related substances.

1.5. Factors Affecting Rate of Solid Waste Generation

1.5.1. Rate of Solid Waste Generation

Rate of generation is one of the most important term in managing solid waste that can be defined as "The amount of waste every single individual produces in a certain period of time expressed either by volume or by weight with weight being more commonly used because it is more stable against change during transport as it is not affected by compression" (Alshamri, 2010: p48).

As reported by the World Health Organization (WHO), solid waste production ranges from 0.4 Kg/person/day in low income countries to 2.5 kg/person/day for high income countries. These percentages are presented in the Table 1.2 given below.

Table 1.2. Percetage of solid waste production per person in low and high income regions

Region	Generation rate (Kg/person/day)
Lowest income regions of Asia and Africa*	0.4
Model cities in Asia, North Africa and South America	0.7
Model cities in industrialized countries	1.1
Model cities in high income regions of the United States and Arabian Gulf**	2.5

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* These regions consume a little amount of food available so produce less waste. Additionally, they own less plastic and paper products and hence less waste.

Source: (Arab organization for education culture and science, City Engineering and Environmental Sciences – Volume 2, 2003. As cited in: Alghamri et al., Comprehensive Waste Management, Modern Liberary, issue: 1, 2009: p7**).**

It is clear from Table 1.2 that highest rate of solid waste generation is in the united states and Arabian Gulf countries that reaches up to 2.5 Kg/person/day, whereas the lowest is in the countries of south east Asia and Africa reaching as low as 0.4 Kg/person/day. Table 1.3 presents the rate of solid waste generation per person in some Arabic countries.

Table 1.3. Rate of waste production per person in some Arabs countries

Country	Rate Kg/person/day	Rank*	Country	Rate Kg/person/day	Rank
Bahrain	1.6	2	Qatar	1.3	3
Egypt	1.2	6	Saudi Arabia	1.3	4
Jordan	0.9	7	Syria	0.5	10
Kuwait	1.8	1	Tunisia	0.6	9
Oman	0.7	8	Yemen	0.45	11
Morocco	0.33	12	United Emirates	1.2	5

Source: (Alghamri et al., Comprehensive Waste Management, Modern Library, issue: 1, 2009: p7.

* Rank was determined by the author of this work**)**

It is clear from Table 1.3 that the rate of solid waste generation is high in some countries like Kuwait and Bahrain that represent the highest rates of generation because they have the highest average per capita income. On the other hand, the rate of generation is lowest in Morocco and Yemen as they have the lowest standards of

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** Vast amounts of food available more than the consumed amounts and hence produce more waste. They also use large amounts of plastic and paper products producing large quantities of solid waste

* Rank was determined by the author of this work.

living for individuals. In Baghdad, the average rate of solid waste generation in 2016 was 0.8-1 Kg/person/day (Baghdad municipality, Department of solid waste and environment, Planning and follow up division, research section: p7, 2010).

1.5.2. Factors Affecting Rate of Solid Waste Generation

Many factors can influence the rate and quality of solid waste generation in a certain city or by an individual. These factors include (Wilson, 2001):

- The economic orientation of the country, either industrial or agricultural. In agricultural countries, it is recognized that the produced waste is composed mainly of organic waste that is rapidly biodegradable because it contains a lot of food remains and agricultural remains. In contrast, industrialized countries produce waste that is dominated by processed substance like boxes glass and metal bottles… etc.

- The economic status of the country. The more developed the economic situation and standard of living the more consumptive the individual behavior and hence the higher the rate of solid waste generation.

- Season of the year affects the amounts and type of solid waste generation.

- Population demographics: the density distribution of population and population age distribution affects the rate and content of solid waste production.

- Social environment presented by customs and traditions specific for each region.

- Rate of solid waste generation is affected by the size of each individual family. That is to say, there is a direct relationship between the family size and the amount of waste produced by each individual member of the family.

- The rate of solid waste generation is affected by the type of services provided by the municipality in the field of solid waste collection and management

1.6. Properties of Solid Waste

Solid waste has several properties that can be determined by several physical and chemical tests. The most important among these properties are density, humidity, physical and chemical composition.

These properties differ from region to another and from time to time. It is important of waste management decision makers to have accurate information about these properties to make informed decisions about the type, size, and quantity of transport vehicles, the optimum labor force volume. The whole collection and transportation process is dependent on the volume and density. The disposal approach is also dependent on the proportion of recyclable or reusable constituents or constituents that are combustible and can serve as energy source (T. G. H. Ellisen, 1997).

1.6.1. Physical Composition

Physical composition is one of the most important properties in determining the optimum handling approach of solid waste like collection, transportation, healthy landfill… etc.

Solid waste is composed of countless number of substances can be categorized into 6 -12 categories (Shemshir, 2001: p26). The proportion of constituents is usually variable with season of the year, economic status, geographical location and other factors. Table 1.4 illustrates the composition of solid waste in different countries of the world.

Table 1.4. Proportions of solid waste composition in different countries

Substance	% USA	% France	% Sweden	% Egypt
Paper	42	29.6	55	10
Organic substances	22.5	24	12	55
Ash	10.5	2.4	-	10
Metals	8	7	6	5
Glass	6	3.5	15	5
Others	11.5	14	12	15

Source: (Shaimaa Rateb Ali, Environmental Pollution by Solid Waste (Rubbish is a Goldmine), a paper submitted to the faculty of low, Assiut University, 2008: p6)

Table 1.4 shows that Sweden has ranked number 1 in paper waste then USA whereas Egypt presented the highest proportion of organic and other substance (55% and 15% respectively), followed by France (24% and 14% respectively). USA has the highest proportion of ash and metals (10.5% and 8%). The highest proportion of glass was in Sweden that reached 15%.

As for Baghdad, the physical composition for solid waste is summarized in Table 1.5 below as:

Table 1.5. Percentage of solid waste composition in Baghdad

Substance	Percentage %
Organic substance	50.57
Cartoon	6.64
Paper	11.97
Plastic	17.39
Glass	2.9
Rubber, leather and textile	2.4
Wood	1.61
Metals	2.75
Others	3.77

Source: (Alrabei et al., “A study on Post-sorting mechanisms”, Baghdad municipality, Department of solid waste and environment, 2010: p3)

The proportion of organic substance in solid waste (especially domestic waste) in Baghdad city is very high reaching up to 50.57%. This can be reused through conversion to soil fertilizers. Other recyclable items such as paper, cartoon, glass, plastic and metals constitute about 41.65% of total generated solid waste in Baghdad city. Recycling these amounts of waste will provide large amounts of raw materials, save energy required for production of new raw materials, decrease the cost of transportation and decrease the volume of waste reaching to healthy landfill areas which decreases the amount of land area required for landfill purposes that can be then utilized for other purposes.

1.6.2. Chemical Composition

Determination of the chemical composition of solid waste is very important in determining the optimum treatment approach for solid waste treatment. It is also important for the evaluation of manufacturing methods economics such as biodegradation, thermal degradation and evaluating the economics of energy recuperation project. This analysis has an essential role in recycling and reuse of waste in energy or fertilizers production through determination of chemical composition. Chemical composition analysis will also reduce transportation costs and decrease the harm inflected to the environment by leaving waste untreated. Moreover, the thermal energy produced by solid waste combustion can be used for heating or electricity generation (Algameely, 1998: p10).

Detailed Chemical analysis of solid waste involves determination of the proportions of various elements such as carbon, hydrogen, oxygen, nitrogen, sulfur, potassium and phosphorus. Table 1.6 gives the detailed chemical analysis of solid waste in some developing countries.

Table 1.6. Percentage of chemical analysis ofsolidwaste insome developing countries

Element	Percentage
Carbon	32 – 43
Hydrogen	4 – 6
Oxygen	34 – 48
Nitrogen	3 – 1
Sulfur	0 – 1
Potassium	0 – 1
Phosphorus	9 – 1
Carbon/nitrogen	12 – 40

Source: (Sohaib Algameely, "Analysis and Evaluation of collection and Disposal Process of Solid Waste Generated in Falloga city and its Environmental Effects on the Region", Master's thesis, 1998: p10**)**

Table 1.6 shows that the percentages of carbon, hydrogen and oxygen are 32 - 43%, 4 - 6%, 34 – 48%, respectively. These proportions are indicators for the usefulness of this waste in combustion for energy production. It is important to note that no study has addressed the analysis of the chemical composition of solid waste in Baghdad city.

1.6.3. Moisture Content

Moisture content parameter is directly used to evaluate the economic value of solid waste when used in combustors as a final disposal route or as a source of energy. The increased moisture content results in increased density and decreased thermal value of solid waste. Moisture content level is dependent on the waste composition, temperature, rain volume, and the collection method.

Solid waste generated in Baghdad city is characterized by increased moisture content as it reached 48% in 1997 and 60% in 1998 (Alrawi, 1999: p12). Recently its proportion ranges from 40 to 71% (Arabei et al., 2010: p3).

1.6.4. Solid Waste Density

Density is one of the important parameters related to the dimensions of solid waste collection storage and transport. It is a continuously changing property during transport process being lowest at the place of generation then increases due to compression in transport vehicles or in-site compression machines and may return to light, economically valuable substances such as paper, plastic… etc. The densities of solid waste in industrialized countries range from 50 – 150 Kg/m^3 in in developing countries 150 – 500 Kg/m^3. This disparity is attributed to many factors including change of properties, geographical locations, collection method and compression use (Alshamri, 2010: p50).

1.7. Concept of Environment and Environmental Pollution

The environment is the medium that comprises all human surroundings including living and inanimate being. It is the sources of all natural resources that humans need for their living activities. The use of resources is dependent on human need and their scientific and technological advances. Because of advanced technological and civilized abilities, humans are consuming much of the available natural resources. Consequently, a lot environmental problems are occurring of which the most important is the environmental pollution. In fact, our environment has suffered a rapid and accelerating deterioration during the last decade of the twentieth century and the beginning of the 21th century. Humans and humanitarian activities are among the major causes of this deterioration that included all natural resources.

1.7.1. Environmental Concept

The term “environment” has become a very common term in the past few years in the scientific and other communities. It has been defined with various definitions according to the point of view that researchers adopt. One of the most widely accepted definitions is the united nation’s definition: “the balance of physical, social and climate resources in a certain time and place that satisfies human needs" (Alhamd et al., 1982: p28).

In the Iraqi law number 3, Year 1997, the environment is defined as "the physical, chemical and biological medium that surrounds living beings" (The law of Improving and Protecting Iraqi Environment, No.3, 1997).

The environment has been also defined as "The frame or space that encompasses human, plants and animals and main components of life which are the climate, soil, water, air, moisture, temperature… etc. through which the humans get their essential needs for life (Kolk, 2000).

Another definition is that the environment is "Everything surrounding humans, animals or plants including phenomena and factors affecting their inception, development and different life aspects. It is associated with humans' life any every place and time, viz., it is the medium that surrounds humans and encompasses all physical and intangible items" (Bazazo, 2010: p51).

From the above, we can conclude that the environment is the collection of things that surrounds us and affects the presence of life beings on the earth. The environment is the frame in which humans live and contains the environmental components (air, water and soil) and what each component encompasses both living and inanimate beings and phenomena that dominate such frame like climate, weather, wind … etc. and the mutual relationship between these factors. This is depicted in Figure 1.1.

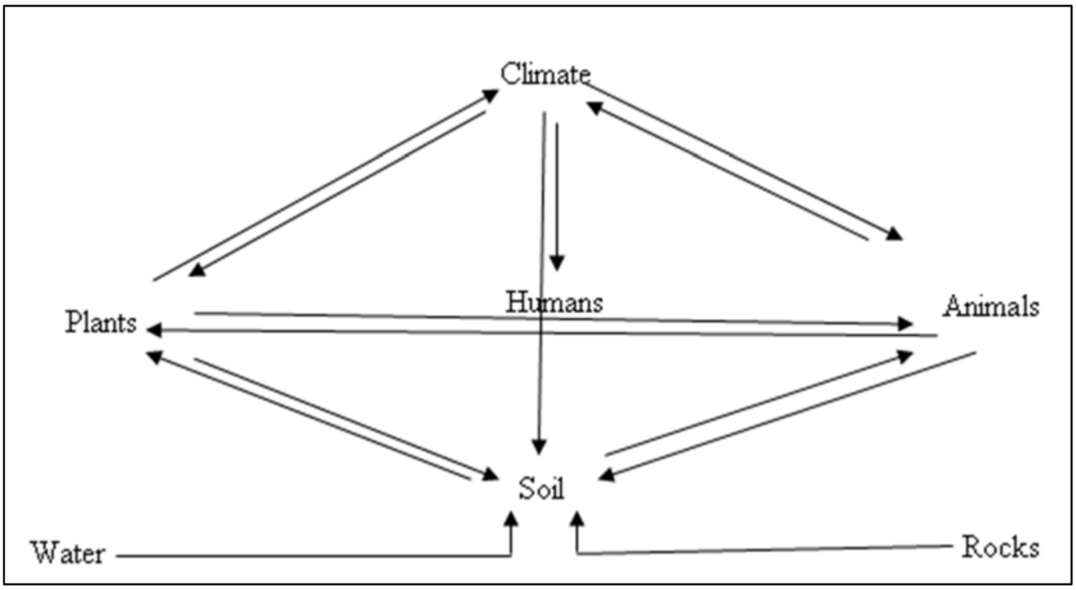


Figure 1.1. Integration between natural and living environmental components

Source: (Kazim Abbas, "Environmental Effects of Industrial Zone", higher diploma, higher institute of urban and territorial planning, Baghdad University, 2009: p22)

Figure 1.1 illustrates that there is a mutual relationship between natural elements of the environment and humans and other living beings on the earth. The climate influences plants, animals and humans and so other elements that have mutual relationships in between each other.

1.7.2. Environmental Components

There is an agreement between researchers regarding the purport of the environmental components even though some may use different terms or different number of components. These components can be classified as natural and man-made (Bazazo, 2010: p54-55, Al-Erkwazi, 2007: p53).

1.7.2.1. Natural environment

Natural environment means all what surrounds humans of living and non-living beings that humans have no effect on its existence. It includes soil, climate, plants, and animals. It differs from one region to another depending on the condition on that specific region of the earth and on the surroundings. Natural environment also includes the soil, metals, energy sources and all living and non-living beings. All these components represent what God gave to humanity to get their life essentials.

1.7.2.2. Man-made environment

Man-made environment is the group of social and economic systems that humans developed to support and organize their lives and increase their luxury. This includes all man-made facilities including buildings, farms, factories, roads, transportations, airports and seaports. Moreover, it also includes different forms of social systems such as customs, traditions, behavioral and cultural patterns and believes that regulate human-human relationships.

1.8. Environmental Pollution Concept and Types of Environmental Pollutants

1.8.1. Environmental Pollution

Environmental pollution is one of the most dangerous, complicated and hard to resolve problems that face humanity in the present age. This problem had become prominent with increased risks in association with the advance of manufacturing technologies and the use of machines, modern tools and mass destruction war weapons. This industrial development created an imbalance in the ecosystem because of increased gas and chemical emissions from factories that dispose their solid and liquid wastes in the environment. In addition, the widespread use of pesticides had an additional negative consequence on the ecosystem (www.eithaar.com, visited on 27/3/2017).

Environmental pollution is one of the urgent environmental problems that has taken dangerous economic and social dimensions especially after the industrial revolution that had taken place in Europe and the widespread technological advancement. The global recognition of the problem is being radically shifted toward increased interest in local and global environmental changes because the entry of harmful substances into the ecosystem had negative consequences on human health, agricultural production and other economic activities like industrial production.

Environmental pollution has been defined by the Iraqi law as “Presence of any of the environmental pollutant in an amount or concentration or unnatural form that directly or indirectly inflects harm to humans or other living beings present” (Iraqi law of Improving and Protecting Iraqi Environment, No 3, 1997).

Pollution has also been defined as “the change in environmental characteristics that directly or indirectly affects life beings or facilities or the ability of humans to perform their normal life activities or it is doing harm to the environment through introducing what negatively impacts its components or its natural balance” (Al-Malakawy, 2008: p22). Pollution has also been defined as “Presence of any substance or energy in the natural environment in different form, quantity, place or time than it naturally occurs, that has the potential to endanger living beings or humans in their peace, health or grace” (Al-Helw, 2009: p45).

Environmental pollution can be defined as any quantitative or qualitative change in chemical, physical or living attributes of the environmental elements including water, air and soil, in a form that endangers life and threatens living beings. It could be natural such as air pollution by gases and vapors of volcanos, or unnatural due to humans’ intervention such as throwing wastes or burning them in a way that pollute the environment.

1.8.2. Types of Environmental Pollutants

Substances that inflect harm to our environment are generally generated from two distinct sources: Natural sources or man-made sources (Callan & Thomas, 2000).

1.8.2.1. Natural pollutants

Natural pollutants originate from natural sources that are not related to humanitarian activities but due to activities of the nature such as earthquakes, volcanoes, storms, hurricanes, floods, soil and natural radioactivity.

1.8.2.2. Man-made pollutants

Man-made pollutants include all wastes and buy-products of production and consumption such as gases, ash residues, chemical waste resulting from petrochemical industries and electronuclear production and nuclear weapons experiments (AlMarzoki, 2004:p46).

1.8.3. Degrees of Environmental Pollution

Environmental pollution can be divided into three categories as acceptable Pollution, Serious Pollution, and Lethal Pollution depending on the severity of the pollution and its potential consequences.

1.8.3.1. Acceptable pollution

Acceptable pollution is a degree of pollution not associated with any harm or danger to living beings in the ecosystem. It is normal, as no environment can be totally free of pollution especially with certain types of pollution that transfer easily from one region to another. This degree of pollution doesn’t affect the balance within the ecosystem and doesn’t infect any harm to any of the environmental components (Algabi, 2006: p.21).

1.8.3.2. Serious pollution

Serious pollution is the degree of pollution that has negative consequences on human health and on the ecosystem itself. This degree of pollution has been largely associated with the industrial revolution and subsequent decades. In this degree, the pollution evolves from being a phenomenon to a problem. It requires rapid measures to halt its negative effects through the utilization of modern techniques that treat pollutants to render them safe and within the internationally accepted levels. It is also important to counteract such level of pollution through strict legislative activities that constrain the effect of heavily polluting factories and industries (Hamdan, 2009: p.6).

1.8.3.3. Lethal pollution

Lethal pollution is the most dangerous degree of pollution at which pollution starts killing living beings and may even kill humans. For example, pollution caused by nuclear activities that is described by the term environmental pollution crisis instead of “problem” (Khalaf: 2009: p.4).

1.8.4. Ranking of Environmental pollution Types

The ranking of environmental pollution types is as given below in detail as air pollution, water pollution and soil pollution

1.8.4.1. Air pollution

Air is one of the essential components for life of almost all organisms on the earth. Although it is available for no cost, it is the most precious item humans have on the earth. Air pollution was defined by the World Health Organization (WHO) as “Human activity caused introduction of substances in air in concentrations that can inflect harm or damage to the humans and other living beings and affect public properties” (Hamdan: 2009: p.7).

Air pollution is considered the most common type of environmental pollution because of its easy spread from region to another in very short time. It directly affects humans, animals and plants. It spoils human health and decreases their productivity also decrease agricultural productivity. Moreover, air pollution is major contributor to global warming and climate changes (Khalaf, 2005: p.204).

1.8.4.2. Water pollution

Water is considered the life elixir. Life on earth is impossible without water. Water pollution has attracted the attention of very early pollution scientists. The volume of literature in this type of pollution is larger than that of all other types of pollution. This may be attributable to two factors as follows:

- The importance of water to life. It is required for all biological and industrial processes and no any living being can survive without water. It is the main constituent in cells, the basic building block of all humans, animals and plants (Hashim, 2005: pp.170-171).

- Water occupies the largest space on the surface of our planet. It is the most abundant material. The space occupied by water on the surface of the earth is 70.8%. It constitutes 60 – 70% of our bodies. Thus, water pollution can cause serious damage to ur health and other living beings. It also affects the overall balance of the ecosystem which will be non-existent at all of its essential component "water" has been spoiled (www.bskra.tech.officelive.com).

Water pollution can be defined as "a damage to the quality of water that causes an imbalance leading to loss of its ability to perform its natural function, or even become harmful to use or lose its economic value specially its fish and other aquatic beings" (Hmmad & Al-Ghamri, 2005: p.66).

1.8.4.3. Soil pollution

Soil is the superficial layer of the earth. It is responsible for the earth's fertility and ability to support various agricultural activities through its content of organic matter, salts and minerals. Soil pollution is "the change of natural, chemical and biological properties of the soil through the introduction or removal of substances" (Hammad and Al-Ghamry, 2005: p.147).

Soil pollution is mostly caused by people abusing the technology through the excessive irrational use of synthetic fertilizers, pesticides and landfills used for disposal of industrial, domestic, animal and nuclear waste. Governments in some regions of the world dispose such dangerous waste through open dumping or land filling which will in either case negatively affect humans, animals, and plants especially on the long run.

1.9. Environmental Effects of Solid Waste

Solid waste problem is one of the most challenging environmental problems that has caught the attention of all states around the globe not only because of it deleterious effects on public and environmental health but also for its negative social and economic consequences that have a high price paid by the hole human community.

Exposed solid waste could be a major factor that contributes to the spread of many diseases. In addition, combustion of solid waste contributes air pollution and so are most waste disposal methods (Wilson, 2001).

1.9.1. Health Hazards

Solid waste is a good medium for breeding of insects and rodents the spread diseases. The accumulation of solid waste with appropriate temperature and humidity is an ideal medium for insect growth and reproduction (Ali, 2008, p.11). Hence, removing solid wastes from residential areas regularly is one of the important measures to protect the public health.

1.9.2. Underground Water Pollution

Solid waste contains high level of water and organic materials. Upon rainfall, waster dissolves all heavy metals and toxic substance is solid waste and seeps down through layers of the earth crust where it finally reaches its storage areas aggregating with other bodies of underground water and polluting them. Underground water pollution causes many diseases to humans. To prevent these deleterious effects underground water pollution should be prevented through control of seepage through underground pipes. These underground pipes collect seeping fluids from below the land fill areas then pumping this seepage to treatments plants (Velntof, 1988).

