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Development of Solid Waste Management System for Some Districts for Karbala City

A Thesis

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Master in Engineering / Environmental Engineering

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بسم الله الرحمن الرحيم

وَقُلْ رَبِّي زِدْنِي

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Supervisors’ Certificate

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Date: / / 2022

DEDICATION

How do I get the description and words that embody your struggle in life…? I dedicate this fruit for the efforts that gave me strength and patience… to my dear father and mother… I ask God to protect them for us. For those who always have hearts… for my brothers, sisters, husband and everyone who helped me in my scientific career.

Fadak Salah Sahib

2021

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Abstract

The issue of solid waste management is one of the important issues in recent years as a result of rapid urbanization and the improvement of the standard of living. Solid waste collection consumes about 60%-80% of the total costs of solid waste management systems.

Through field visits to the study area in the city of Karbala, it was noted that the collection and transportation of solid waste to sanitary waste dumps is in old ways, and there is no effective strategy for solid waste collection mechanisms, and to reduce the cost and time of solid waste collection and transportation, hence the focus of this study shifted to meet the needs of the municipality Karbala.

The study was conducted in (October 2020 to September 2021) the study discussed two main parts related to directing the solid waste collection mechanism for the study area (AL-Mulhaq 1,2, Shuhada Al-Mulhaq, Dhubat Al-Usra, and AL-Usra). The first part dealt with solid waste quantities, collection methods, compressors, and crew efficiency, and the second part dealt with computer programming techniques, using three engineering programs (ArcGIS, AutoCAD, WinQSB).

The information was entered into the (WinQSB) program, which performed a mathematical analysis that resulted in three solutions to obtain the shortest path and the least possible number of connections and to collect the largest possible amount of solid waste at 12%, 16%, 28% (AL-Mulhaq 1,2), and 11 %, 21%, 31% of Shuhada Al-Mulhaq, Dhubat Al-Usra, and 11%, 19%, 30% of AL-Usra. The results were drawn using the AutoCAD program, the results showed that these percentages did not achieve the required efficiency, and to obtain the optimal path and achieve higher percentages, the GIS program was used (ArcGIS)through the application of the three solutions together, which serves

about 78% of AL-Mulhaq(1,2), 68% of Shuhada Al-Mulhaq, Dhubat Al-Usra, and 67% of Al-Usra.

Timetables for the movement of vehicles during the summer and winter have been proposed to be used in other areas in the city of Karbala. Finally, this work shows that the residential neighborhood AL-Mulhaq(1,2) achieved the highest results in terms of the optimal path and the least cost for solid waste collection and the least time.

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Table of Abbreviations

Abbreviation	Explanation
SWM	Solid Waste Management
MSW	Municipal Solid Waste
SWC	Solid Waste Collection
SW	Solid Waste
VRP	Vehicle Routing Problem
Km	Kilometer
Kg	Kilogram
m^3	Cubic meter
m.l	Meter length
D	Day
No.	Number
ID	Iraqi Dinar
TSP	The Salesman Path
CARP	Capacitated Arc Routing Problem
MoN	Municipality of Nikea
TND	Tunisian Dinar (Currency of Tunisia)
SW	Solid Waste
CO_2	Carbon dioxide
NA	Network Analysis
GPS	Global Positioning System
QSB	Quantitative Systems for Business
GIS	Geographic Information System
EPA	Environmental Protection Agency
St.	Street
etc.	To the end

Chapter One
Introduction

Chapter One

Introduction

1.1 Introduction

Solid waste is the undesired material from manufacturing processes, community, or home activities, and is referred to as rubbish, trash, junk, or garbage, depending on the type of substance or regional vocabulary (Akhtar, 2015). Solid waste management has become a serious environmental issue due to the detrimental effects it may have on society and the environment if not effectively implemented.

The problem is aggravated by the high rate of trash generation, which is a result of rapid urbanization and population increase, insufficient funding, poor garbage disposal attitudes among the populace, and a lack of political will. These issues go beyond the capabilities of developing-country local governments to effectively manage solid waste. The processes of waste generation, collection, transportation, treatment, value recovery, and disposal are all part of solid waste management. Any of these procedures that are poorly designed raise operational costs and can pollute the environment. (Guerrero et al., 2013).

For example, the collection and transportation procedure accounts for roughly 60% to 80% of the overall cost of solid waste management (Tavares et al., 2009). Inefficient solid waste collection and transportation will have a substantial impact on management organizations, raising operational costs and, as a result, lowering profit. If emerging economies are to achieve sustainable solid waste management, cost reductions in garbage collection and transportation are required. As a result, through system analysis and operations optimization, efficient and effective solid waste collection is required. As a result, solid waste collection and transportation should be carried out in a cost-effective and environmentally friendly manner (Oduro-Kwarteng, 2011).

Municipal Solid Waste (MSW), sometimes known as "junk" or "trash," is an unavoidable consequence of human activity. It is produced by a variety of sources (households, hospitals, shops, hotels, and so on) and is divided into two types: organic (food, fruit, plant leaves, and so on) and inorganic (paper, plastic, glass, dust, etc.) (Minoglou & Komilis, 2013). Due to increased urbanization, the number of MSW sources is growing, resulting in the creation of massive amounts of solid waste, which has a significant negative influence on collection costs and the environment (Rathore & Sarmah,2019).

The cost of collection is rising due to population expansion, an increase in MSW creation, a lack of adjacent land for disposal, and a long collection period. The amount of time required to discard the collected waste is determined by three factors (Hemmelmayer et al., 2014):

(i) Between sources (hospital, garden, commercial, market, and residential) and landfills, the number of collection locations (waste containers and open dumping) is measured.

(ii) The amount of time a vehicle spends idling at each collecting station.

(iii) Vehicle routing during collecting.

In developing countries, solid waste issues such as insufficient service coverage, irregular garbage collection, trash spillover from bins and storage containers, and people's careless attitude toward indiscriminate disposal on unauthorized sites and garbage littering are frequent. These issues eventually have a negative influence on public health, cause aesthetic annoyance, and pollute the environment. Uncollected solid trash by the public sector or its agent is frequently dumped into drains, rivers, and nearby environments, or it is locally burned or buried due to limited-service coverage. These practices cause significant pollution and destruction of the environment, as well as a substantial health danger to the community (Kwarteng, 2011).

As a result, cost effectiveness is a consideration in the collecting route design. This necessitates take into account the restrictions of the actual road network. The use of optimization and Geographic Information System (GIS) techniques can help design a cost-effective MSW (Municipal Solid Waste) collection system (Abou Najm and El-Fadel 2004; Arribas et al., 2009).

The Resource Conservation and Recovery Act (RCRA) is the public law that creates the framework for the proper management of hazardous and non-hazardous solid waste. The law describes the waste management program mandated by Congress that gave EPA authority to develop the RCRA program. The term RCRA is often used interchangeably to refer to the law, regulations and Environmental Protection Agency (EPA) policy and guidance (Bunnell, 2020).

The route optimization model is a nondeterministic polynomial-time (NP)-hard problem since MSW collecting involves a large number of collection locations in a geographical area. TSP (The Salesman Path) and waste collection routing have been solved effectively using a variety of heuristic methods. However, most available algorithms are constrained in that they do not handle the actual road network in compliance with MSW collection best practices, consider how instantaneous truckloads affect route selection, and use parallelization to speed up convergence (Arribas et al., 2009).

1.2 Statement of the Problem

The comprehensive and rapid development that the city of Karbala is currently witnessing as a result of the implementation of major development projects in various fields and the resulting rise and improvement in the standard of living and social added new and heavy burdens in various matters, especially in the wake of horizontal and vertical urban expansion.

The problem is complicated by the weak material resources available to service agencies, represented in the various equipment required in the process of collecting and transporting solid waste, as a result of the outdated, defective and lack of an alternative for most of these mechanisms. In addition to the weak human potential represented in the volume of labor used in this sector, as there are no previous studies dealing with this problem, which is to find the shortest path for solid waste collection vehicles, which indicates a clear defect in the process of collecting and transporting solid waste from different areas of Karbala.

1.3 Objectives

The main objectives of this study are:

1- To reduce the costs of collecting and transporting solid waste for the study area (Al-Mulhaq (1,2), Shuhada Al-Mulhaq, Dhubat Al-Usra, and Al-Usra) in the city of Karbala, thus reducing time, number of workers and vehicle fuel.

2- Finding the optimal path for solid waste collection and transportation vehicles, which achieves the shortest possible distance for the mechanism and collecting the largest possible amount of solid waste within the study area, using (Win QSB) programs to find three alternatives for each area and then drawing these solutions in Auto CAD program and then using (ArcGIS) program in matching those solutions with each other to get the optimal solution that achieves them all.

1.4 Thesis Structure

The study's approach contains the following: -

1- Chapter one: Introduction, Statement of the problem, Thesis objectives, and Thesis Structure.