1.9.3. Superficial Water Pollution

Superficial water can be polluted by seepage from landfill areas that are connected to them or in a proximity. The usual cause of polluting seepage is the rain water falling on landfill area and passing through it (Algammely, 1998: p.34). There are several measures as given below that can be taken to prevent such pollution (Ali Khan, 2005: p.35):

- Building concrete barriers that prevent seepage from gaining access to surface water.

- Adjusting the outside surface of the landfill area with appropriate inclination to allow the falling water to flow seamlessly without aggregating on the final soil cover of the landfill area.

- Choosing the location of the landfill area on safe distance from surface water locations.

- Avoiding the use of porous soil for landfill.

- Using an impermeable soil cover to prevent the penetration of rain water to the solid waste collections.

1.9.4. Social and Aesthetic Effects

Social and esthetic effects are realized through several aspects as given below (Aldabas 2009: p.7):

- Presence of land spaces with accumulated wastes makes the appearance of the city so ugly with very bad smelling and attraction of insects and rodents.

- Waste accumulation is one of the most significant sources of visual pollution that spoils the esthetic appearance of the city and causes psychological distress to urban residents.

- Solid waste accumulation makes people get accustomed to solid waste disposal in public places and streets. These acquired cultural and behavioral habits hinder the environmental development efforts.

- Loss of ethical values in communities where a lot of conflicts occurring between people due waste disposal in public places.

- Loss of sanitary sense of the population as a religious, civil, social and esthetic value which complicates and aggravates the problem of solid waste accumulation.

1.9.5. Economic Effects

Solid waste accumulation has a negative economic impact resulting from absence of investment in many economic resources that can be recycled and be a source fortune rather than being a source of pollution (Center for Environmental Studies and Research, 2000: p.70). The abundance of landfill areas and inappropriate location has negative effects on the value of the neighboring lands due to loss of utility as residential or economic land spaces. The recycling process is essentially an economic process; this can be proved through the following evidences (www.ecology.net, visited on 2/3/2017).:

- According to the statistics of the Environmental Protection Agency of the United States, the production of 1 ton of 100% recycled paper saves 4100 Kwatt/hour of energy and 28 cubic meters of water and reduces air pollution by 24 Kg of air pollutants. Recycled paper is used in newspaper printing.

- Soft plastic can be recrystallized in recrystallization machines whereas hard plastic can be recycled after washing with hot caustic soda solution and used for production of clothespins, clothes hangers and plastic hoses.

- Metal wastes such as aluminum and iron wastes can be molten and reused. Iron is considered a 100% recyclable metal for unlimited number of times. This process is efficient economically because iron recycling requires less energy than its extraction from metal alloys. The cost of aluminum recycling is only 20% the cost of its production and uses only 5% of the energy required for initial production.

- Glass production is an energy dense process because very high temperatures of up to 1600 °C are required for its production, whereas recycling requires much less energy.

- Recycling has an important benefit of reducing transportation costs through the process of sorting waste and extracting reusable and recyclable material for use as row material in industry thus decrease the need for importation and save the resources the upcoming generations

1.10. Methods of Solid Waste Collection and Transport

Collection and transport of solid waste is one of the most important stages of integrated solid waste management systems. It involves collecting solid waste from production sites: residential areas, commercial areas, industrial areas and laboratories, then transporting it to treatment or disposal sites. This reveals the importance of this stage in that its improvement will have a great effect on the overall cost of solid waste management cost.

1.10.1. Collection of Solid Waste

Collection of solid waste from urban areas is difficult process and is complicated by the wide variety of activities and locations where the solid waste is generated. The process involves picking up waste from production sites loading on collecting vehicles. The process starts when the collection vehicles reache the production site and ends when the vehicle reaches its destination at the end of the day (William, 1986). The following is the explanation of the process of solid waste collection:

1.10.2. Solid Waste Collection Containers

The type and size of solid waste collection containers depends on the properties of waste generated in particular area and on the frequency of the collection process and the location where those containers are placed. Containers have a significant effect on the collection process as it affects the behavior of the area inhabitants on which the optimum approach for collection and disposal of solid waste is determined (Elwan, 1987: p.20). The used containers should be appropriate for the residential area and should be capable of improving the efficiency of solid waste collection and transport process (Wilson, 2001). The following are the most commonly used solid waste collection containers:

Lidded plastic containers (7 -10 liters capacity): They are considered sufficient to collect waste of a 5-member family with a daily collection system.

Lidded plastic container (20-30 liters capacity): They are supplied with metal handle to facilitate lifting. They are considered suitable for waste collection twice weekly from residential units.

Lidded plastic or metal container (50-70 liters capacity): It is necessary for twice weekly waste collection.

Light plastic bags: Used only once (disposable) and has many advantages including water impermeability (prevents seepage).

Galvanized iron containers: This type is used in houses, streets and public areas.

1.10.3. Solid Waste Collection Frequency

Solid waste in developing countries is characterized by the high level of degradable organic waste. Therefore, should be collected and transported from the generation sites as frequently as possible because the longer they remain uncollected the more negative effects on the environment and on public health (emission of bad odor and breeding of insects and rodents). In addition, the accumulation leads to blocking traffic for pedestrians and vehicles if not removed instantaneously (Velntof, 1986). The frequency of waste collection is usually determined by the rate of solid waste generation, standards of living, social level and season of the year.

1.10.4. Basic Collection Approaches

Collection from combined points: The use of combined collection points simplifies the collection process. This is so important in old parts of the city where collection vehicles cannot pass through all of its streets or in areas of very high building (Algameely, 1998: p.18-19). Combined collection points are usually preferred to have a capacity of 200 liters and be distributed over small distance ranging from 50 to 200 meters. This method can be highly efficient because it doesn’t require a lot of effort from citizens and only very little waste thrown on the streets. It can be evacuated into collection vehicles easily.

Collection from service route: In this approach collection vehicles collect waste by passing in a predetermined route on constant regular bases where citizens carry their own waste to the collection points and hand it to the collection workers (Velntof, 1986). This approach is not always suitable because citizens may not be at their homes during the time of collection and the difficulty in reaching all houses and apartments in the city.

Collection from pavements: In this approach, people put their containers on the pavements in a specific time when the collection crew evacuate them and return them to the pavement to taken back by the people to their houses again. This is difficult because containers may get stolen or street animals rummage its content into the streets.

Collection from houses backyards: In this approach, the inhabitant doesn't have any role. Instead, the collection crew collects waste from containers from houses backyards and return it back again (Ali Khan, 2005: p.22-23). This approach costs double the pavement collection cost especially in countries where the labor wage rate is high. On the other hand, this method may be less costly in countries where the labor wage rate is low. This is the single most acceptable approach by the citizens.

1.10.5. Transport of Solid Waste

Transport of solid waste is the process that comes immediately after the collection processes where the collected waste id transferred to temporary collection to permanent disposal locations. There are several systems for collection and transportation of waste.

Waste Collection and Transport System: Waste collection and transport system is categorized into two major categories as portable Container System and Stationary Container System.

Portable container system: In this type of systems, the waste containers are transported to transfer stations or landfills where it evacuates its loads and returns back to the original location or other locations. Collection and evacuation is made done by the vehicle driver and his assistant. This system is commonly used in areas of high waste generation rates where large containers can be transported and evacuated in treatment areas (Peavy, 1986: p.120).

Stationary container system: In stationary container system, the containers of waste stay in place at the generation site and is getting evacuated in a transporter vehicle. This system is useful for all types of solid waste and requires more than 1 worker for carrying and evacuating the container into the vehicle (Al dappas, 2009: p.8-9).

1.10.6. Solid Waste Transport Vehicles

Municipalities around the world use different types of transport vehicles to collect and transport waste from generation sites to partial or final treatment locations. The design of such vehicles is different depending on the public health requirements. The following are some of the most commonly used methods.

Manual carts: These carts are commonly used in old parts of the city where narrow alleys that cannot accommodate the large collection vehicles. One advantage of this tool is the reduced cost compared to other tools and the low level of noise produced by this tool. However, it is a relatively very slow transport method and causes dispersal of waste as it is usually uncovered.

Tractors: Tractors are commonly used in most developing countries due to its availability, simplicity and high level performance. The uncovered upper surface also causes the same problem of waste dispersion in the pathway to the treatment or transfer stations (Alsheikh Abbas, 2006: p.40).

Compressor vehicles: These are vehicles with closed body and a compressing machine to reduce the size of waste and enable loading of the largest possible amount of waste. Waste is being loaded from the back or the side manually or mechanically. This type of vehicles is the most efficient of all other discussed tools because of its ability to transport large quantities of compressed waste and keeping the safety of the environment through prevention of dispersal and air pollution (Tchobanoglous, 1997: p.171).

Container collection cars: These are used for transportation of combined collection containers and is supplied by a hydraulic elevator to carry the container and load it on the transport vehicles to the final disposal of waste (Salvato. J. A, 1982).

Trucks: Widely used in most countries of the world for waste transport. This type of trucks is used mainly for transporting construction materials so is suitable for transporting high density items like garden waste, furniture and rubble. These vehicles are loaded either manually or through loaders or other similar vehicles (Algabory and Alwakeel, 1985: p.25). A common example on this type of vehicles is the small and large tipcarts.

1.11. Transfer Stations

Transfer stations are part of the solid waste management chains; its importance is clear when the final disposal site is far away from collection sites. Transfer stations can be defined as “areas where solid waste is evacuated from small-capacity collection vehicles to larger capacity vehicles followed by waste transportation to treatment plants or landfills” (Holmes, J. R., 1984). Transfer station is intermediate solution to prevent waste accumulation within the cities that would otherwise cause problems such as bas smell and attraction of insects and rodents. These stations are most commonly used when small vehicles are used to collect waste from narrow alleys to transfer stations then larger vehicles are used further transport of solid waste.

Transfer station can be classified based on capacity to small stations with capacity less than 100 tons/day, medium stations with capacity ranging from 100 – 500 tons/day and large transfer stations with capacity of 500 tons/day or more (Tchobanglous, 1997: p.175).

1.11.1. Rational behind using Transfer Stations

Many technical and economic factors make the use of transfer stations imperative. These factors include the following items: (Hall, 1993:p53)

- Large distance between final treatment or landfill and solid waste generation sites.
- Using low capacity vehicles for waste collection.

- Presence of illegal evacuation and collection sites for solid waste which inflects harmful effects to the health and environment.
- Improving the efficiency of transport vehicles through saving time wasted in transporting to distant areas and enable them to make more collection cycles.
- Decrease the number of vehicles reaching the final treatment stations.
- Transfer stations can be used for separation, both mechanically and manually.
- Ensuring complete load of vehicles moving toward the disposal areas.
- Decreasing the cost of maintenance for collection vehicles.

1.11.2. Types of Transfer System

There are two main types of transfer systems as direct transfer system and Hydraulic transfer system.

Direct transfer systems: Where the load of the small vehicles id directly evacuated to either a stationary container in the location then transfer to a large vehicle, or evacuated on the ground then loaded on large vehicles (Alrawi, 1999: p22).

Hydraulic compression system: The load of the waste collection vehicle is evacuated directly into hydraulic compression machines, or wholes or transfer belts, where waste is compressed horizontally through an orifice at the end of the container or box transporter. Compression machines can easily *produce the required densities for the economy of the transport (Ministry of environment, 2010: p. 8-9). In this method, the density of waste can be increased by up to 4 – 5 times its original density.*

1.12. Treatment and Disposable of Solid Waste

The stage of solid waste treatment and disposal is very important to get rid of the harmful effects of solid waste. The treatment process aims at reducing the size and weight of quickly to transform it to harmless form. All treatment procedures known for now require land spaces for the final disposal of waste. Most common treatment approaches are discussed in the following lines.

1.12.1. Resource Recovery Method

Resource recovery method is used for recovery of some valuable items instead of disposing them. Three pathways as reuse, utilization, and recycling are available for resource recovery (Jeffery et al, 1997).

Reuse: Reuse is using some materials extracted from solid waste for the same purpose as the original use. This is not widely applied in developing countries and insignificant because it is informal and unhealthy procedure made by people and waste grubbers and no any specialized organization that can sort waste to determine what can be used then cleaning it in a way that can be used safely. In reach countries, reuse is uncommon.

Utilization: Utilization involves utilizing solid waste in new use that is not necessarily related to its original use. For instance, ash can be used as cement alternative in making concrete for dams, roads and other constructions or using construction waste as pile material or other methods of utilization.

Recycling: Recycling involves using solid waste in the same original purpose or other purposes after some sort of processing. It has many advantages. First, recycling saves natural resources and decreases the need for raw materials importation. Second, it decreases pollution risks. Finally, it requires less energy than producing the resource originally. Recycling aims at reducing the amount of solid waste dumped within landfills. *Recycling has many economic benefits that include (Alsamri and Rgee, 2009: p.301-302):*

- Saving energy: the proportion of combustible materials in waste ranges from 70 – 80% by weight. In Scandinavian countries, waste is used for heating purposes and electricity generation. This experience can be utilized to solve our energy production deficiency.

- Saving precious resources as a direction for sustainable development because recycling produces many resources that can be used instead of consuming precious resources. The global economy points the decreased supply of resources confronted by increase in demand. Recycling will help keeping resources for the upcoming generations without compromising their ability to use such resources.

- Decreases the amount of gases produced from combusting waste that contributes to air pollution and global warming.

- Decreases the risk of psychological and social diseases as result of visual pollution produced by waste accumulation in the streets and public places. It was reported the productivity of a person living in a clean environment is 20 – 38% higher than that of a person living in an unclean environment.

- Providing new job and industrial opportunities. This process provides raw materials for a lot of industries that will eventually leads to founding new plants and offering employment opportunities and decreasing the unemployment rate.

- Decreasing the demand for importation of raw materials that are not produced locally.

- Decreasing the overall cost of solid waste management.

- Decreasing environmental pollution and preventing the spread of many diseases that are transmitted by the insects and rodents that get attracted and breeding where solid waste is being accumulated.

- Decrease the amount of solid waste to be treated or disposed and provide the opportunities to use the saved landfill areas in other useful applications.

1.12.2. Incineration or Combustion Method

The most commonly used method for solid waste disposal for a long time. The incineration technology has evolved throughout the previous decades. Most commonly used incinerators emit a large amount of incombustible pollutants that pollutes the adjacent air. To prevent deposition of this waste over adjacent areas, very high chimneys should be used (Ali Khan, 2005: p.28). Combustion reduces the volume of solid waste by 85 – 90% thus reducing the amount of area required for land filling. In addition, the energy from the incineration process can be utilized for various purposes such as heating or electricity production (Alghamri and Abo Alata, 2009: p.128).

1.12.3. Sanitary Landfill

One of the oldest methods of disposing solid waste is disposal. Most cities of the United States and Europe started land filling their waste in the 1930s when compression machine are used to decrease the amount of land space required for the process then the term sanitary land filling had been introduced to present the process of dumping waste and covering it with a layer of sand.

Land filling can be defined as “a method of waste disposal that improves the environment by the use of waste in land reclamation, excavated digging and returning the land back to its original state through refilling” (Velntof, 1986). Land filling has many health, economic, and social benefits that can be summarized as following (Alrawy, 1999: pp. 55-65, Ali Khan, 2005: pp. 29-30):

- Utilization of exhausted mines and agriculturally unsuitable lands as landfills can reduce the cost of preparing new landfill areas or avoiding the consumption of lands that have potential future benefits.

- Limiting the spread and breeding of insects and rodents that don't have access to waste because the sand covers above it.
- Considered a final method of waste disposal, it doesn't produce remains that need to be treated.
- Lands can be reclimated after land filling and used in many agricultural, industrial or entertainment purposes.
- Less susceptible to waste grubbers than open dumping areas.
- Less susceptible to fire.
- Low cost of implementation compared to other methods of treatment and disposal.
- Improve the general appearance of the area than open dumping technique.
- Increase the soil fertility through degraded organic materials present in solid waste.

1.12.4. Methods of Sanitary Landfill

Sanitary landfill involves three main methods as surface, digging, and land filling methods (Ali Khan, 2005: p.30, Al Najjar, 1998: p.23):

Surface Method: Surface method is commonly used when the terrain of the landfill area is not suitable for digging. Generally, waste is evacuated as narrow and long strips on the surface of the land with depth ranging from 4.5 -8 m. The layers are stacked until the thickness reaches about 1.8 – 3 m and width of 2.5 -6 m. At the end of the day, waste is covered with a layer of sand that is approximately 15 – 30 cm thick and the final cover is 60 cm thick.

Digging Method: Digging method is appropriate where there is a layer of sand of sufficient thickness that allows covering the landfill area. In this method, the solid waste is disposed in wholes of 30 – 120 m long, 2-3 m deep and 4.5-7.5 wide. Waste is spread as layers of 45-60 cm thick. Waste is tacked above each other and the process is continued until reaching a suitable level then covered with a 50 cm thick layer of sand.

Land filling Method: Land filling is one of the best disposal methods used in Iraq generally and in Baghdad specially. Other methods of treatment such as recycling and reuse are very limited and unorganized neither through the government nor through the private sector *but rather remain individual efforts* (Alrawi, 1999: p.55).

CHAPTER 2

LINEAR PROGRAMMING THEORETICAL BASIS AND APPLICATIONS IN THE TRANSPORT MODEL

2.1. Linear Programming Concept and Assumptions

Operation Researches are considered in modern applied sciences and its applications achieved a big success in the civil and military fields as well. The science of Operation Researches involves quantitative techniques and its methods are highly efficient for solving the problems of planning and production, transportation, storage and others, in order to reduce costs or maximize profits. Some researchers consider the method of linear programming as the basis of the quantitative approach. This method studies the distribution of specific resources on alternative uses within the limits or constraints imposed on the business organization to achieve its objectives of maximizing the profits or reducing costs through the objective function.

The broad use of the principles and concepts of linear programming includes multiple aspects in decision making. One of the most important methods that were developed according to this method is the modes of transport and allocation. Transport models are the first applications of the supply sources which represent production or marketing or factories to several demand sites or consumption centers (destinations). If the supply of each source and demand at each site and the cost of transport per unit from each source to each location is well known and specified. The first and actual use of the method of linear programming was in 1947 at the hands of the mathematics scientist, George Dantzig, who developed a method of mathematics with a highly efficiency called as Simplex Method.

2.1.1. The Concept of Linear Programming

The topic of linear programming is at the present time a special center in the field of operational research. It is one of the most common topics and has wide applications for achieving optimality (Temah, 2008: p.115). The programming does not refer to computer programming, but it means the use of mathematical methods to reach the optimal solution, while the word "linear" means that the relationship between the variables is a linear relationship, and this means that the objective function and the constraints of the problem in the form of equations or inequalities of the first degree and this relationship shall be ascertained and not subject to probabilities (Dunn & Ramsing, 1981: p.26).

The issue of linear programming deals with the allocation of limited resources between different uses within the constraints imposed on achieving the objectives of the organization in the case of maximizing the objective function value as to maximize the production value of the production or sales value units, or minimizing the value of the objective function, such as reducing transportation costs or minimization of production costs, and so on (AL-Fadhil 2004: p.19).

Several definitions have been cited in literature for linear programming. One of them defined linear programming as "a mathematical technique related to the allocation of scarce resources and include procedures for the achievement of a particular goal might be represented by maximizing profit or minimizing costs" (Lucey, 1984: P. 289).

Linear programming has also defined as "an effective mathematical technique that can be applied to the problems related to the distribution of facilities and limited resources to activity alternatives to optimize the utilization" (Drury, 2000: P. 1031).

It could also be defined as "the mathematical method that aims to provide information and quantitative data that enable the management to make wise economic decisions regarding the optimal use of limited resources to suit the desired objectives" (Al-Fadhil, 2004, P. 19).

It could be concluded from the above that linear programming is a mathematical method, aiming at analyzing different alternatives, in order to choose the best alternatives that are used to assist the production units in choosing the optimalproduction line that achieves the highest profits or the lowest costs, in the case of relative scarcity resources in the short term.

2.1.2. The Uses of Linear Programming

The use of linear programming in solving many economic problems has increased in recent years. So it has become important in studying the behavior of a large number of systems, as well as being the simplest and easiest types of mathematical models that are used to allocate scarce or limited resources to achieve the goal and the constraints imposed in the form of equations or inequalities. Linear programming aims to optimize the distribution of scarce economic resources between competing products and activities (Temah, 2008, P. 115).

The linear programming method can be used to solve problems in different fields including (Al-Najar, 1982: p.36, AL-Fadhil, 2004: p.17; Roybavn, 1996: p.845):

- To allocate resources (production elements) in away that maximizes revenue and reduce costs the production
- To compare different tactics for producing the same commodity
- To determine the best geographical distribution of economic activities
- To solve problems of production planning and control and to determine the best production mix
- To achieve the optimal use of the operating time of the machines available, usually known as the operational power of machines and equipment

- Address the problems of transport and distribution, as linear programming used to minimize the cost to the lowest when the transfer of production from a certain area to another area

- Address the problems of management that are complex and that contain many constraints, namely (Al-Bashbishi et al., 1994: p.28)

There are several factors that led to the widespread use of linear programming for problem solving purposes (Shibshi et al., 1994: p.28):

- The possibility of representing most of the problems in the form of linear models

- Availability and multiple methods of solving linear programming models

- The abundance of information provided by linear programming models

- Progress, development and popularization of the programs of solving the linear programming model on the electronic computers

Linear programming is an important method used to solve problems related to the allocation of rare and limited resources to achieve the optimal use of these resources, as well as the optimal distribution of products on the receiving centers at the lowest transfer cost possible.

2.1.3. Linear Programming Assumptions

Linear programming is based on the following basic assumptions:

Linearity: For the purpose of applying linear programming, it is assumed that the relationship in the objective function or constraints is a linear relationship, that is, there is a linear relationship between the variables affecting the problem under study so that when any change in the value of one of them causes proportional and constant changes in the value of the other.

The relationship can be expressed mathematically as follows:

$$Y = a + bx$$

Where, Y is the dependent variable, x is the independent variable and both a&b are constant quantities (Al-Naimi and others, 1999: p.19).

Addition: Feature of addition needs the total contribution of all the variables in the objective function and the constraints, that is, the total input is necessarily equal to the total output; i.e. that the use of total resources must equal the total amount of production, and this applies also to the profits achieved (Taha, 2007, p.14).

Divisibility: Divisibility refers to the fact that outputs and productivity resources can be divided into small parts. This means that the optimal production volume is determined by the production of an integer and part of the unit of each product (Naimi, 1999, p.20).

Certainty: Certainty means that linear programming model solves the certain problems but not the probable problems, and so, all parameters, variables and parameter values are assumed to be known, constant, and not probabilistic (Bashbishi et al., 1994, p.29).

Proportionality: Proportionality property refers to the constant relationship between inputs and outputs over a given period of time. In other words, it requires a contribution of each decision variable in each the objective function and the constraints to be directly proportional to the value of the variable (Taha, 2007, p.14).

Non-Negativity: Non-negativity property indicates that decision variables cannot be written as negative quantities and amounts. Logically, negative values of quantities and amounts are impossible, since production values cannot be negative values and this assumption is usually expressed by $xj \geq 0$(Fadhil, 2004, p.161).

2.1.4. Consideration and Requirements for the Implementation of Linear Programming

Constructing the LP problem requires four steps as:

- Step 1. Define the objective function
- Step 2. Define the decision variables
- Step 3. Determine the constraints
- Step 4. Declare sign restrictions

For this particular case of solid waste management in Baghdad city the LP problem is constructed and implemented in the following manner.

2.1.4.1. Determination of the objective function

The problem to be formulated in linear programming (LP) mode should have a certain objective that can be easily and clearly defined. There are two types of objectives for LP problems, either maximization, expressed by the profit, revenue, efficiency or minimization which is expressed in cost and time (Samurai, 1997, p.85).

The objective function consists of variables, either the coefficient for each variable is the profit of one unit in the case of maximizing the objective function or the coefficient is the cost of the unit in the case of the lower objective function (Al-Jawad and Al-Fatal, 2008: p.34).

It can be expressed mathematically as follows:

$$\text{Max or Min } Z = C_1X_1 + C_2X_2 + C_3X_3 + \ldots + CnXn$$

where n is the number of decision variables.

2.1.5. Decision Alternatives

For the purpose of applying the linear programming method to the problems to be solved, there must be several factors to solve this problem in order to reach the desired goal. If the problem had one solution, there was no need to use linear programming, for it is useful to select the best possible solution among various and multiple solutions (Gupta, 1987, p.35).

2.1.6. Constraints

Constraints refer to the set of determinants on the use of the resources and capabilities available to the economic units. These restrictions may be represented by the production capacity, raw materials, working hours and other restrictions that limit the performance and work of the units. For the purpose of applying the linear programming models, the resources of the economic unit must be limited or scarce relativity and all constraints related to and express the problem must be identified and expressed as linear variations or equations. These constraints cannot be exceeded because they represent the maximum that can be reached to achieve the goal (Haizer & Render 2001, p.741).

2.1.7. Decision Variables

Decision variables are mathematical expressions of the objective function and mathematical expressions of each constraint. These expressions include Symbols such as: (X_1, X_2,, . . . , X_n) and are the variables that we want to take a decision regarding them (Samurai 1997 p.81).

2.1.8. The General Formula of the Linear Programming Model

The general formula of the linear programming models is as following (Gupta and Hira, 2008, p.136):

- Objective function

$$\text{Max and Min } Z = C_1X_1 + C_2X_2 + \ldots + C_nX_n$$

- Structural constraints

$$a_{11}X + a_{12}X_2 + \ldots\ldots + a_{1n}X_n \ (\leq, = \geq)\ b_1$$
$$a_{21}X + a_{22}X_2 + \ldots\ldots + a_{2n}X_n \ (\leq, =\geq)\ b_2$$
$$\vdots \qquad \vdots \qquad \qquad \vdots \qquad \qquad \vdots$$
$$am_1X_1 + am_2X_2 + \ldots\ldots a_{mn}X_n \ (\leq, =\geq)\ b_m$$

- Non-negativity constraint

$$X_1, X_2, \ldots\ldots, X_n \geq 0$$

In other words, the model includes three basic elements, objective function, structural constraints and non-negativity constraints. LP problem can be rewritten as the following mathematical formulation (Al-Nuami et al. 1999. P. 22):

- Objective function

$$Max\ or\ Min\ \ Z = \sum_{j=1}^{n} C_j X_j$$

- Structural constraints

$$Subject\ to\colon \sum_{j=1}^{n} aijXj\ \ (\leq, =, \geq)\ b_i\ (i = 1,2, \ldots, m)$$

- Non-negativity constraint

$Xj \geq 0$ $\qquad$ $(j = 1,2, \ldots, n)$

Whereas:

Z: Represents the objective function.

Cj: Represents variable factors in the objective function.

Xj: Represents the variables that require decision making on them.

aij: Represents the quantity of specific materials of type I which shall be allocated for each unit of activity or efficiency j.

bi: Refers to the available resources.

n: Refers to the number of variables.

m: Refers to the number of constraints.

2.1.9. Integer programming and set covering

An integer programming (IP) problem is a mathematical optimization or feasibility program in which all of the variables are restricted to be integers (https://en.wikipedia.org/wiki/Integer_programming, visited on 1/11/2017). Integer programming is also called as discrete programming. Mixed integer programming problem is a model that requires some of the variables to have integer values.

Production planning where mixed integer programming is used to

- Scheduling where integer programming could be used to schedule services and transportation, for example assigning buses to individual routes
- Telecommunications networks

Mathematically the problem of integer programming could be expressed as:

Maximize or minimize

$$\sum_{j=1}^{n} cjxj$$

Subjectto

$$\sum_{j=1}^{n} aijxj = bi \quad i = (1,2,\ldots,m)$$

$$xj \geq 0 \;\; j = (1,2\ldots,n)$$

x_j integer (for some or all j=1,2,…n)

2.1.10. Set covering problem

Set covering problem (SCP) is special case of the general integer linear programming problem. It is used as main model of many applications. These applications include, for example, crew scheduling in railways and mass-transit companies (Caprora, A, Toth 2000). It is used to minimize the cost of a set.

In this class of problems overlapping services are offered by a number of facilities. The objective is to determine the minmum number of installations that will cover of each facility (Hamdy,A.Taha 2007: p.354).

This model used to find the minimum cost of transportation by using a new techniques in transportation.

2.2. Transportation Models

Transport models are one of the applications of linear programming that aim at finding the minimum value of the cost of transporting the goods from several sources of supply sources, which represent the centers of production or marketing or factories toseveral demand sites or consumption (destinations), provided that the offer at each source and demand at each site and the cost of transporting one unit from each source to each site is known and specified. The initial basis for this model dates back to 1941 when F. L. Hitchkook introduced a study entitled "The Distribution of the Product from a Number of Sources to a Number of Sites” which was the first study that contributed to solving transport problems, and in 1947, T. C. Koopman presented a study titled "The Optimal Use of Transportation System", and in 1953, the method of "Stepping Stone Method" was proposed by the researchers, Charners and Cooper, as a way to improve the basic starting solution and then to reach the optimal solution. In 1958, the researchers, Reinfeld and Vogel reached a new method known as "Vogel Approximate Method", and in 1963, Dantzig introduced a new method to improve the initial solution and to reach the optimal solution known as "The Modified Distribution" method or "Multiplication Factors".

2.2.1. The concept of Transportation Problem

The transportation models are one of the important mathematical methods that help to make the appropriate decision to transport a quantity of materials and goods from the sources or centers of production to order or consumption centers to meet the need of these sites at the lowest cost. The problem of transport is also one of the important economic problems facing enterprises of all kinds, whether it is a service or industrial facility. It is also important because transport costs represent a significant element of the total costs incurred by enterprises for production and delivery of goods to the end consumer.

The transport problem has been defined by several definitions, such as "The transport plan for a specified number of goods or services from a number of production sources or processing to a number of demand or consumption sites at the lowest cost"(Samurai, 1997: p.267).

It has been also defined as "The transfer of similar materials from the assets (the production or marketing center) to the finals (demand centers or consumption centers) at the lowest cost or in the shortest time possible (Al-Jawad and Al-Fatal, 2008: p.141).

2.2.2. Characteristics of Transportation Model

Transportation can be defined as an activity that aims at transferring or marketing goods and services from distribution or processing centers, which represent the supply to the consumption or receiving centers, which represent the demand and at the lowest possible total cost. Therefore, we find that the transport model has very wide applications and give us solutions that minimize transportation costs (Samurai, 1997).

Main Transport Model characteristics are as following:

- There are a specific number of homogeneous units that must be transported from several sources to several order (demand) centers
- The costs of transporting one unit from the supply sources to the demand sites are certainly and precisely known
- There are no obstacles to transfer between any source of processing and any demand site
- The objective of the transport problem is to reduce transport costs between processing sources and demand or consumption areas

2.2.3. General Formula of Transportation Models

For the purpose of formulating the mathematical model of transport to transfer the quantities supplied from the sources of production to the receiving or consumption centers that represent the demand, it depends on the following parameters:

(M): Number of sources of processing, which is (S_1, $S_2 \ldots S_m$).

(N): Number of application mars, which is (D_1, D_2, ……Dn).

(ai): Number of the units supplied at the source (i), whereas (ai = a_1, a_2, …. a_m).

(bj): Number of demanded units at the destination, whereas (bj = b_1, b_2, ….bn).

(Xij): Number of the units to be transported from source(i) to destination (j).

(Cij): the cost of transporting one unit from the source to the demand site.

In light of the given characteristics or the objective of the transport model is to determine the optimal number of units to be transferred from source (i) to site (j) at the lowest possible cost. The mathematical model of transport problem can be written as follows(Jaber and Dhawiya, 1988: p.80):

- Objective function

$$Min\ Z = C_{11}X_{11} + C_{12}X_{12} + \ldots .. + C_{mn}X_{mn}$$

The constraints related to transport models above are:

- Supply centers constraints

$$S_1 \longrightarrow X_{11} + X_{12} + \ldots\ldots + X_{1n} = a1$$
$$S_2 \longrightarrow X_{21} + X_{22} + \ldots\ldots. + X_{2n} = a2$$
$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots \qquad \vdots$$
$$S_m \longrightarrow X_{m1} + X_{m2} + \ldots\ldots. + X_{mn} = am$$

- Demand centers constraints

$$D_1 \longrightarrow X_{11} + X_{21} + \ldots\ldots + X_{m1} = a1$$
$$D_2 \longrightarrow X_{12} + X_{22} + \ldots\ldots. + X_{m2} = a2$$
$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots \qquad \vdots$$
$$D_n \longrightarrow X_{1n} + X_{2n} + \ldots\ldots. + X_{mn} = bn$$

- Non-negativity constraints

$$X_{11}, X_{12}, \ldots\ldots\ldots\ldots, X_{mn} \geq 0$$

The general mathematical model of transport problem can be represented as following (Gupta and Hira, 2009/l p.229):

- The objective function

$$Minimize\ Z = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij}X_{ij} \text{ Given numbers to equations}$$

This means that the total cost (Z) of transporting goods and commodities from supply centers to different demand center must be the minimum.

- Supply constraints:

Number of transported units = the number of supplied units.

$$\sum_{j=1}^{n} X_{ij} = ai, \qquad i = 1,2,3, \dots, m$$

- Demand Constraints:

The number of transported units = the number of demanded units.

$$\sum_{i=1}^{m} X_{ij} = bj, \qquad j = 1,2,3, \dots, m$$

- Non- negativity constraints: The product distributed cannot be in a negative amount (Fadhil, 2008: p.134).

$$Xij \geq 0 \quad \text{(i=…; j=…)}$$

Balancing the Transport Models: The basic condition of the transport models is the balance, which means that the quantity supplied in all the sources must equal the demanded quantity in all the sites; i.e. achieving a state of equilibrium, quantities supplied are equal to the demanded quantities (Al-Fadhil, 2008: p.135).

$$\sum_{i=1}^{m} ai = \sum_{j=1}^{n} bj$$

But for practical reality, this is a default condition. Otherwise, the problem of transport becomes unbalanced, as the quantity supplied may be smaller or larger than the demanded quantity. To achieve balance, we add a dummy source or destination as follows:

- If the total demand is greater than the sum of the supply, we will add a dummy supply source, which represents a new column for the transport table by the difference between the quantity demanded and quantity supplied to absorb the excessive quantity demanded at a cost equal to zero (Al-Shamarti and Zubaidi, 2007: p.283).

- The mathematical models will be:

$$Min\ Z = \sum_{i=1}^{m+1} \sum_{j=1}^{n} CijXij$$

S.T

$$\sum_{j=1}^{n} Xij = ai, \qquad i = 1, 2, 3, \dots, m+1$$

$$\sum_{i=1}^{m+1} Xij = bj, \qquad j = 1, 2, 3, \dots, n$$

$$Xij \geq 0$$

Whereas i = m +1 represent the dummy source with the supplied quantity of

$$am + 1 = \sum_{j=1}^{n} bj - \sum_{i=1}^{m} ai$$

At a cost of Cm + 1, j=0 for each j=1, 2, …… , n

- If the total of the demand is less than the sum of the supply, we will add a dummy destination which represents a new column for the transport table by the difference between the quantity supplied and the quantity demanded in order to absorb the excessive supply quantity at a cost equal to zero.

$$Min\ Z = \sum_{i=1}^{m} \sum_{j=1}^{n+1} CijXij$$

The mathematical models will be:

$$\text{S.T} \sum_{j=1}^{n+1} Xij = ai, \qquad i = 1, 2, 3, \dots, m$$

$$\sum_{i=1}^{m} Xij = bj, \qquad j = 1, 2, 3, \dots, n + 1$$

$$Xij \geq 0$$

Whereas, i = n + 1 represent the dummy destination with a demanded quantity of

$$bn + 1 = \sum_{i=1}^{m} ai - \sum_{j=1}^{n} bj$$

At a cost of Cn + 1, i =0 for each i = 1, 2, ……, m

2.3. The Mathematical Models of Transport Problems

The transport models include three main elements:

1. A linear objective function should be as low as possible. This function represents the total transport costs of the quantities of materials transported from the sources to the demand centers.

2. Linear constraints of this function, some reflect the capacities of the sources available, called supply constraints, others reflect the needs of centers, called demand constraints.

3. These restrictions must be non-negative, meaning that the quantities transported must be negative.

It is possible to present the variables of the transport problem in a matrix with dimensions (nXm) called the transport matrix. This matrix can show the relationship between the sources of waste production, landfill sites and quantities transferred from municipalities to landfill sites and according to the cost of transportation and can be presented by the Table 2.1(AL-Shamarti, 2010: p.152).

Table 2.1. General model of transportation

TO / FROM		DESTINATION						SUPPLY
		D1	**D2**	....	**Dj**	....	**Dn**	
Sources	**S1**	C_{11} X_{11}	C_{12} X_{12}	....	C_{1j} X_{1j}	....	C_{1n} X_{1n}	**a1**
	S2	C_{21} X_{21}	C_{22} X_{22}	....	C_{2j} X_{2j}	....	C_{2n} X_{2n}	**a2**
	Si	C_{il} X_{il}	C_{i2} X_{i2}	....	C_{ij} X_{ij}	....	C_{in} X_{in}	**a3**
	Sm	C_{m1} X_{M1}	C_{m2} X_{m2}	....	C_{mj} X_{mj}	....	C_{mm} X_{mm}	**am**
DEMAND		**b1**	**b2**	....	**bj**	....	**Bn**	$\sum ai = \sum bj$

Source: (AL-Shamrti, Hamid Saad Noor, Operation Researches and their concepts and application, 2010, issue 1, Thakira Library, Baghdad, AL-Aadhamia)

Table 2.1 shows above that sources or sites which generate waste (S_1, S_2, S_i, …., S_m) and the amounts of waste available or generated in each municipality (a_1, a_2, a_i, …., a_m), table also shows centers or sanitary landfills where the waste shall be transported to (D_1, D_2, D_j, …..D_n) and also shows the quantities demanded or reached the landfill sites taken by these centers, (b_1, b_2, b_j, …. , b_n). The table as well shows the transportation costs from any source or waste generation site (Si) to the landfill sites or demand sites (Dj) whereas the cost of transportation value referred to as (Cij), while ($\sum$ai),($\sum$bj)refers to the total quantities supplied and demanded, respectively, which must be equal. If the objective of models is reducing the cost of the transported quantities (Xij) from sources of waste generation (i) to demand centers or sanitary landfills (j) as it becomes as less as possible.

2.4. Steps of Transport Models Analysis

Steps of Transport Models Analysis include the basic steps of analysis of the transport models which derived their data from the practical fact. This analysis is done in logical sequential steps (Jaber and Dhawiya, 1988: p.84):

- Determination of the basic feasible starting solution, which completes the variables (xij), which fulfill all the restrictions, contained in the transport models.

Number of transported units = number of supplied units

$$\sum_{j=1}^{n} X_{ij} = ai$$

Number of transported units = number of demanded units

$$\sum_{i=1}^{m} X_{ij} = bj$$

- The achieved solution, in order to be a basic solution, each transport models must contain (m+n-1) of the basic variables as (m) represents the number of rows and (n) represents the number of columns and in the absence of proof of the above equation, an entered variable of the non-basic variables of the unoccupied cells with the lowest cost will be specified and given a transport cost equal to 0 for the achievement of the equation (m+n-1) and the completion of the process of accessing the basic feasible solution (Al-Ankbi, 2010: p.69).
- In order to find the optimal solution, the optimality of the basic solution should be tested. This is done by evaluating all empty cells (non-basic variables), in order to identify the effect of these cells on the objective function; their abilities in reducing costs instead of the occupied cells(basic variables) and that this is done through one of the following methods: Winding path method, method of factors multiplication (Nasi, 1990, p.42). If the test process does not achieve a reduction in the cost, i.e.; the value of

the non-basic variables is positive or 0, the starting basicsolution achieved is considered an optimal solution, but if it leads to the occupancy of non-basic cells the reduction in costs; is that they were of a negative value, the starting solution reached is a solution is not optimal, that there is a non-basic variable that reduce the cost of transportation and in order to achieve this we must move to the other step.

- To identify the external variable of group of basic variables of the occupied cells previously formed and then extract a new basic solution and continue with repeated accounts until we get the optimal solution, feasible solution that makes the value of the objective function (overall cost function) as less as possible.

2.5. Methods of Solving Transport Models via Optimal Solution

Transportation is the important and main way to deliver goods to the consumer and I find the solutions possible to deal with the problems of transport requires the use of appropriate methods that address the problems of transport .We will address the most important methods used in the solution of transport model as the Simplex method and is one of the methods used in the solution of transport models and use other methods used to solve transportation models such as the north-west corner and less expensive and Vogel road and also to address the methods of optimal solution.

2.5.1.Solution of Transport Models by using the Simplex Method

The Simplex method is one of the most common methods of explaining the way in which multiple variable problems are addressed. The Simplex method is a mathematical method for analyzing linear programming problems. This method is based on the selection of variables with the main effect on both the objective function and the constraints (Heizer & Render, 2001: p.758).

It is possible to use the Simplex method to solve transport problems as it is a special case of linear programming problems, and we can explain the basic steps to solve the transport model using the Simplex method as follows (Hillier and liberman, 221: p.365):

- Formulation of the problem of transport in the form of a linear programming model consisting of the objective function of the type (Min Z) and the constraints and the number of variables (Xij) in the objective function = (MN) and their constraints of the type of equality and their number (m+n) and the number of independent constraints = (m+n-1). **(AL-janabi,2010: p.77)**This can be illustrated below:

  $Minimize\ Z = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} X_{ij}$ give numbers to the equations

  $$\text{S.T} \sum_{j=1}^{n+1} Xij = ai, \qquad i = 1, 2, 3, \dots, m$$

  $$\sum_{i=1}^{m} Xij = bj, \qquad j = 1, 2, 3, \dots, n+1$$

  $$Xij \geq 0 \qquad \text{for all i and j}$$

- Adding artificial variables to the constraints by one artificial variable for each model constraint and adding artificial variables to the objective function of a very large factor(Abulrahim, 2010, p.15-18).

- Conversion of the equation of the objective function to the equation zero; calculating (Cj-Zj) and putting it in the row of the objective function, given the nature of the problem of transport, any calculation of the coefficient of each variable is as: Cj-2X (BigM).

- Organizing the starting table of the Simplex method.

- Determination of the entering variable represented by the variable with the biggest negative value in the row of the objective function.

- Determination of the leaving variable of the solution by dividing the right-hand column by the entering variable column and selecting the lowest division result, avoiding the division by zero or a negative number.

- Determination of the pivot element, which represents the intersection of the pivot column of the entering variable with the pivot row of the leaving variable, and then dividing all the values in the pivot row, including the value of the pivot element onpivot element value, thus forming a new row called pivot equation and its position is in the same row as the leaving variable in the following table in order to be replaced with the variable entering.

- The statement of the effect of the entering variable with its new value on both the objective function and other constraints of the problem.

- We continue with the repetitive calculations until the whole objective row becomes positive, then we have reached the optimal solution and the number of basic variables in the final solution table = m+n-1

In order to explain this method, suppose the transport problem clarified in the Table 2.2.

Table 2.2. Transport problem

To / From	D1	D2	D3	D4	Supplied Quantities
S1	C_{11}	C_{12}	C_{13}	C_{14}	a1
S2	C_{21}	C_{22}	C_{23}	C_{24}	a2
S3	C_{31}	C_{32}	C_{33}	C_{34}	a3
Demanded Quantities	b1	b2	b3	b4	$\sum a=\sum b$

We note from the Table 2.2 that the total quantities supplied equal the demanded quantities which means that the transport problem is balanced.