2- Chapter two: Shows the Literatures Review Regarding Solid Waste Management.

3- Chapter Three: Theoretical Formulation and Modeling

4- Chapter Four: displays the results of the experimental work, including a graphical representation of the results and their discussion

5- Chapter five: introduces the conclusions derived from this study and recommendations for potential research works.

Chapter Two

Theoretical Background and Literature Review

Chapter Two

Theoretical Background and Literature Review

2.1 Introduction

Every waste management program requires the collection of municipal solid waste (MSW). It is one of the most difficult tasks confronting garbage managers around the world. The waste must initially be collected, regardless of the waste management method used. The purpose of the targeted waste management strategy, such as resource recovery or landfilling, can be realized by tailoring collection techniques. People and a mode of transportation are normally required for MSW collection to a transfer station, treatment facility, or final disposal site. (Worrell and Vesilind, 2012). The collection systems of industrialized and underdeveloped countries may differ significantly. In most industrialized countries, the concept of the house-to-house collection is most widespread, particularly for residential MSW collection.

However, due to a variety of hurdles, including financial and economic issues, the adoption of this notion has been poor, particularly in poor nations. (Government of Ghana, 2010). In many underdeveloped countries, communal container collection systems appear to be the most common. Communal containers (waste bins) are placed at strategic locations across communities for households to deposit MSW. Containers are then collected, emptied at a final disposal site, and returned to their original sites by collection vehicles. However, this collection system is plagued by issues such as overflow, ground dumping at collection sites, and open/indiscriminate dumping in unapproved locations, all of which result in uncollected garbage. Water resources, particularly rivers/streams and drinking groundwater sources such as boreholes and hand-dug wells, face possible contamination.

MSWM decision-making includes collection route planning, dump cleanup, and future collection site placement to improve the quality of water resources (Osei et al., 2010); (Chalkias and Lasaridi, 2009).

2.2 The Concept of Solid Waste:

Solid waste has been evolved into a global issue that affects most countries, to the point that it can be no longer ignored because it occurs daily and has become the center of attention and interest among employees in this industry (Al-Khafaji, 2016).

Whereas many writers and researchers have defined solid waste as "non-liquid waste resulting from domestic, commercial, agricultural, and public services activities" in various studies and research, it has been defined as "it is the term used to describe non-liquid waste resulting from domestic, commercial, agricultural, and public services activities" in various studies and research (Ahmed,2006).

"They are the materials that are occasionally toxic, have a low content of liquids, and include municipal garbage, industrial trash, commercial trash, trash from agricultural operations, animal husbandry, and other associated activities, demolition debris, and mining trash," it added. (Mkhiriz,2018).

2.3 Sources of Solid Waste

They exist in various combinations depending on the sources from which they originate, and these components differ depending on the diverse activities and resources available to each person, as well as the method employed by the producer. Its sources vary depending on a country's financial situation, as industrialized countries produce large amounts of it in various human activities, and it is the result of human activity for those various activities or activities that reflect human activity on the properties, elements, and composition of this solid waste (AL-Issary,2016).

Solid waste comes from a variety of places in the community, including:

1- Domestic solid waste

2. Commercial solid waste

3. Industrial solid waste

4. Agricultural solid waste

5. Municipal services waste

6. Demolition and construction waste

7. Medical solid waste

In terms of organic compounds containing food residues, household garbage is the most abundant. Plastic, glass, cardboard, paper, and tinplate are among the materials used (EI-Ghamry and Abou EI-Ata, 2009).

2.4 Solid Waste Properties

2.4.1 The Physical Composition of The Waste

Because of the role that physical structure plays in the process of determining the sorting of solid waste and the reuse of some of them, as well as the use of some of them in the energy recovery process, the physical components of solid waste are significant in the phases of solid waste management: -

1- Ingredients

According to changing climatic conditions, geographical location, and cultural evolution, solid waste materials fluctuate and are in varying quantities, affecting the amount and methods of solid waste disposal (Al-Khafaji, 2017).

2-Moisture content (relative humidity)

It shows the percentage of liquids in solid waste based on the types of waste components, the presence of moisture is considered necessary and important, as well as a major factor in the process of determining the production of landfill gas, and it plays an important role in determining the appropriate type of treatment for solid waste and according to its percentage. (Williams,2005).

3-Density

Because the density of solid waste varies with the components and contents of the garbage, as well as the moisture content and level of compression and pressure, the density plays a significant role in determining the mass and size of the waste to be lifted and treated. Solid waste in compression activities has an ideal value of 300 kg/m^3, whereas non-pressurized and compressed solid waste has an optimum value of 130 kg/m^3, and compressed trash in a sanitary disposal site has an ideal percentage of (450-600) kg/m^3 (Okaili, 2009).

2.4.2 Chemical Composition

The goal of determining the chemical composition of solid waste is to determine the components present in the trash, such as oxygen, nitrogen, and sulfur, which indicate the amount of profit gained from burning solid waste. (AL-Mashaikhi,2011).

2.5 The Stages of Solid Waste Management

The solid waste management process involves a number of stages, beginning with the generation of waste and progressing through the process of collecting it for the first time and temporarily storing it in residential areas, before being transported in an organized manner to sanitary landfill sites (final disposal) or treatment sites (AL-Khafaji, 2017).

The stages of solid waste management are as follows: -

2.5.1 Generation of Solid Waste

The process of generation is unavoidable as a result of human beings' daily actions, and it occurs in various quantities based on the circumstances of individuals, their style of living, and other factors. The process of generation is unavoidable as a result of human beings' daily actions, and it occurs in various quantities based on the circumstances of individuals, their style of living, and other factors (Kolekara, 2016).

For this reason, there is waste and excessive consumption of natural resources, which leads to an imbalance in their presence. The issue of trash generation is one of the top goals for solid waste treatment studies and research, to limit the process of creating some products from these wastes (Kolekara, 2016).

2.5.2 Storage of Solid Waste

The fundamental purpose of the solid waste storage process is to preserve public health while also maintaining the aesthetic appeal of the city. The size of the storage containers is determined by the amount of solid waste generated by each individual as well as the number of family members (AL-Shammari,2010).

2.5.3 Collection of Solid Waste

Citizens have an active role in the solid waste collection process. As a result, the majority of complaints related to the solid waste management process arise from collection and transportation issues. This made the local administration pay close attention to the process of transportation and collection of solid waste and consider a top priority; Taking care and strengthening them will improve the country's image and environmental conditions (Al-Salmouni, 2012).

This process represents a significant portion of waste management costs. The initial collection process begins with the collection of garbage from different places for different purposes, which begins at the level of the house. Where the citizen puts the garbage in the bags designated for garbage to be presented abroad for disposal, and then the municipality collects the garbage that the residents leave on public roads and transports it to treatment centers (Adel, 2012).

Garbage collection procedures for vertical buildings differ from waste collection methods in open horizontal spaces and areas with narrow alleys (Sheikh Abbas, 2006).

The procedure of urban solid waste collection is a difficult and complicated procedure due to the range of activities and events and the manner in which the containers are dispersed in them, as well as the hours allotted for collection, and the various areas where this waste is generated as a result of the high cost of gasoline, as well as the dedicated mechanisms that are involved in collecting garbage and transporting it to disposal sites. Garbage collection accounts for about (80-85 percent) of the total cost, according to our results (Ali Khan, 2005).

2.5.4 Transportation of Solid Waste

The purpose of this transfer procedure is to move the solid waste from sources that generate it, whether residential or commercial, as well as all trash-producing activities (a variety of temporary storage locations), to specified sites such as intermediate stations or disposal locations (Kumar, Pandit,2013). The following steps are included in the transfer process:

The process of selecting a suitable vehicle for the location is influenced by several factors, the most important of which are: -

The type of solid waste generated, the method of waste collection, the topography of the location, the time cycle, the available financing, and the distance from a sanitary landfill site (AL-Salmuni,2012).

2.5.5 Transfer Stations

Transfer stations are designated sites where solid waste is received for classification before being transported to another location, where waste collection mechanisms temporarily store the waste in large vehicles to transport it for treatment, recycling, or transfer to a sanitary landfill (Amer,2015).

Because of the increase in the amount of solid waste produced and the large distances to transport them to sanitary landfills or treatment sites, transfer stations are used to collect waste in them through the mechanisms involved with the solid waste collection process, resulting in high transportation costs if the same collection mechanisms are used in a sample.

Waste is collected in these stations and placed in huge container before it is being transferred to final destinations or carried by railways, and the transfer stations have waste compressors, lowering transportation costs and allowing for bigger quantities to be transported. At the same time, garbage is being produced. (Economopouious,2012).