- Objective Function:

$$Min\ Z = C_{11}X_{11} + C_{12}X_{12}+C_{13}X_{13}+C_{14}X_{14}+C_{21}X_{21}+C_{22}X_{22}+C_{23}X_{23}+C_{24}X_{24}+C_{31}X_{31}+C_{32}X_{32}+C_{34}X_{34}.$$

S.T

$$X_{11}+X_{12}+X_{13}+X_{14} = a1$$

$$X_{21}+X_{22}+X_{23}+X_{24} = a2$$

$$X_{31}+X_{32}+X_{33}+X_{34} = a3$$

$$X_{11}+ X_{21}+X_{31} = b1$$

$$X_{12}+X_{22}+X_{32} = b2$$

$$X_{31}+X_{23}+X_{33} = b3$$

$$X_{14}+X_{24}+X_{34} = b4$$

$$Xij \geq 0 \qquad i = 1, 2, 3. \qquad j = 1, 2, 3, 4.$$

We add the artificial variables (Ri) to each of the seven constraints. We have seven synthetic variables from (1) to (7) and add (Ri) to the target function row. Then we put all the information we obtained in the initial solution Simplicity, then determine the internal and external variables and perform the calculations necessary for the replacement process and continue to solve this method for a number of cycles until the optimal solution is obtained in the Simplex table.

2.6. Methods of Finding the Basic Feasible Solution

In previous section, we dealt with an analysis of the models using the Simplex method. In this section, we will present their analysis using the methods of finding the basic starting feasible solution (Taha, 2007, P. 234). There are three basic methods, which are: North West Corner Method and Vogel's Approximation Method.

2.6.1. North West Corner Method

This method is one of the easiest and simplest methods and the most common, whereas the process of finding the basic starting feasible solution and starts according to this method from the north-west corner, so that it is named by this name, and can be summarized by the following steps:

- The solution according to this method after ascertaining that the transport table is in equilibrium; that is, the quantity supplied is equal to the demanded quantity, ($\sum ai = \sum bi$) and if it is not equal it must be equalized by adding a dummy row or column.

- We start with the upper left cell (northwest corner of the transport table) and allocate the largest number of units to that cell, this is the lowest allocated number in the row of quantity supplied or the lowest in the demand column and that allocation is done by the following formula, $X_{11}=$ min (ai, bj).

After the exhaustion of the full amount of the first source or the full demanded quantity for the first consumption center, and the row or column is deleted from any subsequent assignments and the corresponding adjustment is modified by the difference (Jawad and AL-Fatal, 2008, p.144).

- If the supply in the row is equal to zero, we move down in the column to the next cell, but if the demand in the column is equal to zero, we move to the right in the row to the next cell and the minimum value is allocated in the light of the quantity supplied and the quantity demanded according to the equation in paragraph (b) and the continuation of the previous process until all the supplied quantities are allocated to the demanded quantities and then the total cost is extracted by multiplying the number of units of each basic variable (X_{ij}) by the corresponding cost (C_{ij}), which represents the lowest initial transport cost.

This distribution path of the North West Corner Method is illustrated in Figure 2.1.

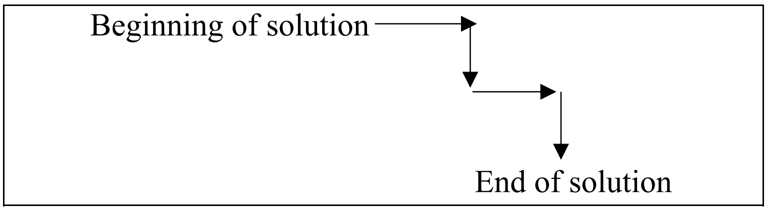


Figure 2.1. Distribution path of North West Corner method

Source: (AL-Fadhil et al., (2008). Access to the Quantitative Methods in Marketing, Al-Masirah House, Amman, p.138).

Although it is easy to use this method, but it is defective that this method does not take into account the cost of transporting the unit transported, but depends on the location of the square in the matrix and the objective of the function is to reduce the total costs to the least possible, as well as that the solution is often reached is far from the optimal solution, which requires improvement of the solution according to the methods followed in this area.

2.6.2. Vogel's Least Cost Method

The least cost method is more precise than the north-west corner because it does not depend on the location of the cell in the matrix, but the distribution is according to the lowest costs and this is done by seen the matrix of costs and finding the least cost to transport the unit and allocate the largest quantity so that it is equal to the available offer or demand, the lesser of them in the row or column, and this is done depending on the following equation: (X_{ij} = min).Then the remaining quantities in the row and the column are adjusted by the difference between them, depending on the deletion principle of the row or column whose value is equal to zero. Then, another smallest possible cost is determined, and a value is allocated for this variable thus we continue until all units are distributed on the demand centers and extraction of the cost of the target function for the basic variables that achieve the following equation: ($m+n-1$) (Jawad and AL-Fatal, 2008: P.145).

Although the Least Cost Method came to address the defects of the North-West corner method, but the defect of this method is in the case of taking the cells (squares) with the least cost in the matrix and a row and column is written off the matrix and the cells with high transport cost will eventually be chosen for lack of others in the model, which leads to a higher total cost (AL-Naimi, 1999, p.133).

2.6.3. Vogel's Approximation Method

Vogel's method is the most important methods of the primary solution for the of this ability of method to access to the best solution or a solution that is near the optimal solution because it exceeds the defects of the previous methods which are related to the adoption of high-cost cells at the end because of its reliance on the calculation of the penalty costs for each row or column and taking the largest possible penalty (Jawad and AL-Fatal, 2008, p.147).

The steps of finding the primary basic solution by this method can be summarized after making sure that the transport schedule is in the case of balance, as follows:

- The penalty costs of for each row or column of the transport table, which is the difference between two costs in each row or column are calculated. The difference between these two represent excessive cost to be eliminated and is names the cost of the penalty or the fine which should be affixed to the right of the row and the bottom of the column for transport model (AL-Ankabi, 2010, p.72).

- We specify the row and the column in the matrix which has the highest penalty cost and allocate the largest number of units for the cell in the row or the column by calculating its value (X_{ij}) as following:

$$X_{ij} = \min (a_i, d_j).$$

- We decrease the supply in the row and the demand in the column by the same number of units specified for the cell, then we delete the row and the column which all their values were allocated fully and became equal to zero.

- We repeat the previous steps until all units supplied on the demand units are reached and access to the feasible primary solution (Gupta & Hira, 2009, p.209).

- Extraction of the primary transport costs after ensuring that the number of occupied cells matches the following equation (m + n-1), by multiplying the quantity transported by the cost of one unit (Alwan, 1985, p.145).

2.7. Methods of finding the Optimal Solution

After obtaining the basic starting feasible solution by one of the above methods, it is necessary to verify whether the solution reached is an optimal solution or not, to make the necessary adjustments and improve the solution and this is done in one of the following two methods:

- Winding Path Method or Stepping Stone Method.
- Modified distribution method or multiplied factors.

2.7.1. Winding path method or stepping stone method

The method requires the evaluation of each cell not occupied in the table of the basic solution to know its impact on the costs of the total transport if one unit is transported to one of the cells which are not occupied and this is done according to the following steps:

- Closed Path of costs for each cell that is not occupied is drawn. This path consists of a set of horizontal and vertical consecutive straights starting from the unoccupied cell and passing through basic variables (at the end of each straight) until the return and completion of the non-basic variable which it started with and in the shortest methods.

- Using the costs path to test the effect of the non-basic variable on the target values by giving a positive signal (+) to the cell to be evaluated and followed, and a negative sign (-) for the following cell in the path and then a positive signal for the next cell, thus for all cells from which forms the path.

- Calculating the indirect cost by collecting the costs of the cells on path of the non-basic variable. If the evaluation of the cell is positive or 0, this means that it is not able to reduce the total costs of transport and the solution is the best solution, but if the cell evaluation is negative, that means The transporting of one unit to the unoccupied cell will reduce costs by that negative value, and the solution is not the best one.

- After determining the non-basic variables with the negative cost, the variable with the largest negative cost is chosen to become an entering; that is, the variable which achieves the largest reduction in the total cost of transport (Jawad and Al-Fatal, 2008: P.149). In order to maintain the equation (m + n-1). After inserting a new entering variable, the leaving variable must be determined from the basic variables, it is chosen by the negative and positive successive signals of the entering variable which meet to the lowest corresponding value in negative signal; that is, the variable which first reaches 0 and has the least transported units.

- After determining the leaving variable which corresponds to the smallest number of units transported, a value will be added to each cell with a positive signal and a value will be subtracted values from each cell with a negative signal. Therefore, the new values of the entering variable path are values of the basic variables, which constitutes the new feasible primary solution. (AL-Ankabi, 2010, P. 76).Testing the optimality of the new basic solution in light of new values by repeating the steps of the previous solution.

To illustrate this method, assume the transport problem shown in Table 2.3.

Table 2.3. First solution using North West solution method

TO / FROM	D1	D2	SUPPLY
S1	C_{11} X_{11}	C_{12} X_{12}	**a1**
S2	C_{21}	C_{22} X_{22}	**a2**
DEMAND	**b1**	**b2**	

For the purpose of testing the solution that was reached, whether the solution is optimal or not, by evaluating the unoccupied cell (S2, D1) by drawing a closed path for it, it starts with the empty cell and ends with it, as shown below:

$$X_{21} \rightarrow X_{11} \rightarrow X_{12} \rightarrow X_{22} \rightarrow X_{21}$$

This can be illustrated in Table 2.4.

Table 2.4. Testing solution using winding path method

TO / FROM	D1	D2	SUPPLY
S1	C_{11} **-1**	C_{12} +1	**a1**
S2	C_{21} +1	C_{22} **-1**	**a2**
DEMAND	**B1**	**B2**	

We shall calculate the value of Cij, which represents the net increase or decrease in the value of the objective function, as a result of converting the non-basic variable (Xij) to a non-basic variable. If we apply the signals to the path extracted in the table above:

$$C_{21}=C_{21}-C_{11}+C_{12}-C_{22}$$

Whereas: $C_{21}=a$, $C_{22}=a+1$, $C_{11}=a+2$, $C_{12}=a+2A>0$

Accordingly, transporting one unit the cell (S2 D1) will affect the total cost by the amount of

$$a -(a+2)+(a+2)-(a+1)=-1$$

This means that transporting one unit to the cell (S2D1) will reduce the total costs by one unit, so that the largest possible amount can be transported to the cell from one two cells (S2D1) or (S2D2), taking the least value, if total rows and columns are maintained; that is,

$$X_{21} = \min (X_{11}, X_{22})$$

2.7.2. Modified Distribution Method

Modified distribution method is one of the methods used to test the starting basic solution to reach the best solution and this method is a development of the previous method and the steps of the solution can be summarized by:

- After extracting the Starting Basic Feasible solution and identifying the variables in rows (Ui) to represent the calculated variables of row (i), whereas (I =1,2,…,m) and identifying columns (Vi) to represent the calculated variables in column (j) whereas (j=1,2,…,n) (Al-Ankabi, 2010, p.82).

- Finding the values of the variables (Ui) (Vj) by forming the equations of the cells occupied according to the following formula:

$$Cij = Ui + C=Vj$$

- Which indicates that the costs are equal to the multiples of columns and rows and the number of these equations is (m+n-1)

- Finding a solution to the equations of the occupied cells and according to the formula mentioned in step 2. Since the number of variables exceeds the number of equations, the value of zero is given to one of the variables and then the other factors can be extracted by direct compensation (Taha, 2007, P. 242).

- After finding the values for all the variables, non-activated cells are evaluated using the following equation:

$$C_{ij} = C_{ij}-(U_i+V_j)$$

- If all the values the non-basic variables produced by the above law are positive values or zero, we stop the calculations of the default and the starting solution to be the optimal solution(AL-janabi:2010, p.199).If there are two or more cells that are not occupied, the indirect cost is negative or the total cost of transport can be decreased by transferring the non-basic variable with the highest negative cost into a basic variable; it is an entering variable and excluding one of the basic variables which corresponds to the least number of units transported and as previously stated in the steps of the winding path method.

2.8. Cost of Transportation or Opportunity Cost

Transport is one of the most important components of any country and an important element in the life of its societies. It plays a positive and effective role in the development of the economies of countries and its rapid economic and social recovery. Transport is also one of the most important cultural dimensions, as it is of the essential requirements and its nets are an important of the infrastructure and the economic port of the world. The cost of transportation is an important element in determining the cost of a product by calculating the final cost of the product.

2.8.1. Concept and Importance of Transport

Transport occupies an important position in the progress of countries and their prosperity and the welfare of their peoples and the sensitive nerve in the economic entity as the instrument of effective in achieving direct communication between the different points of the economic process and productivity. The transport has a big role in the expansion of the market and the exploitation of human and material resources that werenot used before; it as well increases production, diversifies and improves its quality. Transport can also be defined as "economic activity involving the movement of persons, goods, information, capital and communications between its centers of supply and demand centers locally and globally using various means and media under an organizational, technical and information framework, aiming at reducing the cost of the product, (Ibrahim, 1999, p.5). It is clear to us that transport can play an important role in the economic development of any geographical area, whether it is a state, a region or a city, because the level of economic activity in any region depends to a large extent on the quantity, quality and cost of the transport service available in it and that its role in economic development is a dynamic role because it facilitates the exploitation of untapped resources by building different means of transport for industrial, agricultural and service development in the future, which is the work that begins to help economic growth.

The cost of transportation plays a major role in the production process and is an important indicator of the efficiency of transport's economic services and is an important and vital part of the final costs of various finished products, which in turn affect the policy of selling and buying, since transport is one of the most important economic factors that contributes to the possibility of marketing or its weakness, the cost of transport is an important part of the costs borne by the economic units through economic activity. In the United States, the cost of transportation in 1999 was about $ 554 billion, or 6% of the total national production (AL-Ankabi, 2010, P. 42).

Other studies have shown that expenditure on transportation mounts up to 35% of production costs in the UK (Ashmawi, 2005, P. 7). In previous sections, the most important methods used to reduce transport costs were discussed. Our purpose is how to reduce of transporting waste which is a major part of the costs of waste disposal. In the next section, we will discuss how to use the opportunity cost to transfer allocated resources for the collection, transportation, landfill and other uses.

2.8.2. Cost of Alternative Opportunities Cost and the Curve of Production Possibilities

The scarcity of resources is the main focus of economic science. This scarcity is attributed to two main reasons: firstly, unlimited needs; and secondly, the means of production of goods and services are usually limited and rare, and since economic resources are limited or rare in all societies, the ability of the societies to produce required goods and services are also limited. The economic problem revolves around the scarcity of resources and the necessity of choosing between alternative uses in satisfying desires and achieving different goals. Therefore, the scarcity requires us to choose the satisfaction of a commodity rather than another. The choice means to reconcile available resources with different uses and to employ them in the best use to achieve maximum goals and have the greatest possible satisfaction for the individual. In view of scarcity, individuals shall make choices and each choice brings a certain cost which means the amount of sacrifice that must be made or must be submitted in order to get something, the alternative opportunity cost can be defined as "it is the best alternative sacrificed for the chosen alternative", whereas the opportunity cost of a commodity means to provide or the produce any rare commodity which requires the assignment of things or other goods if we want to get the rare commodity. The alternative opportunities cost is useful for determining the option between two alternatives, for example, when someone decides to join the faculty, he gives up some time for self-employment. The correlation among scarcity and choice and alternative opportunity cost can be illustrated by figure 2.2.

Figure 2.2. Relationships among scarcity, choice and opportunity cost

Source: Irvan B. Tucker, 2011, p.36

There is no doubt that life is full of many options and, given the scarce resources available, it was a public obligation to think about how we spend our income and limited time. Here, it is important to think carefully about the alternative opportunity cost to use the resources allocated to the process of collecting, transporting, landfill and their alternative uses, i.e., how to reduce the cost of collecting, transporting and landfill waste through the process of recycling and reusing, and their role in saving the scarce recourses and how to use them in other areas. The opportunity cost can be expressed between the resources allocated for the collecting, landfill, transporting, landfilling and other uses of the curve of production potentials. Since the nature of the economic problem can be presented and obtained a clear vision using the curve of production potential. This curve can be defined as " a curve that shows all possible combinations of production that can be achieved by using a certain amount of productive resources and full and efficient use of these resources and a certain level of technology "(Gawrati and Strobe, 2010, p.43).We can illustrate the opportunity cost between resources directed to the collection, transport, landfill and resource of alternative uses using the production potential curve as depicted in figure 2.3.

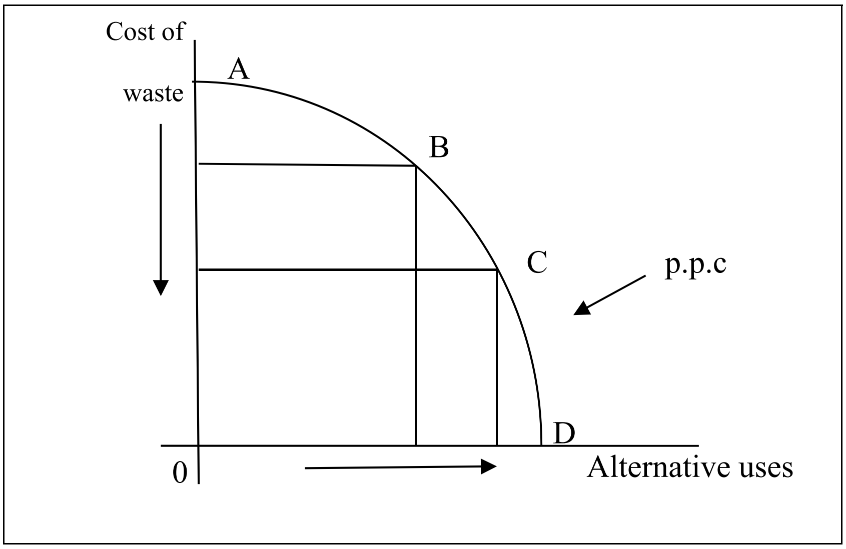


Figure 2.3. The production potential curve and opportunity cost between the costs of collecting, transporting and land fill waste and the alternative uses

Source: Irvin B. tucker, 2011: p.38

It is clear from the figure 3.2 where the vertical axis represents costs of collecting, transporting and landfill of waste while the horizontal axis represents the alternative uses. The figure 3.2 illustrates production potential curve, a set of combinations that can be used among the cost of collecting, transporting, landfill and alternative uses including points (A, B, C, D). For example, if the economy uses all its resources and employs them to collect, transport and landfill waste as in point (A), and nothing is used for alternative uses. Other possibilities available to this economy are to use all available resources and to employ them in alternative uses as in point (D), and not to employ anything for the cost of collecting, transporting and landfill waste. Another production potential curve of the cost of collecting, transporting, land filling and alternative uses is located between the limits or extremities of each point (D) (B), if the point (B) is chosen, it represents the available resources on the curve of production potentials among the cost of collecting, transport and landfilling the waste and the alternative uses, since the more we reduce the cost of collection, transport, landfill and alternative uses, the more we can direct these resources towards the alternative uses. The reduction of the cost of collection, transport and landfill waste through recycling and reusing process, will provide us with the resources that can be reused in other areas, and that it is to move to another point on the production potentials curve. That is, the decline in resources directed to the collection, transport and landfill will increase resources for alternative uses.

CHAPTER 3

LITERATURE REVIEW

3.1. Operational Research on Solid Waste Management

The huge and expanding amounts of solid waste created every year in both industrialized and developing nations, alongside global concern for ecological protection, is making appropriate management of solid waste one of the most important issues to the society. In this specific circumstance, a coordinated Solid Waste Management (SWM) speaks to a genuine demand and a major challenge in the meantime. Studying a SWM framework from an operations research perspective infers demonstrating it through a multi-echelon supply chain in which the following procedures happen: waste production in supply areas; waste accumulation in exchange stations; waste sorting performed at the sources or in separation plants; waste treatment through incinerators, energy-from-waste plants, recovery plants, or composite plants; waste removal via land filling or open dumping. (See Figure 3.1).

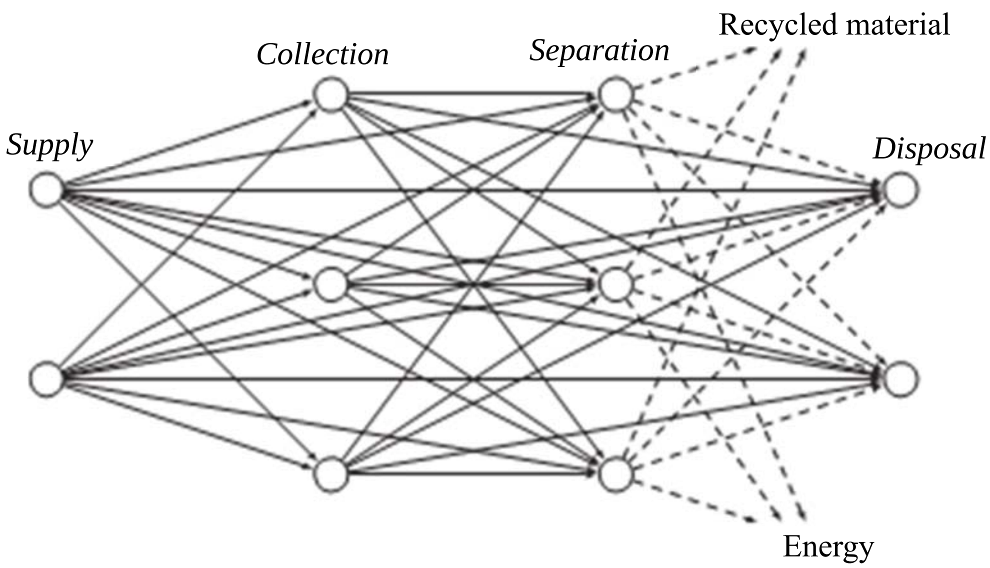


Figure 3.1. Network representation of a SWM system

Operational decisions involved in SWM require solving many combinatorial optimization problems which makes Operational Research (OR) techniques very useful in optimizing the cost of such process and achieve considerable cost savings. The following sections discuss some fields that have been studies by operational researchers and illustrate the concept with selected representative publication for each application.

3.2. Literature Classification

Because of the diversity of the objective and scope of literature on the topic being reviewed, we propose a taxonomic system for the problem family used in this review.