2.6 Solid Waste Treatment and Disposal Methods

Here talking about techniques to change the qualities of solid waste to make it less harmful or non-hazardous. It can be carried or handled more safely, without being collected, kept, or disposed of it is harmful to both people and the environment. It's about the methods (Erses et al., 2005). The following was used:

1- Sanitary Landfill:

Backfilling is one of the most widely used techniques. To dispose of solid waste, landfill sites must be designated with strict engineering standards based on compaction. To absorb the most water and limit permeability, solid trash should be used cover the waste with an insulating and impermeable layer of clay.

After a geological analysis of all potential sites, it should choose a landfill site. To ensure that liquid leaks do not harm the environment as a result of groundwater waste breakdown.

The location of the sanitary landfill must be carefully selected, taking into consideration the following factors (Erses et al., 2005): -

- The site should be compatible with the region's present and future land usage.
- It should be easy to go there at all times of the year.
- To be able to cover the garbage with enough dirt.
- It is forbidden to pollute any water supply.
- It should have enough space to hold the garbage produced by the area it serves for an extended period.
- To be financially viable.
- To be remote from existing and planned population centers in the future.

2- Reuse:

The utilization of materials found in the context of solid waste is included. The space was repurposed for the same reason it was created in the first place, due to its size, waste in underdeveloped countries is too small to be considered. Without the presence of private institutions or sectors whose purpose is to sort garbage, reuse is private, uncontrolled, and harmful because it is left to people. Waste collectors work directly with the public.

Waste is sorted to determine what may be recycled, then cleaned and filtered to be used without fear of negative consequences (Al-Hajar, 2011).

3- Recycling:

The use of solid waste as a raw resource is referred to as recycling. Recycling provides numerous advantages, whether for the same or other objectives. Conserves natural resources, eliminates the demand for raw materials imports, and lowers the risk of contamination.

Sorting and remanufacturing waste components such as broken glass, paper, cardboard, and wood refuse. These components are separated at the source by establishing special containers for the appropriate waste component in regions where this approach requires a large amount of manufacturing, or by using special machines.

4- Recovery:

Many countries, particularly Japan, use heat recovery technology to safely dispose of solid waste. Hazardous waste includes solid and liquid waste, hospital waste, and sewage and industrial sludge. These wastes are burned under certain operating circumstances, such as temperature and burn time, to regulate emissions and ensure compliance with environmental legislation. It can be used in industrial processes as well as to generate steam or electricity.

5- Fertilization:

This is a procedure in which waste is processed, treated, and converted into soil conditioners at particular factories (organic fertilizer).

The breakdown of the organic matter in the garbage by bacteria, fungi, and aerobic yeasts is required for the creation of organic fertilizer, and since waste typically contains organic materials, this method can also be used to dispose of and benefit from a high percentage of garbage, which minimizes the amount of waste that has to be disposed of in sanitary burial and hence the amount of land required for sanitary burial while simultaneously achieving an economic aim.

6- Incineration:

It is a widespread form of solid waste disposal, and techniques for incinerating solid waste have existed for a long time. People and governments have made significant attempts to eliminate garbage and the problems it generates. There are issues, and most of the incinerators currently in service have them.

In most modern incinerators, the air going out of the incinerator contains an excessive amount of uncontrollable pollutants, resulting in pollution of the surrounding air, and therefore ensuring that the rising gases do not fall out. To get rid of these fumes, very high chimneys must be built over the surrounding areas (Al-Ghamry et al, 2009).

2.7 Collection Services

At present, various types of waste collection services are used from municipal, commercial and industrial waste sources, as follows:

2.7.1 Commercial and Industrial Assembly Services

Solid trash collection is one of the most challenging operational issues that most cities encounter. Solid waste collection services from residential buildings and complexes with commercial and industrial activity are carried out through the use of containers that may be mobile or fixed with compresses used to compress waste materials and then transfer to large containers (Ogwueleka,2009).

2.8 Types of Solid Waste Collection:

Solid waste collection systems are classified into two main types:

2.8.1 Hauled Container System

In this type of collection system, the containers used to store the waste are pulled to the treatment area, the transfer station, or the sanitary landfill area, where their cargo is unloaded there and returned to its original location or another location, as shown in fig. (2.1).

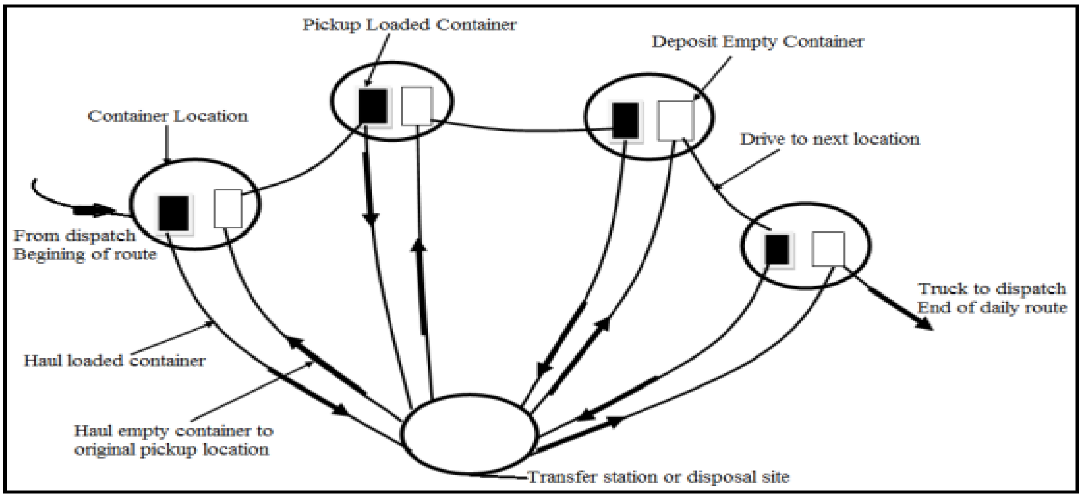

Figure (2.1): Solid waste collection method in a Hauled container system.

(Source: Olukanni et al., 2015)

2.8.2 Stationary Container System

In this type of collection system, the containers used to store waste remain in place (at the point of waste generation) except for their movement during the waste collection, as shown in figure (2.2).

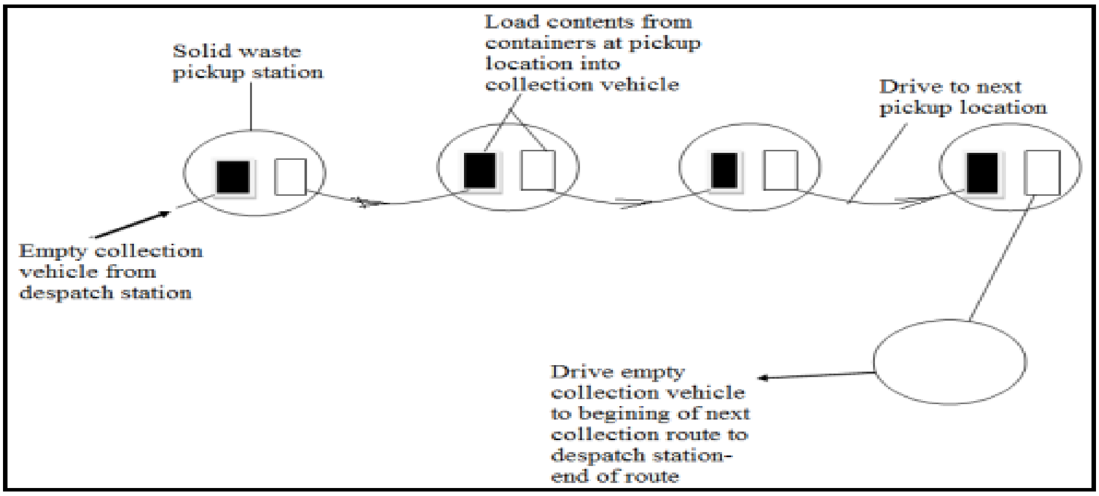

Figure (2.2): Solid waste collection method in Stationary container system

(Source: Olukanni et al., 2015)

2.9 Frequency of Waste Collection

solid waste collection depends on: -

- quantity of waste
- rate of generation
- characteristics of waste
- climate
- density and type of housing
- availability of space within the premises
- size and type of storage facilities (small, large, individual or communal)
- attitude of the generator.

2.10 Previous Study

There have been numerous prior studies that have addressed the topic of solid waste collection route from various perspectives, and this study will analyze several studies that have been employed about its most salient qualities, and point out that the research look at was conducted between

(2007 - 2020), and they encompassed a range of countries and countries with varying temporal and geographical diversity.

Apaydin, 2007 used the least amount of money possible. For this, the Route View Pro program was employed as an optimization tool. Numerical paths, demographic distribution, container distribution, and solid waste production amount were all linked into the software using Geographic Information System (GIS) features. To give you an idea, the city's theme container layer contains 777 container location points. The optimized routes were compared to the current routes after they were run through the software. The optimization technique had a success rate of (4-59) % for distance and 14-65 percent for time. As a result, a route optimization operation on the street stationary container collecting system will result in a total cost savings of 24% The route optimization will provide certain other benefits, such as reduced pollution and noise emissions, traffic congestion, resource conservation, and so on, which may be more essential for city life quality than cost.