The categorization consists of four fields' *p / s / c / o,* each represents a component of the problem. The first field *"p"* corresponds to period of the problem: it takes value 1 if the study focuses on single time period and T if more than one period is considered. Field 2; *"s"* is associated with the supply chain structure and might have several subfields delimited by comas: C, if the best location of new collection areas is considered. S, if the existence of current or future transfer stations is considered. P, if either developing new processing plants or optimizing the activities of current facilities is analyzed. L, if current or new landfill, open dumping or marketing facilities are taken into account. Field 3: *"c"* describes more constraints and properties of the problem, also could separate by commas: "multiwaste", if many types of solid waste are taken into account, "uncert", if the waste production rate is unknown or unconfirmed. The last field *"o"* is related to the optimization goals: TC, if the objective is to minimize transportation cost. PC, if the goal is to optimize processing cost at facilities, FC, if the included cost of existing facilities or current operations are considered fixed, "multiobj", if the research seeks to optimize more than one objective.

3.2.1. Location Models Considering Single Time Period

This group of research aim to optimize the location of solid waste processing facilities in order to achieve a significant reduction in the total cost of SWM.

A representative paper of this group is the Wassenhove et al., 1996) the aims of this paper at minimizing the overall cost of opening new facilities for either waste processing or disposal and the cost of transportation to and from those facilities.

This model has been used similarly in other researches. For instance, Jenkins (1982) proposes a 1/S,P,L/–/PC,FC fixed-charge model, including transportation of recycled waste to consumers, to optimize the location of resource recovery facilities in Southeastern Ontario.

3.2.2. Location Models Considering Multiple Time Period

In contrast to previously discussed papers, the following researches consider that demand that might change over time. Baetz et al., (1994) propose a dynamic programming method to answer a multi-period T/L/–/TC,PC,FC model with the objective of evaluating the best size and timing for landfills and energy-from-waste producing facilities. The planning phase is divided into time periods with a capacity to expand facilities only at the beginning of any period. A linear program is used to determine the best location of any given pair of energy-from-waste facility and a landfill area.

Another related model is proposed by Berger et al.(1998) which is a T/P,L/multiwaste/TC, PC, FC, multiobj model that has several waste types, in which capacity of landfill and processing facilities can be expanded infinitely at any time point with the goal of minimizing the overall cost. However, this paper has not presented a tailored algorithm.

3.2.3. Location Models with Multiple Objectives

In this category, the models developed optimize several objectives through multi-commodity flow models. A remarkable example on this category is authored by Caruso et al., (1993) and it proposes a 1/P,L/multiwaste/TC,FC, multiobj model. This model seeks to optimize three objectives, namely, recyclable material loss, effect on the environment and overall processing cost. A weighting method is utilized to aggregate the three objectives into one. An add drop heuristic search is then used to search for a group of approximate Pareto solutions. The final solution is determined by the decision maker through the aid of the reference point method.

3.2.4. Waste Generation Uncertainty Model

When waste generation rate is uncertain, the waste flow allocation problem complication occurs in the waste flow allocation process. Unfortunately, very few papers dealt with this problem in spite of its practical importance. Uncertainty can occur with regard to many aspects, in addition to generation rate, such as waste processing cost per facility, fraction of waste that is recyclable. Solutions to this problem utilize stochastic programming based algorithms.

A representative publication by Huang et al. 1998 used a case study of an Ontario base municipality that has a problem of uncertainty to determine the optimum waste flow allocation. Authors proposed Grey Linear Programming (GLP) based approach which was able to deal with interval input data, through conversion of interval parameters into a pair of deterministic model. Models of this type guarantee the stability of the upper and lower bounds of the answer. Huang et al.(1998) were able to estimate the solution for the problem using the GLP, through which they could use only small changes to the current waste management system to consistently reduce the cost of the current system.

3.2.5. Sectioning

Sectioning (or zoning) phase is to identify the optimum collection zones. The zone should be determined so as to ensure that the amount of solid waste loaded into collection site doesn't exceed the capacity of the facility that will perform the various operations. The zoning issue is not sufficiently studies in literature and zones are mostly considered pre-determined priori. Nevertheless, zoning can have a positive effect on the following phases such as routing or other strategic choices.

Sectioning was studied by researchers, Male and Liebman(1978), who used heuristic based zoning approach that uses a constructed auxiliary graph with nodes representing trips whilst edges mark the possibly agreeable trips. Their sectioning method has a numerous small circles where every edge belongs to each cycle of them which are then used to determine the zones.

3.2.6. Waste Collection Schemes

Waste collection schemes are the selection of waste collecting and other different operations days. It is important, in particular, to determine the maximum number of days waste is allowed to accumulate and the frequency of service provision. These decisions are important in that if not taken correctly, problems may ensue such as collecting trucks may be overfilled in some days and only partially filled on other days, a problem called inconsistent refuse removal. This could subsequently lead to increased collection costs especially for operations following the collection phase. Hence, overall cost minimization can be achieved through minimization of the maximum load of waste collected during a peak day.

Mansini and Speranza(1998) explored the possibility of gaining this objective through efficient collection scheduling of household waste through deciding the collection days of each zone within the city. In particular, domestic waste production is assumed to occur at a stable rate while waste collection is considered to be periodic. A user defined set contains the number of successive conglomeration days at each collection area. The objective chosen by the authors of minimizing the maximum amount of waste collected which is the same as minimizing the amount of manpower and vehicle required for waste collection. The authors Mansini and Speranza could achieve a peak reduction of 10% - 16% by solving their model from data collected from the case study of Bresciaas compared to maximum values obtained without the use of the model they proposed.

However, the above models are limited by their inability to differentiate between different types of waste which can be overcome by generalizing the model to a case of separate collection of multi-commodity refuse.

3.2.7. Fleet and Crew Composition

According to Shamshiry et al.(2011) about 75% of the total solid waste management cost is incurred by waste collection which is related to the equipment and the workforce. Hence, a significant cost saving can be achieved through optimization of those aspects. Nevertheless, optimization of fleet assignment and crew composition has been understudied in literature.

One of the commonly cited article in this area is written by Altman et al.(1971) that has proposed a non-linear model for crew composition requirements for solid waste collection. It is useful in making a match between the work shifts and the change in demand for collection of solid waste. A modification of the gradient method is used as an algorithm for solving the non-linear method. A case study on data from some zones in New York City was used to perform the numerical calculations.

3.3. The Solid Waste Problem in IRAQ

Following quite a while of turmoil and global penalties, a significant part of the key common basic services inside Iraq has fallen into dilapidation, prompting a substantial decrease in the provision of essential and basic civil services. This is especially valid for waste and asset administration benefits that have seen years of underdevelopment and disintegration. The waste sector was one of the most severely affected sectors. This is evidenced by the replacement of the formal waste management system by the uncontrolled informal system for collection, transport, recycling and disposal of domestic solid waste (Naji et al., 2009).

The formal system of waste management is being operated by the municipalities and normally restricted to collection from common bins. Common bins are available in large cities or towns like Al-Nassiriya, Basrah Central, Al-Zubayr and in Ammara Central. The private sector system has been introduced recently in large cities. In low-income areas, wastes are dumped in open areas and drainage ways, and workers spend much time cleaning around these areas. The collection equipment employed for such areas is very primitive and principally relies on donkey-driven carts. Solid wastes are collected and disposed into refuse piles in open lands, where the waste stays giving rise to odor and other problems. Local authorities also provide collection services for domestic wastes generated from hospitals and clinics. However, medical and pathogenic wastes are usually incinerated by the hospital authorities within the hospital grounds. Industrial wastes are the responsibility of industry itself and are collected by transported by the industry (R. A. Yasir et al., 2012). In the present state, daily per capita generation of MSW is much lower in developing countries than in developed countries. Differences also arise between high and low income countries in terms of waste composition and physical characteristics of wastes.

Waste generation rates in cities and urban areas are usually significantly higher than those of rural areas. For this reason, the waste generation rate of Baghdad is expected to be above the national average. Lack of available data is the most effected barrier on establishing and improving waste management. (Alsamawi et al., 2009).

In the past, solid waste in Iraq used to be disposed in unregulated landfill sites in different places in the country mainly through open dumping. There was no concern about the potential pollution and human health risks associated with such methods of solid waste disposal. Even more, formally constructed landfill lacked the minimum requirement for pollution prevention such as covering leakage and gas neither collection nor liner systems.

The following section will discuss two studies. One is reporting an Iraqi National Solid Waste Management Plan (NSWMP) that has been developed in response to the aforementioned situation (Knowles, 2009). The other study discussed here will be about the composition of solid waste generated in Baghdad city (Naji et al., 2009).

3.3.1. IRAQ National Waste Management Plan

The Iraq NSWMP was created in 2007 via the cooperation between several international specialists and consultants of waste management and some staff members at the University of Baghdad. Its development objectives included:

- Identifying the principles of improving solid waste management in the upcoming 20 years.
- Determining the range of solid waste management option in Iraq.
- Establishing definitive roles and responsibilities of different Iraqi organizations and institutions in the process of solid waste management.
- Establishing a guide for implementation as well as opportunities of funding for the plan to be executed.

The plan was based on a never-have-been-used principle in Iraq that included but not limited to:

- Sustainability of development; achieving growth without compromising other generations' rights in using the earth's resources.

- Managing solid waste locally as close as possible to the collection sites.
- Carefully following strict environmental policies.
- The producer of the waste shares responsibility of the cost and risks of its disposal.

The execution of the NSWMP required a variety of activities to be performed. The operational framework addresses issues of waste collection, transfer, recycling and disposal as well as collecting relevant information that will help to optimize the provision of solid waste management services. These technical issues are categorized into four categories:

Collection and Analysis of Information: For waste management resources to be sustainably developed, it is very important to collect and generate some sort of data. Unfortunately, there is a scarcity of information available to decision makers in Iraq with this respect and generally. It is therefore imperative to develop a system for collection and analysis of relevant data and information. One of the most important achievements of the NSWMP team is the estimation of the amounts of waste based on a mathematical model which was based on a 1.4-kg per person waste generation rate that was assumed to be the rate per head of population. Table 3.1 illustrates landfill requirements based on these estimates.

Table 3.1. Expected Iraqi landfill requirements till 2027 in selected governorates

Governorate	Landfill volume over 20 years (Mm^3)	No. of landfills required in 2027
Anbar	32	2
Baghdad	138	6
Basrah	36	2
Diyala	32	2
Erbil	32	2
Missan	16	1
Najaf	22	1

Structure and Planning: The NSWMP team decided to delegate some of their responsibilities in the early stages to the local governorates, districts and municipalities through the short-term improvements in the local solid waste management facilities. The local solid waste management facilities shall provide in depth analysis of the gap to be filled later by the NSWMP.

Collection and Transportation: The primary focus at the initial phases was on reducing or even removing the human health risk posed by the accumulated waste by developing the most basic collection and transport system. They started by removing areas of waste collection that were in close proximity to the residential areas.

Recycling and Disposable: In the near future, the only affordable method for solid waste disposal in Iraq is landfill which is the cheapest method of waste disposal even though environmental protection measures should be taken into account to avoid adverse consequences such as underground and/or superficial water pollution. The final goal of the strategy is to reach category A; "recognized best available practice sites are operational and accepting waste". Table 3.2 shows the milestones set by the NSWMP for *reaching a 2027-objective.*

Table 3.2. Recommended landfill operation and closure milestones

Category	Properties	Target end date
A	Controlled, clean landfill locations with full capacity and operational landfill gas and leachate management	Continuous operation
B	locations with environmental and health protection, these may be justified to create controlled, clean landfill locations	12/2017
C	Locations with some limited form of	03/2014

	environmental and health protection, may continue to be used in the temporary period prior to the completed development of controlled landfill locations.	
D	High-risk locations without any form of environmental and health protection and are in need of urgent mitigation measures	02/2009
E	Uncontrolled dumping locations without any management or form of control, locations require urgent mitigation measures	02/2009

Limitations and Challenges: A large number of the difficulties confronted all through the project team's arrangement of the NWSMP project originated from problems and obstacles innate to working for a nation that is undeveloped with constrained resources because of maintained inside conflict. Access to exact data related to prevalent conditions demonstrated to a great degree hard to acquire as did a working understanding of the complex inter-relationships between the different organizations working inside the nation.

3.4. Solid Waste Composition in Baghdad

Abudi et al.(2009) collected and analyzed solid waste survey data in the time frame from 1977 to 2002 and estimated generation projections for six regions in Baghdad for the period 2000-2005. The authors reported the volume of waste generated and their corresponding sources, the chemical and physical composition and potential risks and toxicity associated with them have also been reported.

3.4.1. Solid Waste Generation Rate

The study reports that Baghdadis are generating a progressively increasing amount of waste every year. The amount of solid waste generated has been reported to be increased by fivefold over the past 30 years. For instance, the volume of solid waste was 0.388 million tons in 1987 and has risen to around 2 million tons in 2005 (Ministry of Environment, 2006). This increase in solid waste production is proportional to increase in Baghdad population as depicted in Figure 3.2.

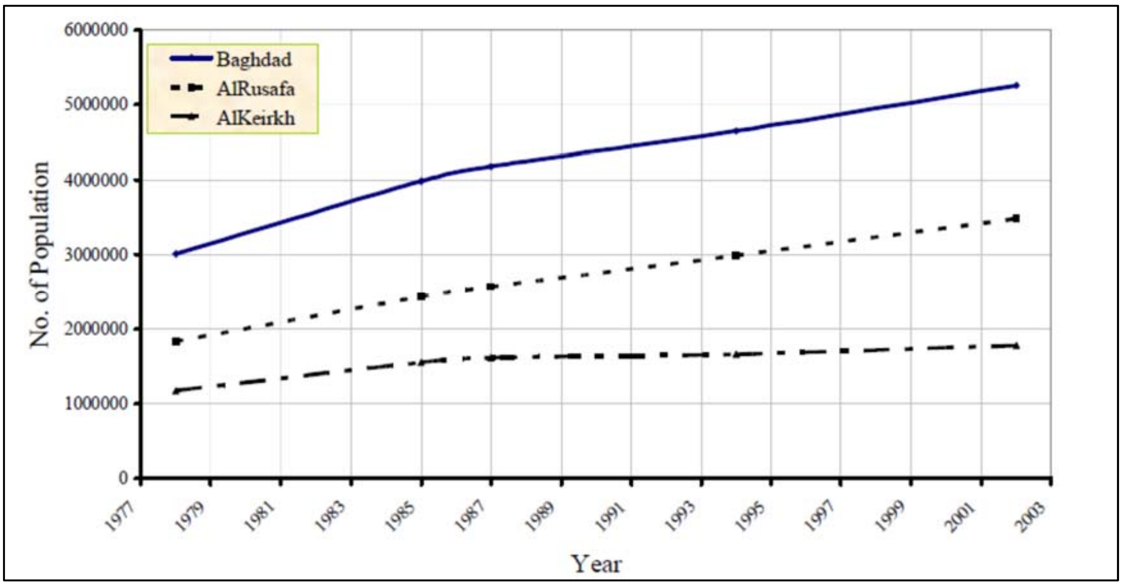


Figure 3.2. Population trend in Baghdad in the period 1977-2002 as compared to Rusafa and Keirkh

The waste generation rate in Baghdad has increased from 0.345 Kg/day per person in the late 70s to more than one Kg/day per person at the beginning of the current millennium. This is depicted in Figure 3.3.

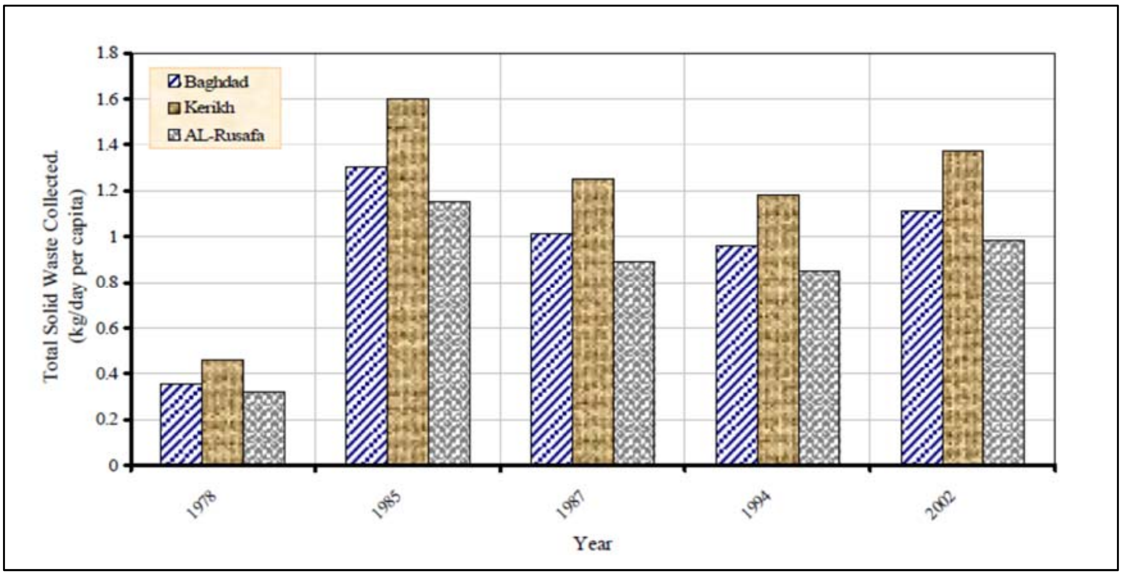
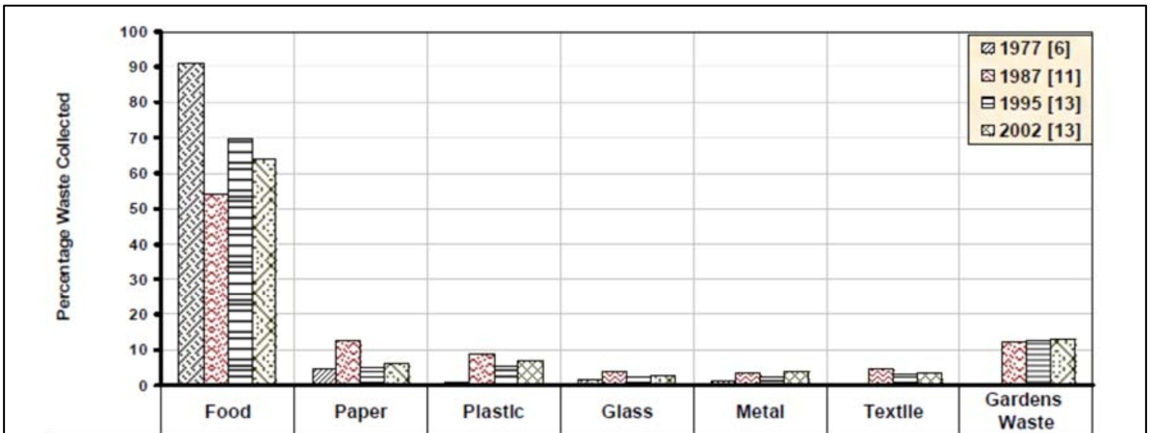


Figure 3.3. Daily solid waste generated by each person in Baghdad, Rusafa and Kerikh in the time frame from 1978 to 2002

3.4.2. Solid Waste Composition

The waste is generally composed of about 60% organic material in the form of food waste, plastic material of about 10%, while paper, metal and glass waste represent 7.9%, 6.8, 6.1%, respectively. Additionally, about 6% is formed of textile while the remaining proportion is composed of wood, construction waste and other minor materials. This is indicated by figure 3.4 that shows that food waste forms the largest proportion of domestic solid waste in Baghdad (Abudi et al., 2009).



	Food	Paper	Plastic	Glass	Metal	Textile	Gardens Waste
1977 [6]	91.17	4.53	0.96	1.59	1.12	0.63	0
1987 [11]	54.13	12.43	8.76	3.93	3.71	4.83	12.2
1995 [13]	69.6	5	5.3	2.2	2.2	3	12.7
2002 [13]	64	6	6.8	2.7	4	3.5	13

Figure 3.4. Proportions of different types of solid waste types in Baghdad city in the period from 1977 to 2002

3.4.3. Variability of Solid Waste Composition within Baghdad City

High income regions of Baghdad produce waste that is reach in packaging materials made of paper, plastic, glass and metals which imparts waste a low density. Moreover, the moisture content of that waste is relatively low but sometimes is high due to large amounts of fresh vegetables and fruits. On the other hand, low income regions produce waste that is highly inconsistent in composition and is characterized by high density due to high proportions of rubble.

Additionally, the composition of solid waste in Baghdad fluctuates significantly with seasons of the year. This is made clear in Figure 3.5.

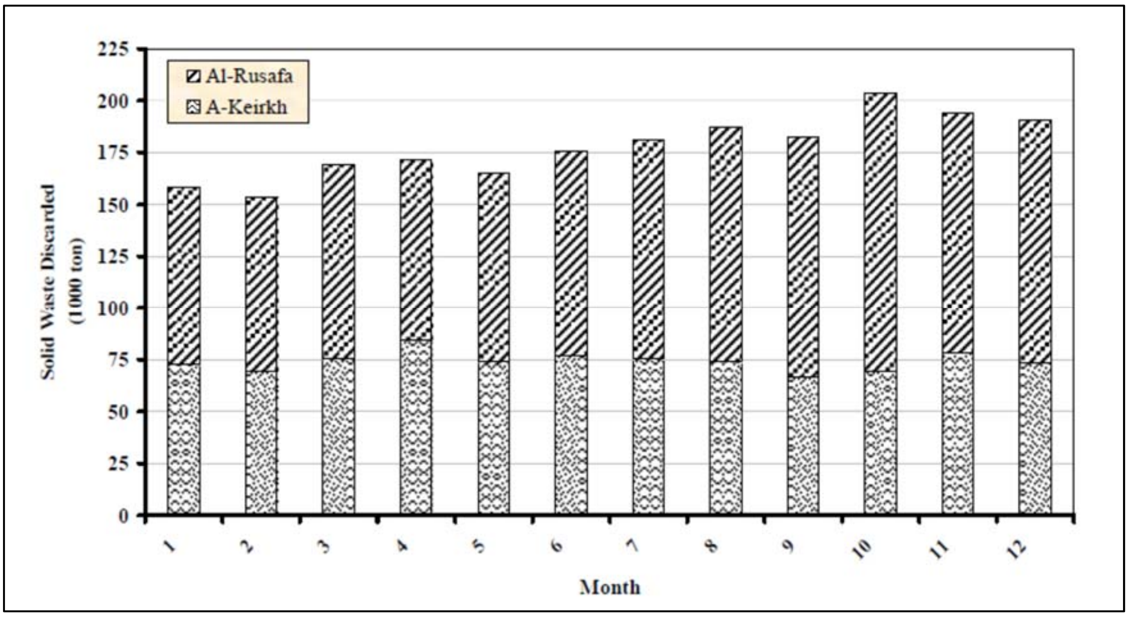


Figure 3.5. The average monthly weight of solid waste collected in Baghdad's two sides of Tigris River in 2002

Finally, the composition of solid waste varied significantly through years as result of the economic situation and political status.

3.4.4. Physical Characteristics

The physical analysis of characteristics of Baghdad solid waste shows that on wet basis the levels can range from 42%-69%. The wastes largely comprise of bio-degradable organics. The high moisture and organic content associated with weather temperatures make it necessary that solid waste locations being cleaned frequently. Such a places consider an additional load on the system. Burning is not a total solution for solid wastes. The ash remains from burned waste still must be land filled or used otherwise. The reason behind burning waste is to reduce the quantity of solid waste. In Baghdad, it has not found much use as the garbage tends to be low in calorific value and volumes are generally low for a central facility. The combustion technology is not produced locally and importing it would produce prohibitively high acquisition cost. Figure 3.6 shows the proportion of solid waste types in Baghdad during the period from 1978 to 2002.

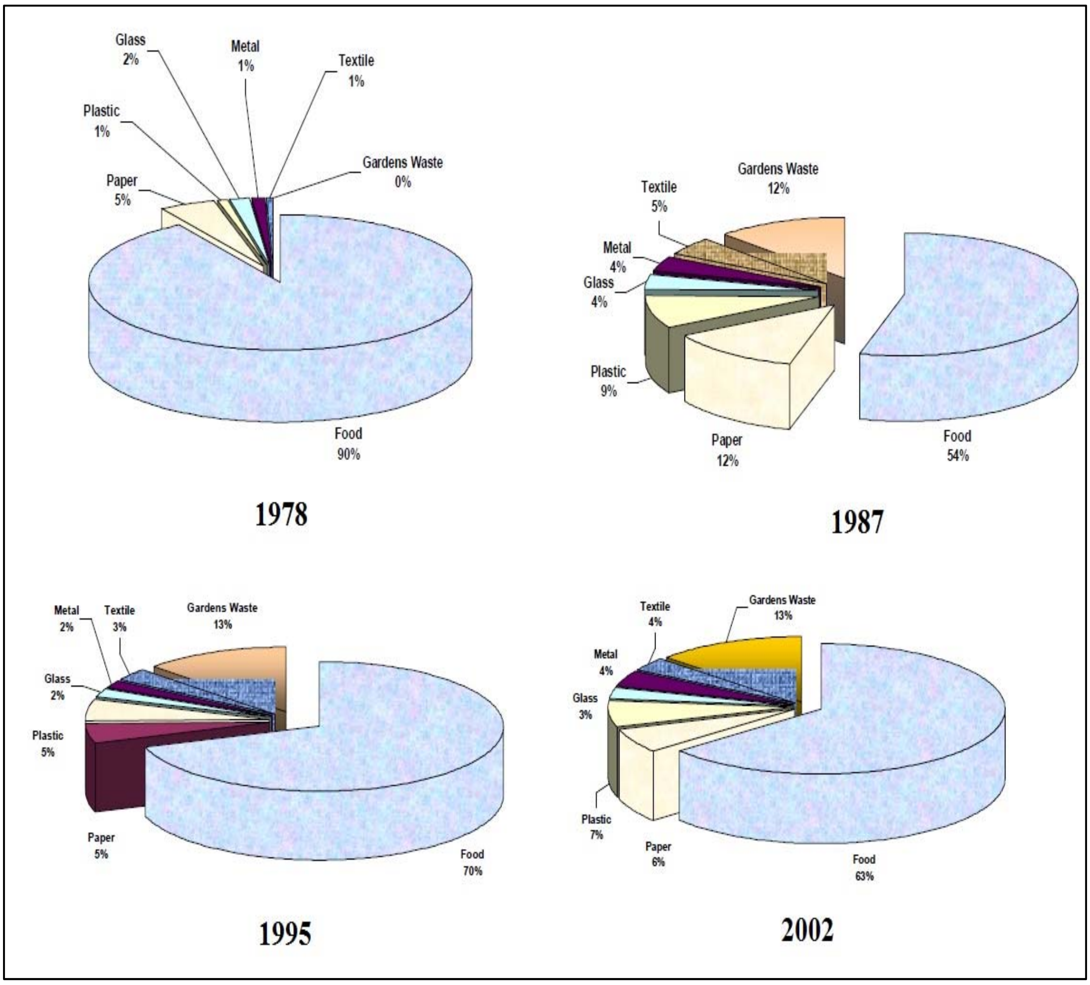


Figure 3.6. Proportion of solid waste types in Bagdad in the period from 1978 to 2002

CHAPTER 4

APPLICATION PART

4.1 Problem of Research

Municipality of Baghdad is the government body responsible for the Iraqi capital of Baghdad. It was founded with the beginning of the establishment of the kingdom of Iraq in (1921). The municipality of Baghdad needs to minimize the total cost of solid wastes transfer in Baghdad city. So, the municipality of Baghdad has 14 sources and 3 destinations. The sources are :

1-Al.karkh
2-Al.kadhimyiah
3-Al.shoala
4-Al.mansour
5-Al.Rashed
6-Al.dowra
7-Al.Rasafa
8-Al.Adhamiya
9-Al.Shaab
10-Al.Sadr 1
11-Al.Sadr 2
12-Al.Ghadeer
13-New Baghdad
14-Al.Karada

And the destinations are :

A-Arkaya B-Al.Amary C-Al.Nahrawan

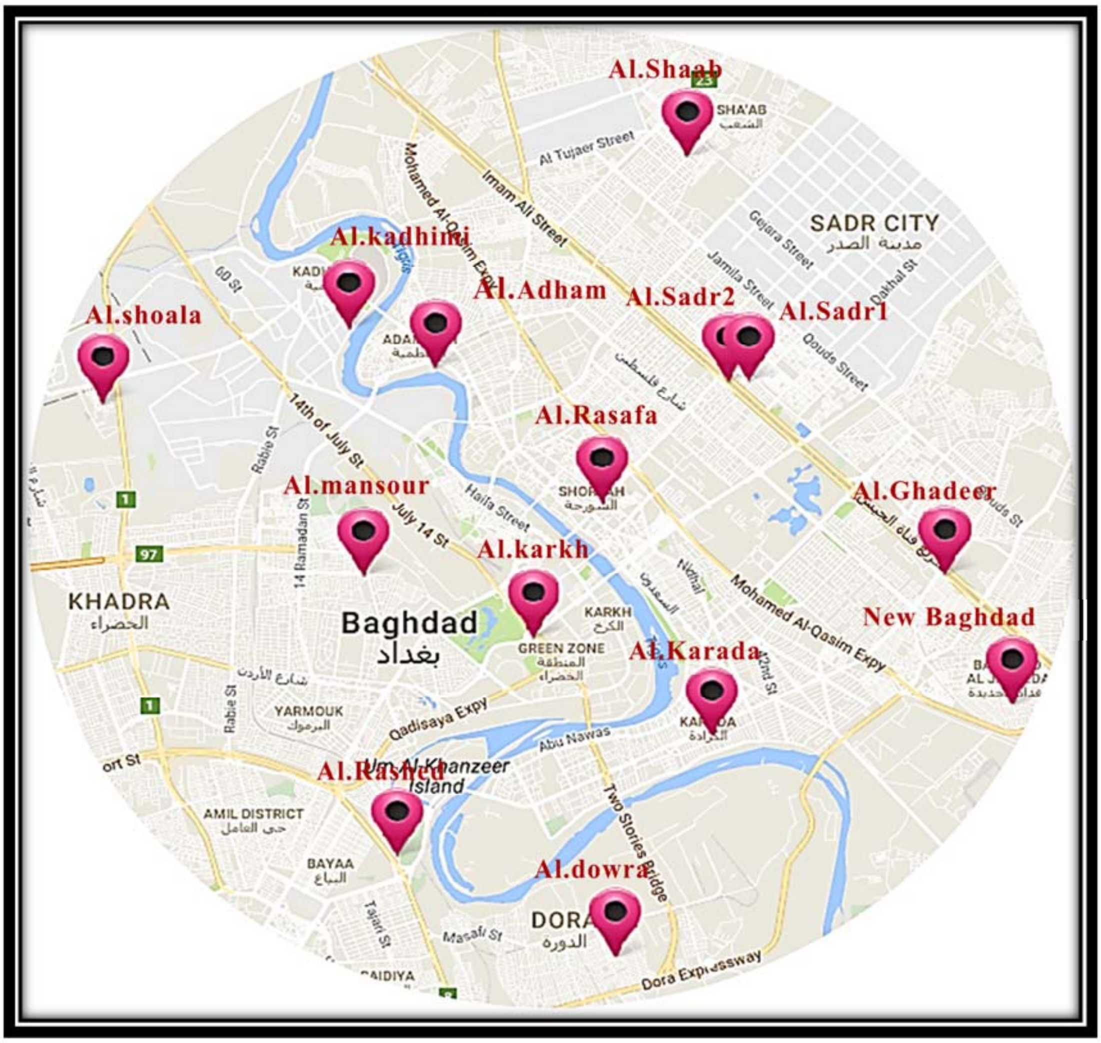


Figure 4.1: Sub-municipalities (Sources of solid waste) in Baghdad city

Source: Google Earth: 23 Nov 2017

4.2 Data of Research

This section clarifies all the data that it is used in this paper. The data were obtained from municipality of Baghdad. The data are the quantities of solid waste (supply and demand). Measured by (M^3) and costs of transportation measured by currency (Iraqi dinar "I.D."). We can show data of distances with (km) between sources and Land filing locations (Destinations) in the following Table 4.1.

Table 4.1: Distances with (km) between sources and Land filing locations

No	From Sources (Municipalities)	To Destinations (Locations)		
		A (Arkaya)	B (Al.Amary)	C (Al.Nahrawan)
1	Al.karkh	40	29	31
2	Al.kadhimiyah	45	30	33
3	Al.shoala	35	29	45
4	Al.mansour	40	28	31
5	Al.Rashed	25	28	46
6	Al.dowra	26	28	37
7	Al.Rasafa	28	29	25
8	Al.Adhamiyah	36	29	27
9	Al.Shaab	43	31	42
10	Al.Sadr 2	35	40	29
11	Al.Sadr 1	35	40	29
12	Al.Ghadeer	32	41	40
13	New Baghdad	37	46	39
14	Al.Karada	25	32	30

The rent cost of the solid waste transportation is 100 Iraqi Dinar (ID) for 1 km/m^3. So that the transportation costs will be calculated by multiplying the rent cost times the traveled distance as shown in Table 4.2.

Table 4.2: Quantities of Solid waste m^3 and Costs of Transportation I.D.

No.	From Sources (Municipalities)	To Destinations (Locations) A (Arkaya)	B (Al.Amary)	C (Al.Nahrawan)	SUPPLY (m^3)
1	Al.karkh	4000 I.D.	2900 I.D.	3100 I.D.	375
2	Al.kadhimiyah	4500 I.D.	3000 I.D.	3300 I.D.	687
3	Al.shoala	3500 I.D.	2900 I.D.	4500 I.D.	826
4	Al.mansour	4000 I.D.	2800 I.D.	3100 I.D.	992
5	Al.Rashed	2500 I.D.	2800 I.D.	4600 I.D.	593
6	Al.dowra	2600 I.D.	2800 I.D.	3700 I.D.	75
7	Al.Rasafa	2800 I.D.	2900 I.D.	2500 I.D.	985
8	Al.Adhamiyah	3600 I.D.	2900 I.D.	2700 I.D.	719
9	Al.Shaab	4300 I.D.	3100 I.D.	4200 I.D.	329
10	Al.Sadr 2	3500 I.D.	4000 I.D.	2900 I.D.	803
11	Al.Sadr 1	3500 I.D.	4000 I.D.	2900 I.D.	714
12	Al.Ghadeer	3200 I.D.	4100 I.D.	4000 I.D.	423
13	New Baghdad	3700 I.D.	4600 I.D.	3900 I.D.	309
14	Al.Karada	2500 I.D.	3200 I.D.	3000 I.D.	1112
DEMAND (M^3)		4000	4000	4000	8942 / 12000

We can summarize Baghdad's transportation problem of solid waste in the following figure 4.2.

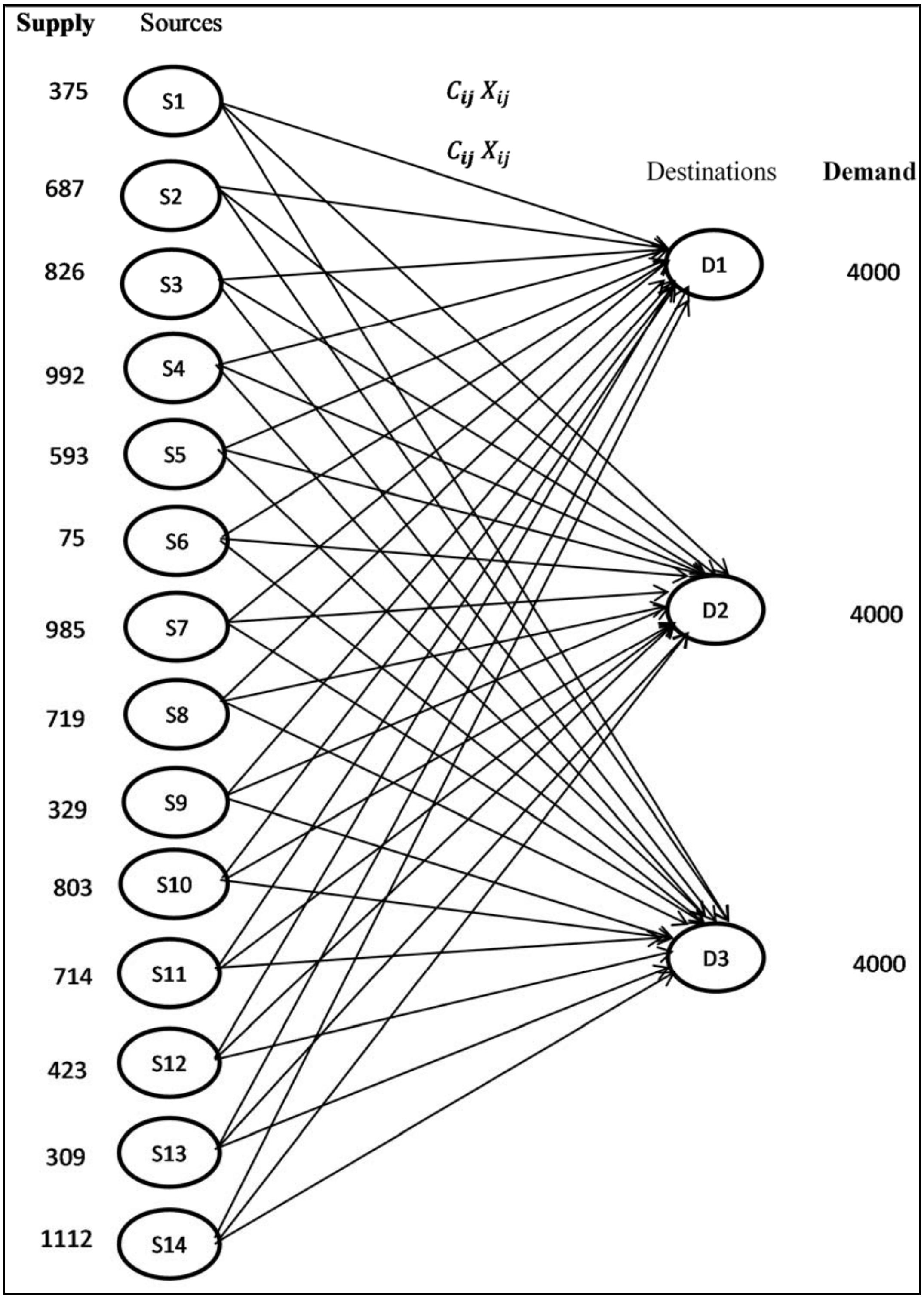


Figure 4.2: Baghdad's transportation problem

4.3 Conversion of Unbalanced Problem to Balanced Problem

Before adding the methods of solution to the transportation problem, it should be certain that the problem is balanced ($\sum ai = \sum bj$), if it is not balanced ($\sum ai < \sum bj$) or ($\sum ai \neq \sum bj$) adding these methods is not possible. The problem in this case is not balanced because the supply is (8942 m^3) and the demand is (12000 m^3) so it should be satisfied balance condition by adding dummy row (dummy source) to be the source number 15 with quantity of supply equal to difference between sum quantities of demand and sum quantities of supply. In other words.

Supply of dummy source (dummy row) = $\sum bj - \sum ai$

= 12000 – 8942

= 3058 M^3

And the sum of supply will be equal to:

8942 + 3058 = 12000 M^3

We have satisfied the balance condition as following:

$$\sum ai = \sum bj = 12000\ M^3$$

Now, we can create a new table that refers to balanced transportation problem by adding dummy source have costs of transportation equal to zeros. The following Table 4.3 shows costs of transfer as below.

Table 4.3: Cost table of the problem

No.	From Sources (Municipalities)	To Destinations (Locations)			SUPPLY (M^3)
		A (Arkaya)	B (Al.Amary)	C (Al.Nahrawan)	
1	Al.karkh	4000 I.D.	2900 I.D.	3100 I.D.	375
2	Al.kadhimiyah	4500 I.D.	3000 I.D.	3300 I.D.	687
3	Al.shoala	3500 I.D.	2900 I.D.	4500 I.D.	826
4	Al.mansour	4000 I.D.	2800 I.D.	3100 I.D.	992
5	Al.Rashed	2500 I.D.	2800 I.D.	4600 I.D.	593
6	Al.dowra	2600 I.D.	2800 I.D.	3700 I.D.	75
7	Al.Rasafa	2800 I.D.	2900 I.D.	2500 I.D.	985
8	Al.Adhamiyah	3600 I.D.	2900 I.D.	2700 I.D.	719
9	Al.Shaab	4300 I.D.	3100 I.D.	4200 I.D.	329
10	Al.Sadr 2	3500 I.D.	4000 I.D.	2900 I.D.	803
11	Al.Sadr 1	3500 I.D.	4000 I.D.	2900 I.D.	714
12	Al.Ghadeer	3200 I.D.	4100 I.D.	4000 I.D.	423
13	New Baghdad	3700 I.D.	4600 I.D.	3900 I.D.	309
14	Al.Karada	2500 I.D.	3200 I.D.	3000 I.D.	1112
15	Dummy source	0	0	0	3058
DEMAND (M^3)		4000	4000	4000	12000 / 12000

4.4 Methods of Solution

The solutions have been found for the transportation problems are Vogel's method, Modified method, set cover model and Integer programming method as following.

4.4.1 Vogel's Method

This section discovers the best initial feasible solution by using Vogel's method that it will be near to optimal solution as in the following Table 4.4.

Table 4.4: Solution of The transportation problem by using Vogel's method

From/To	A	B	C	SUPPLY	Row Penalty values ‰
S1	4000	2900	**375** 3100	~~375~~ 0	0.2 0.2 0.2 0.2 0.2 0.9 0.9 0.9 0.9 0.9 0.9
S2	4500	3000	**687** 3300	~~687~~ 0	0.3 0.3 0.3 0.3 0.3 1.2 1.2
S3	**213** 3500	**613** 2900	4500	~~826~~ ~~213~~ 0	0.6 0.6 0.6 0.6 0.6
S4	4000	2800	**992** 3100	~~992~~ 0	0.3 0.3 0.3 0.3 0.3 0.9 0.9 0.9 0.9
S5	**593** 2500	2800	4600	~~593~~ 0	0.3 0.3 0.3 0.3 0.3 2.1
S6	**75** 2600	2800	3700	~~75~~ 0	0.2 0.2 0.2 0.2 0.2 1.1 1.1 1.1
S7	**985** 2800	2900	2500	~~985~~ 0	0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3
S8	3600	2900	**719** 2700	~~719~~ 0	0.2 0.2 0.2 0.2 0.2 0.9 0.9 0.9 0.9 0.9
S9	4300	**329** 3100	4200	~~329~~ 0	1.1 1.1
S10	3500	4000	**803** 2900	~~803~~ 0	0.6 0.6 0.6 0.6
S11	**290** 3500	4000	**424** 2900	~~714~~ ~~290~~ 0	0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6 0.6
S12	**423** 3200	4100	4000	~~423~~ 0	0.8 0.8 0.8
S13	**309** 3700	4600	3900	~~309~~ 0	0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2 0.2
S14	**1112** 2500	3200	3000	~~1112~~ 0	0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
Dummy Source	0	**3058** 0	0	~~3058~~ 0	
DEMAND	~~4000~~ ~~3577~~ ~~2984~~ ~~2909~~ ~~1797~~ ~~812~~ ~~599~~ ~~309~~ 0	~~4000~~ ~~942~~ ~~613~~ 0	~~4000~~ ~~3197~~ ~~2510~~ ~~1518~~ ~~799~~ ~~424~~ 0		
Column Penalty values ‰	2.5	2.8	2.5		
	0	0	0.2		
	0	0	0.2		
	0	0	0.2		
	0	0	0.2		
	0		0.2		
	0.1		0.2		
	0.1		0.2		
	0.3		0.2		
	0.3		0.2		
	0.3		0.4		
	0.3		0.5		
	0.3				

Table 4.4 clarify the initial solution calculated by Vogel's method which is near to the optimal solution.

X_{1C} =375 M^3 Quantity should be shipped from source 1 (Al.karkh) to destination C (Al.nahrawan).

X_{2C}=687 M^3 Quantity should be shipped from source 2 (Al.kadhimiyah) to destination C (Al.nahrawan).

X_{3A} =213 M^3 Quantity should be shipped from source 3 (Al.Soala) to destination A (Arkaya).

X_{3B} =613 M^3 Quantity should be shipped from source 3 (Al.Shoala) to destination B (Al.amary).