Ogwueleka, 2009 studied the problem which was to reduce the entire cost, and mostly determined by the distance traveled by the vehicle. Inspired by Nigeria's garbage collection issues, the paper offered a heuristic method for generating a realistic solution to an extended Capacitated Arc Routing Problem (CARP) on an undirected network. The route first, cluster second strategy is part of the heuristic process. In Onitsha, the computational experience with the heuristic was discussed. In terms of cost, time, and distance traveled, the methodology was compared to the previous timetable. The proposed heuristic was implemented in Onitsha, resulting in a reduction in the number of current automobiles. The proposed heuristic algorithm performed well, indicating that it could be effective in vehicle scheduling.

Ogwueleka, 2009 studied solid waste management procedures and issues were investigated. Inefficient collection methods, poor coverage of the collection system, and incorrect disposal characterize solid waste management. To attain long-term sustainability, the study recommended investigating institutional, political, social, financial, economic, and technical aspects of municipal solid waste management Nigerian solid waste management is efficient and effective. It is necessary to train waste employees to manage solid waste challenges, including developing policies for community-based programs, waste reduction and recycling projects, and drafting laws. Operating costs will be reduced if existing vehicles are replaced with contemporary vehicles. Some landfills should have measurement stations installed. Operating costs will be reduced as a result of the new transfer station's construction.

Ramakrishnaiah et al., 2011 studied the examination of current solid waste management strategies and the usage of a geographic information system (GIS) as a tool for waste management planning were used. Waste collection and transportation account for a significant portion of the entire cost of municipal solid waste management. For the City Municipal Council of Chikmagalur, an endeavor has been made to design and create acceptable storage, collection, and routing system. For an efficient collection path for transferring solid waste to the disposal site, a GIS optimal routing model based on criteria such as population, waste generating capacity, road network and types of roads, storage containers, and collecting vehicles was designed. Fuel consumption savings are related to distance reductions. The waste management issues focused on providing dumper placer container allocation and ArcGIS route network analysis. Secondary containers are assigned according to CPHEEO criteria. The current study presents a GIS-based approach for determining the best position and number of secondary containers in the study area.

Siddam, 2012 used geo-informatics, researchers proved to optimize the collection and transportation of the city's municipal solid trash. All supplementary data was initially gathered from a variety of sources. The location of every dust bin in the city is collected using a hand-held GPS device, and the information is turned into a shapefile. The roads are digitized from the municipal corporation's road network map. Using Arc-GIS 9.2, a network database for the complete road is created from the shapefile of the existing road network. The routes are optimized for each vehicle journey, taking into account the capacity of the solid waste carrying vehicle, and the total distance to be travelled is determined for each journey. Finally, the cost of solid waste disposal utilizing this methodology is compared to the present Municipal Corporation method. Based on the findings, it is concluded that the Geo-informatics technique improves route optimization accuracy and can be used as a decision support tool by municipal authorities for more efficient management of daily operations such as solid waste transportation, load balancing within vehicles, managing fuel consumption, and generating work schedules for workers and cars to reduce total costs.

Antmann et al., 2012 proposed simulation-based decision-making and optimization framework for the analysis and implementation of successful solid waste management and recycling programs, under unpredictable conditions. A database, as well as two modules: an assessment module and a resource allocation optimization module, are included in the proposed framework. The assessment module locates the system's sources of uncertainty and creates a parameterization for them to be used in the resource allocation optimization module. This module includes a discretecontinuous model of the system under evaluation, including waste types and characteristics, costs, environmental impacts, processing facility kinds, location, and capacities, and capabilities. The multi-criteria problem of constrained resource allocation is then handled using the optimization mechanism built into the resource allocation optimization module. The user defines the best solution, which is infinitely variable. In the state of Florida, the proposed decision-making framework has been successfully proven for the Miami-Dade County Solid Waste Management System.

Bouanini, 2013 showed a number of strategies for efficiently managing municipal solid waste in China, as well as tactics to raise people's living standards and the quality of the environment by following environmental laws. As reduce, reuse, and recycling become more widely used in China, so does the amount of municipal solid waste that is produced but not generated. The quantity of waste that must be disposed of in a landfill or incinerator lowers when more products are reduced, reused, and recycled, which causes a decrease in the production of municipal solid waste.

Chalkias and Lasaridi, 2015 studied methodology for optimizing the garbage collection and transport system, based on GIS technology, has been created. GIS technology is being used to increase waste collection and transportation efficiency in the Municipality of Nikea (MoN), Athens, Greece, by reallocating waste collection bins, introducing new vehicle routes, and introducing new vehicle time. The proposed scenario significantly improves efficiency in terms of collecting time, travel distance, CO_2 emissions, and fuel consumption, according to the results. The goal of the designed system was to find the best scenario for commingled waste collection in terms of decreasing collection time, distance traveled, and manpower.

Kallel, et al., 2016 used the ArcGIS NA (Network Analysis) to increase the efficiency of rubbish collection and transportation in the Cite El Habib district of the municipality of Sfax, Tunisia. For the purpose of identifying optimal routes, three scenarios were created and analyzed: S1-optimized route utilizing the same work devices (just changes in sequencing stops); S2-optimized route with vehicle change; and S3-optimized route with collection mode change (changing the transportation equipment and reallocation of containers). Scenario S3 allows savings of about 40%, 57 %, 40.5 %, and 48 % in the number of workers, working time, traveled distance, and fuel consumption, respectively, resulting in a gain of about 60,000 TND/year, in addition to other benefits related to CO_2 emissions, hours of work, vehicle wear/maintenance, and so on, when compared to the current situation. These findings suggest that GIS-based optimal scenarios can significantly enhance the SW (Solid Waste) collection/transport system, as well as the financial and environmental expenses associated with it. These findings could be improved even more by optimizing container placement, which could then be tried out across the entire city of Sfax.

Pathak, 2017 proved that the municipal waste of all municipalities is suitable for producing compost. The households mainly in rural areas of municipalities are doing household composting in the traditional way, but urban families, where land is scarce, do not often use household composting. Because of a lack of technical and human resources, data, statistical records, effective planning, limited funding, less public and commercial participation, and unneeded political concerns, municipalities are unable to meet their solid waste management goals. Based on statistics provided by surveyed municipalities, municipalities allocate an average of 2% of their total budget to SWM (Solid Waste Management), yet many new municipalities have yet to set aside funds for this purpose. Open dumping in forests, open space, and depressed areas is undertaken by 26 of the 60 municipalities studied, while waste is disposed of at river banks by 13 municipalities. Eight municipalities use either the open dump or the riverside dump approach.

Demir et al., 2017 used the solid waste route for garbage collection vehicles in Faith sub-district of metropolitan city of Istanbul, ArcMap and the Network Analysis Vehicle Route Problem Tool were used in Turkey. In comparison to existing run routes in the area, the GIS approach allows for the creation of an optimal route that is both cost-effective and time-consuming. The findings revealed that GIS may be utilized as an effective and useful tool to determine the best approach for implementing an integrated solid waste collection and management program, as well as assisting local governments in lowering solid waste collection costs.

Alhassan et al., 2018 used two primary methodologies to determin the best route for solid waste pickup vehicles has been studied: mathematical programming and geographic information systems (GIS). They are primarily used to conserve resources by reducing distance, time, and operational and maintenance costs. When routing systems designed from mathematical programs are applied in reality, partial or quasi-optimal solutions are generated. Current GIS-based techniques are constrained in terms of street and traffic limits, making them difficult to adapt and apply in different jurisdictions. Few studies have been attempted to estimate the environmental impact of routing systems through CO_2 and other pollutant emissions. If cost reduction and environmental conservation are priorities in solid waste management, optimal routing for solid waste collection and transportation is critical. Studies should focus on enhancing the efficiency of truck routing systems through the adjustment of organizations' delivery schedules to improve their efficiency.

Hoang et al., 2019 complicated interrelationships of waste composition were identified, collection frequency, collection type, and truck compartment configurations in a modest waste collection zone in Austin, Texas. There are a total of 48 scenarios that have been modelled and explored. Vehicle travel distances have been found to be affected by collection frequency, truck capacity, truck compartment volume ratio, and trash density. According to the findings, increasing garbage density and garbage collection frequency reduced trip distances by 18.2 percent and reduced journey time by 41.9 percent. Regardless of vehicle design, waste content has a considerable impact on trip distance. By increasing truck capacity by 25%, truck travel distances were reduced by (4.1–24.4) percent.