X_{4C}=992 M^3 Quantity should be shipped from source 4 (Al.Mansour) to destination C (Al.nahrawan).

X_{5A} =593 M^3 Quantity should be shipped from source 5 (Al.Rashed) to destination A (Arkaya).

X_{6A} =75 M^3 Quantity should be shipped from source 6 (Al.dowra) to destination A (Arkaya).

X_{7A} =985 M^3 Quantity should be shipped from source 7 (Al.Rasafa) to destination A (Arkaya).

X_{8C}=719 M^3 Quantity should be shipped from source 8 (Al.Adhamiya) to destination C (Al.nahrawan).

X_{9B} =329 M^3 Quantity should be shipped from source 9 (Al.Shaab) to destination B (Al.Amary).

X_{10C} =803 M^3 Quantity should be shipped from source 10 (Al.Sadr2) to destination C (Al.nahrawan).

X_{11A} =290 M^3 Quantity should be shipped from source 11 (Al.Sadr1) to destination A (Arkaya).

X_{11C} =424 M^3 Quantity should be shipped from source 11 (Al.Sadr1) to destination C (Al.nahrawan).

X_{12A}=423 M^3 Quantity should be shipped from source 12 (Al.Ghadeer) to destination A (Arkaya).

X_{13A}=309 M^3 Quantity should be shipped from source 13 (New Baghdad) to destination A (Arkaya).

X_{14A}=1112 M^3 Quantity should be shipped from source 14 (Al.karada) to destination A (Arkaya).

X_{15B}=3058 M^3 Quantity should be shipped from source 15 (Dummy source) to destination B (Al.Amary).

So we can satisfy from number of basic variables as following:

m+n-1=15+3-1=17 Basic variables

And we will calculate Total cost As following:

Total cost = $3100 \times 375 + 3300 \times 687 + 2500 \times 593 + 2900 \times 613 + 3100 \times 992 + 2600 \times 75 + 2800 \times 985 + 2700 \times 719 + 3100 \times 329 + 2900 \times 803 + 3500 \times 290 + 2900 \times 424 + 3200 \times 423 + 3700 \times 309 + 2500 \times 1112 + 0 \times 3058$

= **26274900** I.D.

4.4.2 Modified distribution Method

To find the minimum cost of the transportation problem, the best initial feasible results of Vogel's method in Table 4.4 will be used in the method of modified distribution as calculated in the following iterations:

Iteration 1:

We will find (Ui,Vj) values for every row and column by applying the following equation :

Ui + Vj= Cij for all basic variables

Where i refers to row , i=1,2,…..,15 and j refers to column ,j=1,2,3

We will set u_1= 0 , Then :

$C_{13} = u_1 + v_3$

3100 = 0 + v_3 → v_3= 3100 – 0

v_3= 3100

And we had calculated other (Ui,Vj) values as below in the following Table 4.5:

Table 4.5: Ui and Vj values

From / To	A	B	C	Ui
S1	4000	2900	375 3100	u1=0
S2	4500	3000	687 3300	u2=200
S3	213 3500	613 2900	4500	u3=200
S4	4000	2800	992 3100	u4=0
S5	593 2500	2800	4600	u5=-1200
S6	75 2600	2800	3700	u6=-1100
S7	985 2800	2900	2500	u7=-900
S8	3600	2900	719 2700	u8=-400
S9	4300	329 3100	4200	u9=0
S10	3500	4000	803 2900	u10=-200
S11	290 3500	4000	424 2900	u11=-200
S12	423 3200	4100	4000	u12=-500
S13	309 3700	4600	3900	u13=0
S14	1112 2500	3200	3000	u14=-1200
Dummy Source	0	3058 0	0	u15=-3100
Vj	V1=2900	V2=2900	V3=2900	

From Table 4.5 indirect cost will be calculated for every non-basic variable as following:

$\overline{C_{ij}}$ =(Ui + Vj)– Cij

$\overline{C_{11}}$ = (U1 + V1) - C_{11} → $\overline{C_{11}}$ = (0 + 3700) - 4000 = 3700

$\overline{C_{12}}$ = 200, $\overline{C_{42}}$ = 300, $\overline{C_{72}}$ = -700, $\overline{C_{93}}$ = -1100, $\overline{C_{12,2}}$ = -1500

$\overline{C_{21}}$ = -600, $\overline{C_{52}}$ = -900, $\overline{C_{73}}$ = -300, $\overline{C_{10,1}}$ = 0 , $\overline{C_{12,3}}$ = -1400

$\overline{C_{22}}$ = 300, $\overline{C_{53}}$ = -2700, $\overline{C_{81}}$ = -300 , $\overline{C_{10,2}}$ = -1100, $\overline{C_{13,2}}$ = -1500

$\overline{C_{33}}$ = -1600, $\overline{C_{62}}$ = -800, $\overline{C_{82}}$ = -200, $\overline{C_{11,2}}$ = -1100, $\overline{C_{13,3}}$ = -800

$\overline{C_{41}}$ = -300, $\overline{C_{63}}$ = -1700, $\overline{C_{91}}$ = -600, $\overline{C_{14,2}}$ = -1300, $\overline{C_{14,3}}$ = -1100

$\boxed{\overline{C_{15,1}} = 600,}$ $\overline{C_{15,3}}$ = 0 .

From above values, we note that there are some positive values. Then there is no optimal solution and total cost = **26274900 I.D.**

Iteration 2 :

Now, we note that the maximum positive value was $\overline{C_{15,1}}$ = 600. Then $X_{15,1}$ will be the entering variable to be basic variable with value equal to **Θ** and X_{31} will be the leaving variable to be non-basic variable .As in the following Table 4.6:

Table 4.6: Determination of closed loop for $X_{15,1}$

From / To	A	B	C	Ui
S1	[4000]	[2900]	375 [3100]	u1=0
S2	[4500]	[3000]	687 [3300]	u2=200
S3	X_{31} **213-Θ** [3500]	**613+ Θ** [2900]	[4500]	u3= -200
S4	[4000]	[2800]	992 [3100]	u4=0
S5	593 [2500]	[2800]	[4600]	u5= -1200
S6	75 [2600]	[2800]	[3700]	u6= -1100
S7	985 [2800]	[2900]	[2500]	u7= -900
S8	[3600]	[2900]	719 [2700]	u8=-400
S9	[4300]	329 [3100]	[4200]	u9=0
S10	[3500]	[4000]	803 [2900]	u10=-200
S11	290 [3500]	[4000]	424 [2900]	u11=-200
S12	423 [3200]	[4100]	[4000]	u12=-500
S13	309 [3700]	[4600]	[3900]	u13=0
S14	1112 [2500]	[3200]	[3000]	u14=-1200
Dummy Source	$X_{15,1}$ Θ [0]	**3058- Θ** [0]	[0]	u15=-3100
Vj	v1=3700	V2=3100	V3=3100	

From Table, min= 213 .Then the entering variable will be $X_{15,1}$= 213 (basic variable) and the variable X_{31} will be out (non-basic). As shown in the Table 4.7:

Table 4.7: Final results for iteration 2

From / To	A	B	C	Ui
S1	4000	2900	3100 375	u1=0
S2	4500	3000	3300 687	u2=200
S3	3500	2900 **826**	4500	u3=200
S4	4000	2800	3100 992	u4=0
S5	2500 593	2800	4600	u5=-1200
S6	2600 75	2800	3700	u6=-1100
S7	2800 985	2900	2500	u7=-900
S8	3600	2900	2700 719	u8=-400
S9	4300	3100 329	4200	u9=0
S10	3500	4000	2900 803	u10=-200
S11	3500 290	4000	2900 424	u11=-200
S12	3200 423	4100	4000	u12=-500
S13	3700 309	4600	3900	u13=0
S14	2500 1112	3200	3000	u14=-1200
Dummy Source	0 **213**	0 **2845**	0	u15=-3100
Vj	v1=3700	V2=3100	V3=3100	

From Table 4.7, the optimal cost is 26147100 I.D.

When we had applied the iterations, we got the optimal solution in the 7th iteration as shown in Table 4.8:

Table 4.8: Iteration 7 Calculations

From \ To	A		B		C		Ui
S1		4000	**375**	2900		3100	u1=0
S2		4500	**687**	3000		3300	u2=100
S3		3500	**826**	2900		4500	u3=0
S4		4000	**992**	2800		3100	u4= -100
S5	**593**	2500		2800		4600	u5= -400
S6	**75**	2600		2800		3700	u6= -300
S7		2800		2900	**985**	2500	u7=-400
S8		3600		2900	**719**	2700	u8=-200
S9		4300	**329**	3100		4200	u9=200
S10		3500		4000	**803**	2900	u10=0
S11		3500		4000	**714**	2900	u11=0
S12	**423**	3200		4100		4000	u12=300
S13	**309**	3700		4600		3900	u13=800
S14	**1112**	2500		3200		3000	u14= -400
Dummy Source	**1488**	0	**791**	0	**779**	0	u15= -2900
Vj	v1=2900		V2=2900		V3=2900		

From Table 4.8, we found the optimal solution which represents the minimum cost equal **25098900 I.D.**, and the number of basic variables equal 17 as following:

X_{12} =375 M^3 Quantity of solid waste should be shipped from source 1 (Al.karkh) to destination B (Al.Amary).

X_{22} =687 M^3 Quantity of solid waste should be shipped from source 2 (Al.kadhimiyah) to destination B (Al.Amary).

X_{32} =826 M^3 Quantity of solid waste should be shipped from source 3 (Al.shoala) to destination B (Al.Amary).

X_{42} =992 M^3 Quantity of solid waste should be shipped from source 4 (Al.mansour) to destination B (Al.Amar).

X_{51} =593 M^3 Quantity of solid waste should be shipped from source 5 (Al.Rashed) to destination A (Arkaya).

X_{61} =75 M^3 Quantity of solid waste should be shipped from source 6 (Al.dowra) to destination A (Arkaya).

X_{73} =985 M^3 Quantityof solid waste should be shipped from source 7 (Al.Rasafa) to destination C (Al.nahrawan).

X_{83} =719 M^3 Quantity of solid waste should be shipped from source 8 (Al.Adhamiyah) to destination C (Al.nahrawan).

X_{92} =329 M^3 Quantity of solid waste should be shipped from source 9 (Al.shaab) to destination B (Al.Amary).

$X_{10,3}$ =803 M^3 Quantity of solid waste should be shipped from source 10 (Al.sadr2) to destination C (Al.nahrawan).

$X_{11,3}$ =714 M^3 Quantity of solid waste should be shipped from source 11 (Al.sadr1) to destination C (Al.nahrawan).

$X_{12,1}$ =423 M^3 Quantity of solid waste should be shipped from source 12 (Al.Ghadeer) to destination A (Arkaya).

$X_{13,1}$ =309 M^3 Quantity of solid waste should be shipped from source13(NewBaghdad) to destination A (Arkaya).

$X_{14,1}$ =1112 M^3 Quantity of solid waste should be shipped from source 14 (Al.Rashed) to destination A (Arkaya).

$X_{15,1}$ =1488 M^3 Quantity of solid waste should be shipped from source 15 (Al.karada) to destination A (Arkaya).

$X_{15,2}$ =791 M^3 Quantity of solid waste should be shipped from source 15 (Al.Rashed) to destination B (Al.Amary).

$X_{15,3}$ =779 M^3 Quantity of solid waste should be shipped from source 5 (Al.karada) to destination B (Al.nahrawan).

4.4.3 Integer Programming (IP)

MODI method which we applied to our problem in the previous section uses simplex algorithm. So the results of integer programming and MODI are always equal to each other.

Defining the Decision Variables:

We can suppose: X_{ij} = Quantity (m^3) to be shipped from source i to Destination j .

where: i=1,1,….,15 sources and j=1,2,3 Destinations (A,B,C)

In other words that's mean the following :

X_{1A}= Quantity of solid waste to be shipped from source 1 (Al.Karkh) to destination 1 (Arkaya).

X_{1B}= Quantity of solid waste to be shipped from source 1 (Al.Karkh) to destination 2 (Al.Amary).

X_{1C}= Quantity of solid waste to be shipped from source 1 (Al.Karkh) to destination 3 (Al.Nahrawan).

X_{2A}= Quantity of solid waste to be shipped from source 2 (Al.kadhimyiah) to destination 1 (Arkaya).

X_{2B}= Quantity of solid waste to be shipped from source 2 (Al.kadhimyiah) to destination 2 (Al.Amary).

X_{2C}= Quantity of solid waste to be shipped from source 2 (Al.kadhimyiah) to destination 3 (Al.Nahrawan).

X_{3A}= Quantity of solid waste to be shipped from source 3 (Al.kadhimyiah) to destination 1 (Arkaya).

X_{3B}= Quantity of solid waste to be shipped from source 3 (Al.kadhimyiah) to destination 2 (Al.Amary).

X_{3C}= Quantity of solid waste to be shipped from source 3 (Al.kadhimyiah) to destination 3 (Al.Nahrawan).

X_{4A}= Quantity of solid waste to be shipped from source 4 (Al.mansour) to destination 1 (Arkaya).

X_{4B}= Quantity of solid waste to be shipped from source 4 (Al.mansour) to destination 2 (AlAmary).

X_{4C}= Quantity of solid waste to be shipped from source 4 (Al.mansour) to destination 3 (Al.Nahrawan).

X_{5A}= Quantity of solid waste to be shipped from source 5 (Al.Rashed) to destination 1 (Arkaya).

X_{5B}= Quantity of solid waste to be shipped from source 5 (Al.Rashed) to destination 2 (AlAmary).

X_{5C}= Quantity of solid waste to be shipped from source 4 (Al.Rashed) to destination 3 (Al.Nahrawan).

X_{6A}= Quantity of solid waste to be shipped from source 6 (Al.dowra) to destination 1 (Arkaya).

X_{6B}= Quantity of solid waste to be shipped from source 6 (Al.dowra) to destination 2 (AlAmary).

X_{6C}= Quantity of solid waste to be shipped from source 6 (Al.dowra) to destination 3 (Al.Nahrawan).

X_{7A}= Quantity of solid waste to be shipped from source 7 (Al.Rasafa) to destination 1 (Arkaya).

X_{7B}= Quantity of solid waste to be shipped from source 7 (Al.Rasafa) to destination 2 (AlAmary).

X_{7C}= Quantity of solid waste to be shipped from source 7 (Al.Rasafa) to destination 3 (Al.Nahrawan).

X_{8A}= Quantity of solid waste to be shipped from source 8 (Al.Adhamiyah) to destination 1 (Arkaya).

X_{8B}= Quantity of solid waste to be shipped from source 8 (Al.Adhamiyah) to destination 2 (AlAmary).

X_{8C}= Quantity of solid waste to be shipped from source 8 (Al.Adhamiyah) to destination 3 (Al.Nahrawan).

X_{9A}= Quantity of solid waste to be shipped from source 9 (Al.shaab) to destination 1 (Arkaya).

X_{9B}= Quantity of solid waste to be shipped from source 9 (Al.shaab) to destination 2 (AlAmary).

X_{9C}= Quantity of solid waste to be shipped from source 9 (Al.shaab) to destination 3 (Al.Nahrawan).

X_{10A}= Quantity of solid waste to be shipped from source 10 (Al.sadr2) to destination 1 (Arkaya).

X_{10B}= Quantity of solid waste to be shipped from source 10 (Al.sadr2) to destination 2 (AlAmary).

X_{10C}= Quantity of solid waste to be shipped from source 10 (Al.sadr2) to destination 3 (Al.Nahrawan).

X_{11A}= Quantity of solid waste to be shipped from source 11 (Al.sadr1) to destination 1 (Arkaya).

X_{11B}= Quantity of solid waste to be shipped from source 11 (Al.sadr1) to destination 2 (AlAmary).

X_{11C}= Quantity of solid waste to be shipped from source 11 (Al.sadr1) to destination 3 (Al.Nahrawan).

X_{12A}= Quantity of solid waste to be shipped from source 12 (Al.Ghadeer) to destination 1 (Arkaya).

X_{12B}= Quantity of solid waste to be shipped from source 12 (Al.Ghadeer) to destination 2 (AlAmary).

X_{12C}= Quantity of solid waste to be shipped from source 12 (Al.Ghadeer) to destination 3 (Al.Nahrawan).

X_{13A}= Quantity of solid waste to be shipped from source 13 (New Baghdad) to destination 1 (Arkaya).

X_{13B}= Quantity of solid waste to be shipped from source 13 (New Baghdad) to destination 2 (AlAmary).

X_{13C}= Quantity of solid waste to be shipped from source 13 (New Baghadad) to destination 3 (Al.Nahrawan).

X_{14A}= Quantity of solid waste to be shipped from source 14 (Al.karada) to destination 1 (Arkaya).

X_{14B}= Quantity of solid waste to be shipped from source 14 (Al.karada) to destination 2 (AlAmary).

X_{14C}= Quantity of solid waste to be shipped from source 14 (Al.karada) to destination 3 (Al.Nahrawan).

And the Integer linear programming model can be formulated as following :

Min Z = 4000 X_{1A}+ 2900 X_{1B}+ 3100 X_{1C}+ 4500 X_{2A}+ 3000 X_{2B}+ 3300 X_{2C}+ 3500 X_{3A}+ 2900 X_{3B} + 4500 X_{3C}+ 4000 X_{4A}+ 2800 X_{4B} + 3100 X_{4C}+ 2500 X_{5A}+ 2800 X_{5B}+ 4600 X_{5C}+ 2600 X_{6A}+ 2800 X_{6B} + 3700 X_{6C}+ 2800 X_{7A}+ 2900 X_{7B}+ 2500 X_{7C}+ 3600 X_{8A}+ 2900 X_{8B} + 2700 X_{8C}+ 4300 X_{9A}+ 3100 X_{9B} +4200 X_{9C}+ 3500 X_{10A}+ 4000 X_{10B} + 2900 X_{10C}+3500 X_{11A}+4000 X_{11B}+2900 X_{11C}+3200 X_{12A}+ 4100 X_{12B} + 4000X_{12C}+ 3700 X_{13A}+4600 X_{13B} +3900 X_{13C}+2500 X_{14A}+3200 X_{14B} + 3000 X_{14C}

Subject to :

Constraints of Supply

$X_{1A} + X_{1B} + X_{1C} \geq 375$

$X_{2A} + X_{2B} + X_{2C} \geq 687$

$X_{3A} + X_{3B} + X_{3C} \geq 826$

$X_{4A} + X_{4B} + X_{4C} \geq 992$

$X_{5A} + X_{5B} + X_{5C} \geq 593$

$X_{6A} + X_{6B} + X_{6C} \geq 75$

$X_{7A} + X_{7B} + X_{7C} \geq 985$

$X_{8A} + X_{8B} + X_{8C} \geq 719$

$X_{9A} + X_{9B} + X_{9C} \geq 329$

$X_{10A} + X_{10B} + X_{10C} \geq 803$

$X_{11A} + X_{11B} + X_{11C} \geq 714$

$X_{12A} + X_{12B} + X_{12C} \geq 423$

$X_{13A} + X_{13B} + X_{13C} \geq 309$

$X_{14A} + X_{14B} + X_{14C} \geq 1112$

Constraints of Demand

$X_{1A}+X_{2A}+X_{3A}+X_{4A}+X_{5A}+X_{6A}+X_{7A}+X_{8A}+X_{9A}+X_{10A}+X_{11A}+X_{12A}+X_{13A}+X_{14A} \leq 4000$

$X_{1B}+X_{2B}+X_{3B}+X_{4A}+X_{5B}+X_{6B}+X_{7B}+X_{8B}+X_{9B}+X_{10B}+X_{11B}+X_{12B}+X_{13B}+X_{14B} \leq 4000$

$X_{1C}+X_{2C}+X_{3C}+X_{4C}+X_{5C}+X_{6C}+X_{7C}+X_{8C}+X_{9C}+X_{10C}+X_{11C}+X_{12C}+X_{13C}+X_{14C} \leq 4000$

$X_{ij} \geq 0$ and integer for all i and j (Non-negative constraint) , i=1,2,3,....,15 & j=1,2,3

We found the optimal solution for the Integer programming model of the transportation problem by using a software program called as WinQsb, The results were as in the following Table 4.9.

Table 4.9: Results of Integer programming

	Decision Variable	Solution Value	Unit Cost or Profit c(j)	Total Contribution	Reduced Cost	Basis Status	Allowable Min. c(j)	Allowable Max. c(j)
1	X1A	0	4000	0	1100	at bound	2900	M
2	X1B	375	2900	1087500	0	basic	0	3100
3	X1C	0	3100	0	200	at bound	2900	M
4	X2A	0	4500	0	1500	at bound	3000	M
5	X2B	687	3000	2061000	0	basic	0	3300
6	X2C	0	3300	0	300	at bound	3000	M
7	X3A	0	3500	0	600	at bound	2900	M
8	X3B	826	2900	2395400	0	basic	0	3500
9	X3C	0	4500	0	1600	at bound	2900	M
10	X4A	0	4000	0	1200	at bound	2800	M
11	X4B	992	2800	2777600	0	basic	0	3100
12	X4C	0	3100	0	300	at bound	2800	M
13	X5A	593	2500	1482500	0	basic	0	2800
14	X5B	0	2800	0	300	at bound	2500	M
15	X5C	0	4600	0	2100	at bound	2500	M
16	X6A	75	2600	195000	0	basic	0	2800
17	X6B	0	2800	0	200	at bound	2600	M
18	X6C	0	3700	0	1100	at bound	2600	M
19	X7A	0	2800	0	300	at bound	2500	M
20	X7B	0	2900	0	400	at bound	2500	M
21	X7C	985	2500	2462500	0	basic	0	2800
22	X8A	0	3600	0	900	at bound	2700	M
23	X8B	0	2900	0	200	at bound	2700	M
24	X8C	719	2700	1941300	0	basic	0	2900
25	X9A	0	4300	0	1200	at bound	3100	M
26	X9B	329	3100	1019900	0	basic	0	4200
27	X9C	0	4200	0	1100	at bound	3100	M
28	X10A	0	3500	0	600	at bound	2900	M
29	X10B	0	4000	0	1100	at bound	2900	M
30	X10C	803	2900	2328700	0	basic	0	3500
31	X11A	0	3500	0	600	at bound	2900	M
32	X11B	0	4000	0	1100	at bound	2900	M
33	X11C	714	2900	2070600	0	basic	0	3500
34	X12A	423	3200	1353600	0	basic	0	4000
35	X12B	0	4100	0	900	at bound	3200	M
36	X12C	0	4000	0	800	at bound	3200	M
37	X13A	309	3700	1143300	0	basic	0	3900
38	X13B	0	4600	0	900	at bound	3700	M
39	X13C	0	3900	0	200	at bound	3700	M
40	X14A	1112	2500	2780000	0	basic	0	3000
41	X14B	0	3200	0	700	at bound	2500	M
42	X14C	0	3000	0	500	at bound	2500	M
	Objective	Function	(Min.) =	25098900				

From Table 4.9, the optimal solution is calculated by only one iteration and total CPU processing time 0.017 seconds. The optimal cost was found as 25098900 I.D. The same result as the MODI method has been reached as expected.