Sadoon, 2020 discovered a scientific way for resolving the solid waste transportation problem in Baghdad. Seeked out practical options for lowering total transportation costs and achieving an efficient solid waste management system. In this study, a novel methodology for selecting the best SWM transit routes in Baghdad city was established, which incorporates calculating the best-supposed scenario. Integration of Global Positioning System (GPS) technology with a Network Analysis model is part of the proposed technique (NA). As a result, this work presents a sophisticated decision-making framework for analyzing and simulating the optimal transport routes problem in SWM. Using these modeling tools, choose the scenario that provides the most economic benefits by reducing trip time, distance, and total transportation costs.

2.11 Summary

Through the literature review, the researchers used the ArcGIS program to collect solid waste in order to reduce cost, time and distance, and it achieved high results in accuracy.

With regard to reuse and recycling and thus reduce the amount of solid waste. Also, using a GPS program can provide economic benefits by reducing travel time, distance and transportation costs.

Chapter Three

Application and Case Study

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Application and Case Study

3.1 Introduction

Solid waste management (SWM) is always a prime concern in every country. Solid waste collection (SWC) is one of the most challenging steps among all the operational steps of SWM. Municipal solid waste (MSW) is a major by-product of the urban lifestyle, which is rising even faster than urbanization (Hannan et al., 2015), and its quantity has been significantly increased due to the rapid population growth. Thus, the growth of population and urbanization, combined with growing environmental concerns has created a critical situation such that the management or policy-makers must look for different sustainable means of effectively collecting and disposing of the mounting waste (Poser and Awad, 2006; Xue et al., 2015). It has also made SWC more delicate in terms of traffic congestion and fuel consumption and its subsequent cost, environmental pollution (greenhouse gas emission), etc. Moreover, a huge amount of the budget is spent on this sector. The concern regarding its efficiency has increased even more with the emerging modern era.

In consequence of this concern, many municipalities (especially in industrialized nations) are forced to assess the cost-effectiveness and environmental impacts of their SWM systems, particularly waste collection route designs. Therefore, some studies have been conducted to reduce this expenditure (Economopoulou et al., 2013), described a software system to cut the annual capital investment and annual operating cost of MSW transportation, treatment, and final disposal operation and achieve significant economic savings. Hence, with the proper study of SWC efficiency, the cost in this sector can be cut by avoiding permanent adverse effects on the environment. Management of solid waste. is a multi-tasking process. It involves the generation, source separation, storage, collection, transfer and transport, processing and recovery, and disposal (Rada et al., 2010).

3.2 Practices of Solid Waste Collection in Different Parts of The World

Solid waste collection challenges continue to be a problem in many places of the world. Various solid waste collecting systems have been implemented in various countries, based on a variety of criteria, political concerns, public opinion, and so forth economics, public health, and acceptability status of the environment.

Waste collection processes account for the majority of these countries' solid waste management expenditures. In most cases, the waste removal is more expensive, or due to its concentration, collection particularly in large cities. Many efforts have been undertaken in Asia to manage solid waste throughout its nations. However, some have objected up to this point, several countries are still fighting their efficiency in collecting data and strategies for transportation.

The majority of the expense of solid waste management in East Asia/Pacific is spent on the collection and transportation of this trash. Furthermore, the majority of countries in the southern hemisphere and western Asia are confronted with the problem of time-consuming procedures that aren't necessary waste management is a job that requires a lot of effort. This Workers' health could be jeopardized (Visvanathan, 2005).

3.3 Point and Link Collection

The process of determining the path for the solid waste collection vehicle falls into two categories depending on what is required of the services in the collection area. If the services (waste collection) are required at separate points that are linked between them by interconnections, which are streets within the road network in the area to be served, then a matter of this kind is called (The Salesman Path). It is symbolized by (TSP), The specific goal of this type of issue is to find a path that begins and ends at a specific point, provided that it passes through all the points required to be serviced at the lowest total cost (Ehrgott, 2000).

As for the solid waste collection, the waste collection paths from some sites of economic and industrial activity where the waste collection points are far apart and are considered an application of the method (TSP).

In many other cases, such as street sweeping, services are required along the streets in the road network and not at specific points. This represents the second type called an extended waste collection. The goal here is to achieve one traffic of a waste collection vehicle on every street in the network at the lowest possible cost. Although solid waste collection from residential areas requires service in a large number of separate collection points, these points are close and distributed along the street so that a path can be found for them (Paquete et al., 2004).

3.4 Mission Definitions (Sector, Tour, Path):

The solid waste collection process can be viewed as having three parts:

1- Dividing the area whose waste is to be collected into smaller areas called sectors, each of which represents a full load of waste collection vehicles.

2- Determining the path of the collection wheel or the so called journey from the entry point of the sector to the sanitary landfill area.

3- The combination of the sectors as well as the trips that you cover in a full working day to be the so-called route, which must include one or more trips to the waste disposal area or garage.

In practice, the three steps mentioned above do not need to be implemented in the order indicated. Rather, the municipality defines the area whose service constitutes a full working day instead of one carload and then defines the path for that area.

When identifying the sectors as in the first step, the process of expanding the trip to include the garage is a simple process that is summarized in determining the shortest path from the garage to the nearest point in the sector.

In any case, the location of the sector and its borders will have a significant impact on the costs of the trips that take place to and from the garage. Therefore, these costs must be taken into consideration when determining the sectors (Rodrigues et al., 2018).

3.5 Network Presentation:

The streets from which the waste is collected represent the connections in the network and the intersections of these streets represent the nodes. If the waste collection process takes place on both sides of the street at the same time and the street is a non-one way, then it is represented by a single tie without direction. But if the assembly process is carried out for each side separately, then the situation is represented by two links facing the same direction in which the assembly car is moving.

The types of road networks can be divided for the waste collection process into: -

1- The undirected network (this means that all streets have two lanes and that the assembly process takes place on both sides of the street simultaneously).

2- Directional networks in which all streets have one lane, or the waste collection process takes place separately for each side.

3- Networks of the type that contain directed and non-routed links. This case represents the most difficult issue in determining the optimal paths (Jerrum, 2003).

3.6 Routing Objectives:

There is a cost to achieve a complete service (waste collection) for each grope. The process of determining the path aims to form the so-called journey through which waste is collected from all the connections in the network and to reduce the total costs involved to a minimum**.**

The cost of collecting waste from any bundle is treated as an almost fixed value. Although the real cost of collection may be affected by the traffic situation at the time of collection, it is not possible to take all these matters into consideration, and in any case, it is possible to avoid the collection of waste during hours of heavy traffic.

The waste collection process takes place on all the connections in the network, and accordingly, the cost is affected only by the dead paths, which are those paths whose waste is supposed to be collected at a later time or that does not require the collection of waste in the first place. Therefore, if a trip is found free of dead paths, then this trip certainly represents the journey the least expensive.

Techniques for determining the sword when determining the direction on the dead paths and not on the cost of the waste collection because the first is the dominant factor in determining the path (Mihail and Winkler, 1996).

3.7 The Method is Summarized by the Following Assumption

Each link the compactor passes only once to collect waste, and choose a part of these links to pass additional times, and this extra section is the called dead paths.

The calculation of dead track costs for each bundle can be simple or complex, as desired by the track designer. For example, the designer may consider the cost roughly proportional to the distance, in which case an estimated length of the link is used as representing the cost, or, the process can be done in a more complicated way by measuring the exact distance and the average time it takes to pass again on each tie and calculating the real cost in light of this, taking into consideration the number of workers and the cost of operation and maintenance...etc.

The links are classified according to the time taken to cover the distance of the link, and then the cost per unit length of the link is estimated, and then the cost of each tie is estimated based on its length.

There are other assembly costs unrelated to the length of the tie or the cost of moving on the tie for each unit length of it, for example, the costs resulting from the delay at the traffic lights and the stop signs and turns to the right or the left (Liebman et al., 1975).

3.8 Tracks Optimized for the Study Area

To determining the path of the waste collection vehicle, this solution is for issues that fall under the heading of the Chinese postman who covers all the streets and lines in the network, and that (the lack of mechanisms, the cost of labor, the lack of waste storage equipment ... etc.) throughout Iraq, the linear programming method was used in this study, which dealt with three main axes, the shortest possible path, the minimum linkages, maximum objectives (Collect the largest amount of solid waste) through the Win QSB program.

This part is related to the Win QSB program that have created alternatives that can be taken to determine the path of the compressors, while the second part of the processors is represented by using the concept of geographic information systems or what is called ArcGIS, and the purpose of that is to reach the selection of the best alternative spatially through the application of the multi-layer model.

3.9 (Win QSB) Program

QSB stands for (Quantitative Systems for Business). An excellent operational research educational program for solving many problems complexity of a quantitative nature (Abdul Ghani et al., 2011).

3.9.1 Win QSB Program description: -

1. Complete the survey process for the study area and field trips.
2. Obtaining horizontal plans for the site from the Urban Planning Department.
3. Perform a software trial run of (QSB).