Where 2nd column (Solution Value) refers to Quantity of solid waste should be shipped from source i to destination j as the following :

X_{1B} =375 M^3 Quantity of solid waste should be shipped from source 1 (Al.karkh) to destination B (Al.Amary).

X_{2B} =687 M^3 Quantity of solid waste should be shipped from source 2 (Al.kadhimiyah) to destination B (Al.Amary).

X_{3B} =826 M^3 Quantity of solid waste should be shipped from source 3 (Al.shoala) to destination B (Al.Amary).

X_{4B} =992 M^3 Quantity of solid waste should be shipped from source 4 (Al.mansour) to destination B (Al.Amar).

X_{5A} =593 M^3 Quantity of solid waste should be shipped from source 5 (Al.Rashed) to destination A (Arkaya).

X_{6A} =75 M^3 Quantity of solid waste should be shipped from source 6 (Al.dowra) to destination A (Arkaya).

X_{7C} =985 M^3 Quantity of solid waste should be shipped from source 7 (Al.Rasafa) to destination C (Al.nahrawan).

X_{8C} =719 M^3 Quantity of solid waste should be shipped from source 8 (Al.Adhamiyah) to destination C (Al.nahrawan).

X_{9B} =329 M^3 Quantity of solid waste should be shipped from source 9 (Al.shaab) to destination B (Al.Amary).

$X_{10,C}$=803 M^3 Quantity of solid waste should be shipped from source 10 (Al.sadr2) to destination C (Al.nahrawan).

$X_{11,C}$=714 M^3 Quantity of solid waste should be shipped from source 11 (Al.sadr1) to destination C (Al.nahrawan).

$X_{12,A}$=423 M^3 Quantity of solid waste should be shipped from source 12 (Al.Ghadeer) to destination A (Arkaya).

$X_{13,A}$=309 M^3 Quantity of solid waste should be shipped from source 13 (NewBaghdad) to destination A (Arkaya).

$X_{14,A}$=1112 M^3 Quantity of solid waste should be shipped from source 14 (Al.Rashed) to destination A (Arkaya).

4.4.4. Proposed Model: Set Covering Model

The proposed model (set covering model), will use the distances between sources and landfills, where each location will cover some of near sources, that means, the location A will cover the sources (S5, S6, S12, S13, S14), the location B will cover the sources (S1, S2, S3, S4, S9), and the location C will cover the sources (S7, S8, S10, S11) as it is shown in Table 4.10 and Table 4.11.

Also in this model, transport costs will be different from source to source by depending on the distance between them and the center of the city, where the cost for the sources that located in the center of the city will be 100 ID for each km/m^3, while the sources that located out of the city will cost 95 ID for each km/m^3.

Table 4.10: Distances between sources and destinations by Km

	S	2	3	4	5	6	7	8	9	10	1S	2S	3S	4S
A	40	45	35	40	25	26	28	36	43	35	35	32	37	25
B	29	30	29	28	28	28	29	29	31	40	40	41	46	32
C	31	33	45	31	46	37	25	27	42	29	29	40	39	30

Google Earth: 23 Nov 2017

Table 4.11: Sets cover

A	5S	6S	S12	S13	S14
B	S1	2S	S3	S4	S9
C	S7	S8	S11	S12	

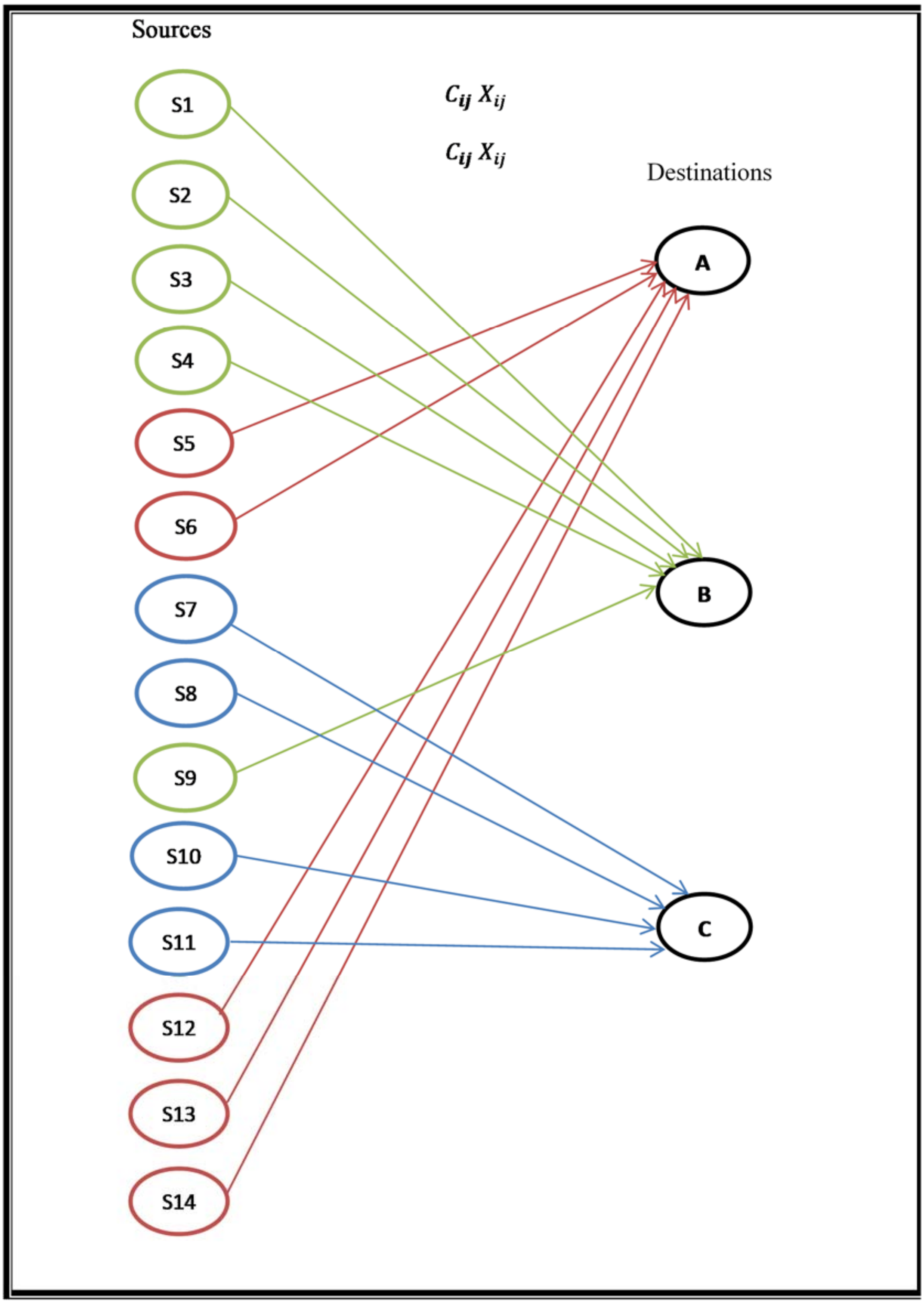


Figure 4.3: Flow chart of Set Covering Problem

The location A will cover the sources (S5, S6, S12, S13, and S14) where the transport costs of these sources will vary due to the different distances between them. The transport costs of the sources (S5 and S6) will be 95 ID for km/m^3 because these sources are located outside of the city, while the locations (S12, S13, and S14) will cost 100 ID for km/m^3 because these locations are located inside the city, as shown in Table 4.12.

Table 4.12: Cost of transportation from sources S5, S6, S12, S13, and S14 to location A

A	Km	Cost ID	Unit cost	M3	Total cost
S5	**25**	**95**	**25×95** **2375**	**593**	**2375×593** **1,408,375**
S6	**26**	**95**	**26×95** **2470**	**75**	**2470×75** **185,250**
S12	**32**	**100**	**32×100** **3200**	**423**	**3200×423** **1,353,600**
S13	**37**	**100**	**37×100** **3700**	**309**	**3700×309** **1,143,300**
S14	**25**	**100**	**25×100** **2500**	**1112**	**2500×1112** **2,780,000**
					6,870,525 ID

The location B will cover the sources (S1, S2, S3, S4, and S9) where the transport costs of these sources will vary due to the different distances between them. The transport costs of the sources (S3 and S9) will be 95 ID for km/m^3 because these sources are located outside of the city, while the locations (S1, S2, and S4) will cost 100 ID for km/m^3 because these locations are located inside the city, as shown in Table 4.13.

Table 4.13: Costs of transportation from sources S1, S2, S3, S4, and S9 to location B

B	Km	Cost ID	Unit cost	M3	Total cost
S1	**29**	**100**	**29×100** **2900**	**375**	**2900×375** **1,078,500**
S2	**30**	**100**	**30×100** **3000**	**687**	**3000×687** **2,061,000**
S3	**29**	**95**	**29×95** **2755**	**826**	**2755×826** **2,275,630**
S4	**28**	**100**	**28×100** **2800**	**992**	**2800×992** **2,777,600**
S9	**31**	**95**	**31×95** **2945**	**329**	**2945×329** **968,905**
					9,170,635 ID

The location C will cover the sources (S7, S8, S10, and S11) where the transport costs of these sources will vary due to the different distances between them. The transport costs of the sources (S10 and S11) will be 95 ID for km/m^3 because these sources are located outside of the city, while the locations (S7, and S8) will cost 100 ID for km/m^3 because these locations are located inside the city, as shown in Table 4.14.

Table 4.14: Costs of transportation from S7, S8, S10, and S11 to location C

C	Km	Cost ID	Unit cost	M3	Total cost
S7	**25**	**100**	**25×100** **2500**	**985**	**2500×985** **2,462,500**
S8	**27**	**100**	**27×100** **2700**	**719**	**2700×719** **1,941,300**
S10	**29**	**95**	**29×95** **2755**	**803**	**2755×803** **2,212,265**
S11	**29**	**95**	**29×95** **2755**	**714**	**2755×714** **968,905**
					8,583,135 ID

The Table 4.15 shows that the transport cost of the proposed model will be 24624295 ID, and this cost is less than the results of the previous models.

Table 4.15: Total costs

	TOTAL COSTS
A=	**6,870,525**
B=	**9,170,635**
C=	**8,583,135**
total cost	**24,624,295 ID**

4.4.5 Comparison Between Methods

Table 4.16: Comparison between Methods

	Integer prog. Model	Set cover model	Different between models
Cost	25,098,900	24,624,295	**474,605**
Actual cost	27,650,300	27,650,300	
Different between models and actual cost	**2,551,400 ID**	**3,026,705 ID**	

From Table 4.16 it has been clarified that the methods of Integer programming and the proposed one (set cover model) are better than the method that followed by the Municipality of Baghdad, where the calculated costs are 25,098,900 ID and 24,624,295 ID by integer programming method and the proposed method respectively, and 27,650,300 ID for the method of Municipality of Baghdad.

In comparison between the integer programming method to the method that followed by Municipality of Baghdad, it is clear that the difference between the two costs is 2,551,400 ID, and for the comparison between the proposed method to the method that followed by Municipality of Baghdad, the difference of the cost is 3,026,705 ID because of the kind of trucks that have used in this method, where they were bigger and lower cost trucks.

In comparison between the integer programming method to the proposed method, it is clear that the proposed method gives the minimum cost by a difference amount equal 474,605 ID because it has used different kinds of transportations between some of the sources and the landfills locations, as it is been from the sources S5, S6, S3, S9, S10, and S11 to the location (a).

CONCLUSION

The results of the research has proven that the use of integer programming model has led to reduce the costs of transporting the solid wastes from the sources to the landfill locations with amount of 2,551,400 Iraqi dinar per day as compared with the actual costs of Baghdad Municipality.

The proposed model led to reduce the cost of transporting the solid wastes from the sources to the landfill locations with amount of 3,026,705 Iraqi dinar per day as compared with the actual costs of Baghdad Municipality.

The results of the research has proven that the use of the proposed model set covering model led to reduce the transportation costs with amount of 474,605 Iraqi dinar as compared with integer programing method. Thus, we suggest to use set covering model in order to transport the wastes from the sources to the landfill.

The proposed model led to reduce the transportation costs from some sources which locate outside of the city center to 95 Iraqi dinar for each cubic meter as compared with the real cost which was 100 Iraqi dinar per cubic meter by the use of trucks with larger size.

Domestic waste represents the majority of solid waste in cities. In Baghdad, the domestic solid waste represents 55 – 65 % of the total amount of solid waste because the residential areas in Baghdad represent the largest proportion of the total area of the city compared to commercial or industrial regions. Rust represents 20 – 40% of the total solid waste whereas organic matter constitutes 50.57% of the total amounts of solid waste and can be used in production of natural fertilizers.

41.65% of the solid waste produced in Baghdad can be reused and recycled, a process that will provide a plenty of raw materials for and energy for various production activities in Iraq and reduces the cost of transportation and the volume of waste reaching the landfill sites.

There is no sorting procedure of solid waste generated in the city of Baghdad. Collection vehicles collect waste from the collection sites and transport them directly to the landfill areas without allowing an opportunity to reuse useful materials.

REFERENCES

Ahuja, Ravindra K., Thomas L. Magnanti, and James B. Orlin. "Chapter Iv Network Flows." Handbooks in Operations Research and Management Science 1 (1989): 211-369. Print.

Altman, SM, et al. "Nonlinear Programming Model of Crew Assignments for Household Refuse Collection." IEEE TRANSACTIONS ON SYSTEMS MAN AND CYBERNETICS.3 (1971): 289-+. Print.

Angelelli, E., and M G Speranza. "The Application of a Vehicle Routing Model to a Waste-Collection Problem: Two Case Studies." Journal of the Operational Research Society 53.9 (2002): 944-52. Print.

Baetz, Brian W., and Alan W. Neebe. "A Planning Model for the Development of Waste Material Recycling Programmes." Journal of the Operational Research Society 45.12 (1994): 1374-84. Print.

Baetz, Brian W., Eric I. Pas, and Alan W. Neebe. "Trash Management: Sizing and Timing Decisions for Incineration and Landfill Facilities." Interfaces 19.6 (1989): 52-61. Print.

Integrated Vehicle Routing and Crew Scheduling in Waste Management (Part Ii). Dagstuhl Seminar Proceedings. 2009. Schloss Dagstuhl-Leibniz-Zentrum für Informatik. Print.

Berger, C, G Savard, and A Wizere. "Eugene: An Optimization-Based Decision Support System for Long-Term Integrated Regional Waste Management Planning." Int J Environ Pollut 13 (1998): 437-49. Print.

Bloemhof-Ruwaard, Jacqueline M., Marc Salomon, and Luk N. Van Wassenhove. "The Capacitated Distribution and Waste Disposal Problem." European Journal of Operational Research 88.3 (1996): 490-503. Print.

Bommisetty, Devika, Mohamed Dessouky, and Larry Jacobs. "Scheduling Collection of Recyclable Material at Northern Illinois University Campus Using a Two-Phase Algorithm." Computers & Industrial Engineering 35.3 (1998): 435-38. Print.

Caruso, C., A. Colorni, and M. Paruccini. "The Regional Urban Solid Waste Management System: A Modelling Approach." European Journal of Operational Research 70.1 (1993): 16-30. Print.

Dueck, Gunter, and Tobias Scheuer. "Threshold Accepting: A General Purpose Optimization Algorithm Appearing Superior to Simulated Annealing." Journal of Computational Physics 90.1 (1990): 161-75. Print.

Erkut, Erhan, et al. "A Multicriteria Facility Location Model for Municipal Solid Waste Management in North Greece." European Journal of Operational Research 187.3 (2008): 1402-21. Print.

Ferrell, William G., and Haluk Hizlan. "South Carolina Counties Use a Mixed-Integer Programming-Based Decision Support Tool for Planning Municipal Solid Waste Management." Interfaces 27.4 (1997): 23-34. Print.

Ghiani, Gianpaolo, et al. "Simultaneous Personnel and Vehicle Shift Scheduling in the Waste Management Sector." Waste Management 33.7 (2013): 1589-94. Print.

Ghiani, Gianpaolo, et al. "Capacitated Location of Collection Sites in an Urban Waste Management System." Waste Management 32.7 (2012): 1291-96. Print.

Hanafi, Saïd, Arnaud Freville, and Polo Vaca. "Municipal Solid Waste Collection: An Effective Data Structure for Solving the Sectorization Problem with Local Search Methods." INFOR: Information Systems and Operational Research 37.3 (1999): 236-54. Print.

Integrated Vehicle Routing and Crew Scheduling in Waste Management (Part I). Dagstuhl Seminar Proceedings. 2009. Schloss Dagstuhl-Leibniz-Zentrum für Informatik. Print.

Huang, G. H., B. W. Baetz, and G. G. Patry. "Trash-Flow Allocation: Planning under Uncertainty." Interfaces 28.6 (1998): 36-55. Print.

Ignall, Edward, Peter Kolesar, and Warren Walker. "Linear Programming Models of Crew Assignments for Refuse Collection." (1971). Print.

Jenkins, Larry. "Parametric Mixed Integer Programming: An Application to Solid Waste Management." Management Science 28.11 (1982): 1270-84. Print.

Balanced Clustering Algorithms for Vehicle Routing Problems. Proceedings of the Institute of Industrial Engineers annual conference. Houston, USA. 2004. Print.

Kulcar, Thierry. "Optimizing Solid Waste Collection in Brussels." European Journal of Operational Research 90.1 (1996): 71-77. Print.

Kytöjoki, J, T Nuortio, and O Bräysy. Two Efficient Metaheuristics for Huge Scale Vehicle Routing Problems: Working paper. Department of Environmental Sciences, University of Kuopio, Finland, 2004. Print.

Labelle, A., A. Langevin, and J. F. Campbell. "Sector Design for Snow Removal and Disposal in Urban Areas." Socio-Economic Planning Sciences 36.3 (2002): 183-202. Print.

List, George F., et al. "Robust Optimization for Fleet Planning under Uncertainty." Transportation Research Part E: Logistics and Transportation Review 39.3 (2003): 209-27. Print.

List, George F., et al. "Logistics Planning under Uncertainty for Disposition of Radioactive Wastes." Computers & Operations Research 33.3 (2006): 701-23. Print.

Male, James W, and Jon C Liebman. "Districting and Routing for Solid Waste Collection." Journal of the Environmental Engineering Division 104.1 (1978): 1-14. Print.

Mansini, Renata, and M. Grazia Speranza. "A Linear Programming Model for the Separate Refuse Collection Service." Computers & Operations Research 25.7–8 (1998): 659-73. Print.

Mladenović, N., and P. Hansen. "Variable Neighborhood Search." Computers & Operations Research 24.11 (1997): 1097-100. Print.

Mourão, Maria Cândida, Ana Catarina Nunes, and Christian Prins. "Heuristic Methods for the Sectoring Arc Routing Problem." European Journal of Operational Research 196.3 (2009): 856-68. Print.

Nuortio, Teemu, et al. "Improved Route Planning and Scheduling of Waste Collection and Transport." Expert Systems with Applications 30.2 (2006): 223-32. Print.

Pearce, David W. "The Economics of Refuse Collection." Resources Policy 2.4 (1976): 298. Print.

Rahman, Mushtaqur, and Michael Kuby. "A Multiobjective Model for Locating Solid Waste Transfer Facilities Using an Empirical Opposition Function." INFOR: Information Systems and Operational Research 33.1 (1995): 34-49. Print.

Sahoo, Surya, et al. "Routing Optimization for Waste Management." Interfaces 35.1 (2005): 24-36. Print.

Optimization of Municipal Solid Waste Management. Proceedings of the 2010 international conference on biology, environment and chemistry. 2011. Print.

Solomon, Marius M. "Algorithms for the Vehicle Routing and Scheduling Problems with Time Window Constraints." Operations Research 35.2 (1987): 254-65. Print.

Taillard, Éric, et al. "A Tabu Search Heuristic for the Vehicle Routing Problem with Soft Time Windows." Transportation Science 31.2 (1997): 170-86. Print.

Vigo, Daniele, et al. "Key Elements for Optimal Integrated Usw-Management-International Experiences." Bologna, Italy: Esculapio (2007). Print.

Voudouris, Christos, and Edward PK Tsang. "Guided Local Search." Handbook of Metaheuristics. Springer, 2003. 185-218. Print.

Wierzbicki, Andrzej P. "The Use of Reference Objectives in Multiobjective Optimization." Multiple Criteria Decision Making Theory and Application: Proceedings of the Third Conference Hagen/Königswinter, West Germany, August 20–24, 1979. Eds. Fandel, Günter and Tomas Gal. Berlin, Heidelberg: Springer Berlin Heidelberg, 1980. 468-86. Print.

Yeomans, J. S., G. H. Huang, and R. Yoogalingam. "Combining Simulation with Evolutionary Algorithms for Optimal Planning under Uncertainty: An Application to Municipal Solid Waste Management Planning in the Reginonal Municipality of Hamilton-Wentworth." 2015 2.1 (2015). Print.

Yeomans, Julian Scott. "Efficient Generation of Alternative Perspectives in Public Environmental Policy Formulation: Applying Co-Evolutionary Simulation–Optimization to Municipal Solid Waste Management." Central European Journal of Operations Research 19.4 (2011): 391-413. Print.

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