3.9.2 Win QSB Optimal Path Ways of Study Area

Linear programming method include: -

- The Shortest Path.
- The Minimum number of links.
- Achieving the collection of the largest possible amount of waste (Maximum Objective), as shown in figure (3.1).

This relates to the mathematical processing that have created alternatives that can be taken to determine the path of the compactors.

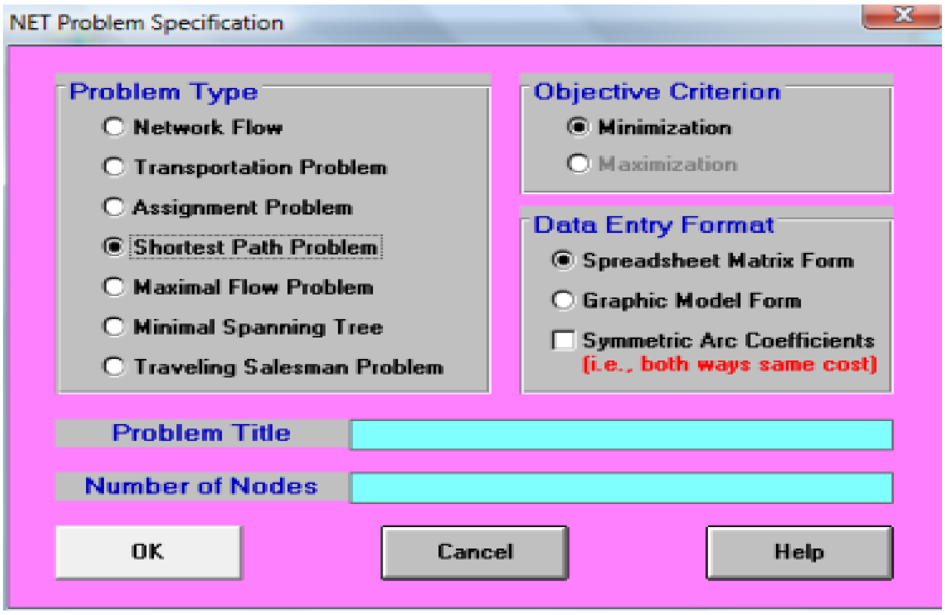

Figure (3.1): Win QSB Interface

3.10 Description of the study area

Three residential areas in the city of Karbala were chosen to be the study implementation area, which are AL-Mulhaq (1,2), Shohada Al-Mulhaq & Dhubat Al-Usra and AL-Usra. AL-Mulhaq (1,2) is characterized by the presence of residential neighborhoods, shops, schools, restaurants, parks, clinics and laboratories. As for Shohada Al-Mulhaq & Dhubat Al-Usra, it is characterized by the presence of residential houses and a lower population density than those in the AL-Mulhaq neighborhood. The AL-Usra neighborhood is characterized by the presence of residential neighborhoods, shops, government departments, schools, and hospitals. Accordingly, the researcher found that there is a comprehensive diversity in the different activities that are practiced in these residential neighborhoods, with a clear discrepancy in the extent of these activities as shown in figure(3.2)

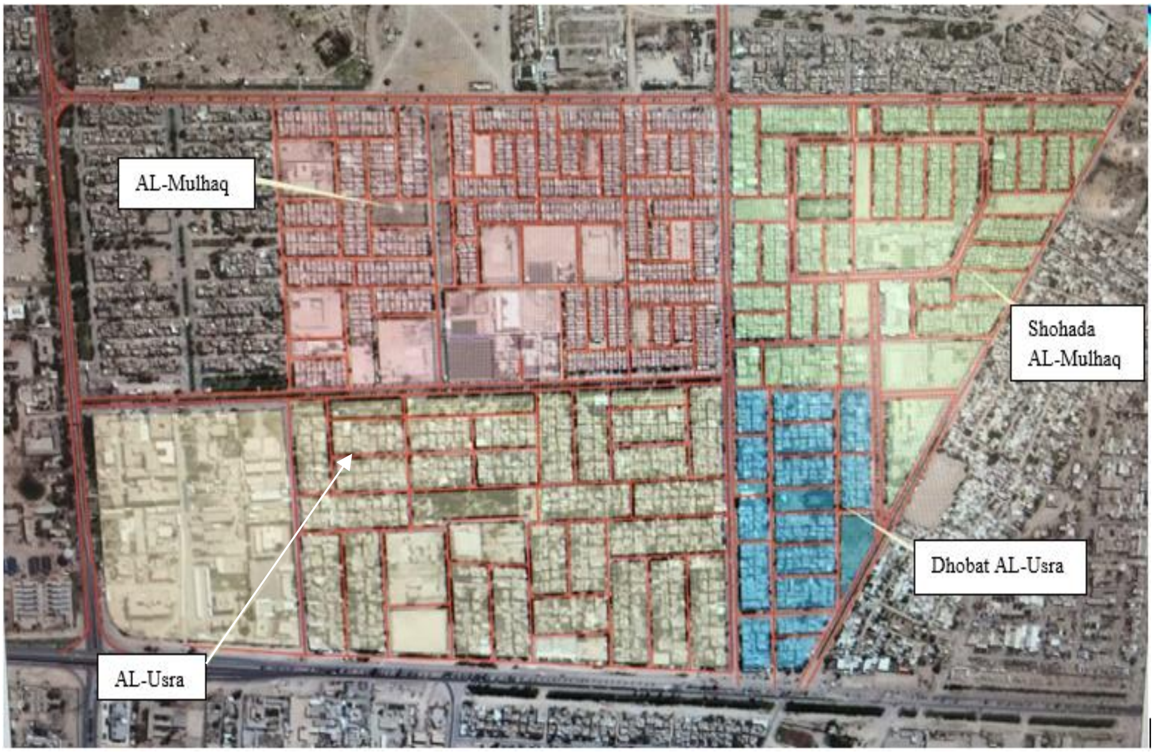

Figure (3.2): Digital Map of The Study Area [Karbala Municipality Directorate,2020]

3.11 Survey of the study area

The drawing scheme of the study site plans was adopted to determine the lengths of the main and secondary streets of these neighborhoods in Table (3.1).

Table (3.1) The total length of the streets

Study Area Name	Total length of the Streets, (m)
Al-Mulhaq (1,2)	15610
Shohadaa Al-Mulhaq & Dhobat AL-Usra	13353
Al-Usra	9382

Most of these streets are of the unguided type, in which the movement of compactor is free in direction, except for the main streets that are directed.

Street lengths were calculated from the beginning of the node to the end of the node for AL-Mulhaq (1,2) and the information is entered in Table (3.2).

Table (3.2): Input Data for Al-Mulhaq (1,2) (Shortest, Min)

Branch Number	Branch Name	Start Node	End Node	Distance (m)
1	<B1>	<1>	<2>	<+38.000>
2	<B2>	<1>	<3>	<+110.000>
3	<B3>	<2>	<32>	<+30.000>
4	<B4>	<2>	<34>	<+125.000>
5	<B5>	<3>	<4>	<+38.000>
6	<B6>	<3>	<5>	<+250.000>
7	<B7>	<4>	<25>	<+30.000>
8	<B8>	<4>	<27>	<+128.000>
9	<B9>	<5>	<6>	<+38.000>
10	<B10>	<5>	<7>	<+100.000>
11	<B11>	<6>	<12>	<+30.000>
12	<B12>	<6>	<14>	<+125.000>
13	<B13>	<7>	<8>	<+38.000>
14	<B14>	<8>	<9>	<+125.000>
15	<B15>	<9>	<11>	<+38.000>
16	<B16>	<9>	<77>	<+30.000>
17	<B17>	<10>	<11>	<+125.000>
18	<B18>	<10>	<12>	<+30.000>
19	<B19>	<11>	<13>	<+30.000>
20	<B20>	<12>	<13>	<+125.000>
21	<B21>	<13>	<14>	<+30.000>
22	<B22>	<14>	<15>	<+30.000>
23	<B23>	<15>	<16>	<+125.000>
24	<B24>	<15>	<17>	<+30.000>
25	<B25>	<16>	<18>	<+30.000>
26	<B26>	<17>	<18>	<+125.000>
27	<B27>	<17>	<19>	<+45.000>
28	<B28>	<18>	<20>	<+45.000>
29	<B29>	<19>	<20>	<+125.000>
30	<B30>	<20>	<21>	<+30.000>
31	<B31>	<21>	<22>	<+125.000>
32	<B32>	<21>	<23>	<+48.000>
33	<B33>	<22>	<24>	<+48.000>
34	<B34>	<23>	<24>	<+125.000>
35	<B35>	<23>	<25>	<+30.000>
36	<B36>	<24>	<26>	<+30.000>

The daily waste production rate for the study area is shown in Table (3.3) (the annual statistical report of Karbala municipality 2020).

Table (3.3) Waste production rate (Karbala Municipality Directorate)

Region	**Waste production rate ton/day**
Al-Mulhaq (1,2)	20
Shohadaa Al-Mulhaq & Dhubat AL-Usra	10
Al-Usra	8

The total amount of waste generated in the study area is about 38 tons/day, knowing that this figure was deduced through the movement of the compactors that collect solid waste and the load of each of them, in addition to the data recorded with the authorities responsible for cleaning in the study area.

The rate of solid waste production varies from one region to another, as it constitutes the largest rate of waste in AL-Mulhaq (1,2) which is distinguished from Shohadaa Al-Mulhaq & Dhubat Al-Usra with its high population density as a result of the presence of the old multi-family houses, apartments, residential buildings and the distinguished movement of citizens in this site for purposes Shopping, treatment and other activities.

The mechanisms assigned to the fourth municipal center of the Karbala municipality center, which includes the study area as shown in Table (3.4).

Table (3.4) The machines allocated to the fourth municipal center

Machines	**Number**
Tipper	3
Shuffle	5
Compactor	6
Sweeper	3
Puller	3

Through the field tours at the study site and meetings and deliberations with service authorities in the region, the following points and observations were established regarding the process of collecting and transporting solid waste:

1- The distance between the garage for the vehicles used in the collection of solid waste and AL-Mulhaq (1,2), Shohadaa Al-Mulhaq & Dhubat Al-Usra and Al-Usra are 7, 5 and 6 km, respectively.

2- Solid waste is collected from the study area using dump trucks to the sanitary landfill area located behind the green belt, which is approximately 52 km away from the study area.

3- The start time of the compactors for work is (6:30-7:00 AM), and ends at 2:00 in the afternoon for the first shift, and the second shift starts at 2:30 in the afternoon until 8:00 in the evening, and then the evening work at (8:00 - 12:30 PM) interspersed with an hour's rest period, as shown in Table (3.5)

4- The number of (2-3) assembly cars, a dump truck, and several 2 trucks are used for each neighborhood in the study area, and the number of cleaning workers is 35, most of them are daily wages, due to a shortage of workers on permanent staff.

Table (3.5): Timing Information (Karbala Municipality Directorate)

Property	Districts		
	Al-Mulhaq (1,2)	Shohadaa Al-Mulhaq & Dhubat Al-Usra	Al-Usra
Distance from garage to district (km)	7	5	6
Distance from district to disposal site (km)	52	32	42
Time leaving garage	6:00a.m	6:15a.m	6:30a.m

Time starts working	6:30a.m	7:00a.m	7:00a.m
Time to leave district to dispose	10:00a.m	10:30a.m	11:00a.m
Time to arrive at district again	12:30p.m	1:00p.m	1:30p.m
Time to leave district to dispose	2:30p.m	3:00p.m	3:00p.m
Time to return to garage	4:30p.m	5:00p.m	5:00p.m
Resting time (hr)	1	1	1
Coefficient (a)	0.269	0.269	0.269
Coefficient (b)	0.016	0.016	0.016

3.12 The Method of Work

After completing the survey process for the study area and field tours, and after obtaining the horizontal plans of the site, where the second stage was office work, and its activities are summarized in the following paragraphs:

1- The numbering of the nodes in the study area, which represent street intersections, and the numbering of the links that connect the nodes, where the number of nodes is in Table (3.6).

Table (3.6) the Number of Nodes

Region	Number of Nodes
Al-Mulhaq (1,2)	167
Shohadaa Al-Mulhaq & Dhobat AL-Usra	110
Al-Usra	66

2- Calculating the lengths of the ties that represent the distance between one node and another.

3- Determining the amount of solid waste generated in each bundle, so that this quantity is distributed to the two nodes that represent the beginning and end of the bundle, respectively. The following relationship was used: (Shamshir, 2001).

Amount of waste generated in each area (kg/m.l/day) = total waste generated in the locality (kg/day)/total length of streets (m.l)….(3.1)

As shown in Appendix A Tables (A-7), (A-8) and (A-9).

4-Tab and tabulate the data in steps (1,2, and 3) above and use it as input to the program.

5- Running a program and get the three solutions, the shortest path, the fewest number of connections, and collecting the largest possible amount of solid waste.

7- Drawing the paths obtained from running the program (Win QSB) on the site plans using the engineering drawing program (AutoCAD), where three plans are obtained for each residential neighborhood within the study area.

3.13 The GIS System

A GIS (Geographic Information System), is a computer system for collecting, entering, processing, analyzing, displaying and outputting geographical and descriptive information for specific purposes. This definition includes the ability of the system to enter geographical information (maps, aerial photographs, satellite images) and descriptive (tabular information, processing, storing, retrieval, analysis (spatial and statistical analysis) and displaying it on a computer screen or on paper in the form of maps, reports and graphs.

Functions of GIS include: data entry, data display, data management, information retrieval and analysis. A more comprehensive and easy way to define GIS looks at the disposition, in layers, of its data sets. "Group of maps of the same portion of the territory, where a given location has the same coordinates in all the maps included in the system". This way, it is possible to analyze its thematic and spatial characteristics to obtain a better knowledge of this zone.

An effective municipal solid waste management system is composed of optimized routes, systematic collection, transport, and transfer of wastes. The geographical information system (GIS) can be effectively applied for cost minimization and maximization of waste collection and transportation efficiencies in any area. The route optimization depends on many factors, including the location of waste bins, collection details, types of vehicles, travel impedances, and integrity of the road network (Chaudhary et al,2019): (Jazmati and Makdissi, 2001).

3.14 Database Design

The indicative map of the study area has been converted into a numbered map using the geographic information system
The paper map was entered into the computer through a scanner, then added to the geographic information system, and then the map was digitized and converted into a numbered map (Vector), according to the following steps:

Add the map to the program and return it to the geographical coordinates of the city of Karbala, which are:

Projected coordinate systems ⟶ UTM ⟶ WGS 1984 UTM ZONE 38 N

From the Catalog Arc we create a Geodatabase File folder and inside this folder create a Layers container, Dataset Feature and within it, we create the required layers.

To number the nodes, we have added a layer to the nodes of type Point, and we enter them in a table, The area to which the nodes belong (Wazan,2010). As shown in fig (3.3)

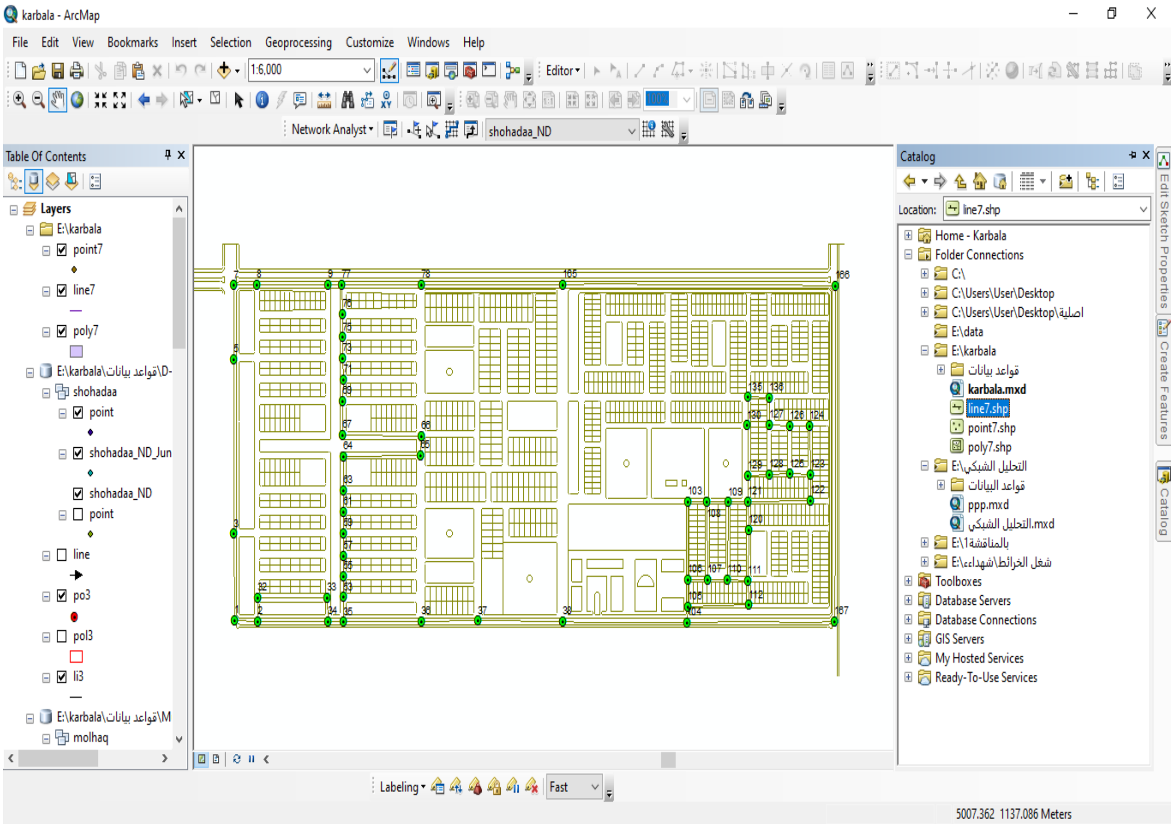

Figure (3.3): ArcGIS Program Input

Chapter Four

Results and Discussion

Chapter Four
Results, and Discussion

4.1 Introduction

Solid waste is one of the most important problems that should be taken care of because of its direct impact on the life of the individual and society in general. And directly with the presence of solid waste in residential, commercial or industrial complexes randomly (Iyad and Hamid, 2015).

The problem of waste accumulation has emerged as one of the biggest challenges that, societies face a threat to the security and health of the planet and humans alike. Urban solid waste is a prominent environmental problem worldwide and a source of pollution environmental, on the other hand, the increasing interest in how to get rid of them is increasing and exacerbating them.

The process is a very complex matter and is subject to many considerations and criteria and requires in-depth studies of the maps data, and activation of specialized computer programs in order to control informational, cartographic, and qualitative diversity or quantitative.

The use of GIS (Geographic Information System) as a spatial analytical tool for dealing with information and data, the geography needed by planners and decision makers in cities and in the waste management process (Sharifi and Ottoman, 2018).

4.2 Study Area and Population Estimates

Karbala is one of most important Iraq's tourist destinations, and it covers 5560 km^2 and divided into seven administrative units (four sub-districts) and three districts. The estimated population of the city is 1,250,516 residents (Republic of Iraq Ministry of Planning Central Statistical Organization, 2020).

It is situated on the eastern side of the desert plateau, west of the Euphrates River, in Iraq's central region. It is astronomically placed at (31° 43') north latitude and (44° 30' 43 15") east longitude, and so it is on the boundaries of the desert environment, bordered to the north and west by the Al-Anbar, to the east lies the province of Babylon, which is 42 kilometers from the city of Hilla, and to the south and southwest is the governorate of Najaf, which is 78 km from the city center and 106 km from the capital Baghdad (Al-Rubaie, 2020).

As follows in Tables (4.1) Calculate the urban, rural population and the generation of solid waste per year, and Figures (4.1) Shows the borders of Karbala.

Table (4.1): Karbala City Background Information and Key Waste-Related Data

Year	Population			Area (km^2)	Total MSW generation ton/yr	SW generation per capita kg/yr	Reference
	Urban	Rural	Total				
2014	773506	377646	1151152	5034	650000	564.5	[Environment Statistics Department, 2014]
2020	858171	425313	1283484	5560	702707	547.5	[Statistics Directorate of Karbala Governorate, 2020]

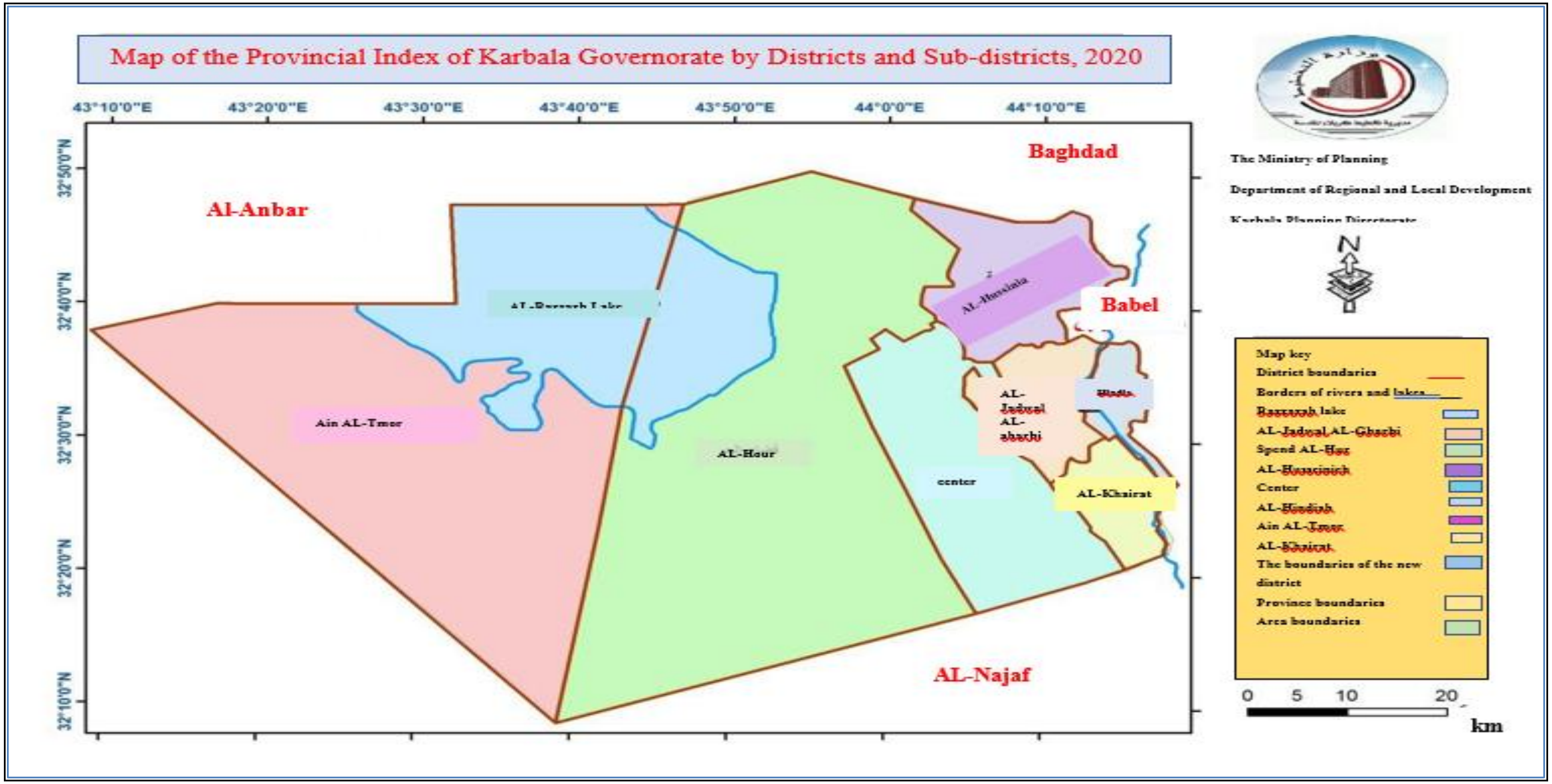

Figure (4.1): Digital Map of Karbala City [Karbala Municipality Directorate,2020]

Figure (4.2) to gather with Figure (4.1) shows the area and population of the districts and sub-districts of Karbala.

Table (4.2): Area and Population of Karbala City [Statistics Directorate of Karbala Governorate, 2020]

Number of Districts	Number of Sub Districts	Population	District Area (km^2)	Density (capita/km^2)
Kerbela	Kerbela District Center	562956	1865	302
	Al-Hassainya Sub District	161419	356	453
	Al-Hur Sub District	253546	415	611
Ain Al-Tamur	Ain Al-Tamur District Centre	29990	2558	12
Al-Hindiya	Al-Hindiya District Centre	123778	71	1743
	Al-Jadwal Al-Ghrabi Sub district	91033	154	591
	Al-Khairat Sub district	60762	141	431

Table (4.3) shows the population of Karbala Center and the comparison between 2008-2020.

Table (4.3): Karbala District Center Population

Year	Population	References
2008	415238	[Muna, 2008]
2020	562956	[Statistics Directorate of Karbala Governorate,2020]

The population and Residential units were calculated from Table (4.4) for study area.

Table (4.4): Population and Residential Units for Selected Districts from Fourth Municipal Sector 2020 [Karbela Municipality Directorate]

District	District Number	Population	Residential Unit
Al-Mulhaq (1,2)	57011-57012	13470	1068
Shohadaa Al-Mulhaq & Dhubat Al-Usra	57013	6486	766
Al-Usra	47034-47035	6035	431

4.3 Generation Rates

The average amounts produced are susceptible to alteration according on a variety of local conditions, including the season, customs, level of education, the people's economic situation, and whether they live in an urban or rural area. Because the landfills in Karbala lack scales, it is only possible to develop a solid waste generation factor using estimations of weight. Typically, this component is given as kilograms per person, per day. According to projections from the Karbala Municipality Directorate, it will be (1.5 kg/day. Capita) for Karbala in 2020.

The study area was located in the fourth municipal section of the city center, which was divided into six sectors by the Karbala Municipality. Based on data from Tables (4.5), the number of residents, housing units, and solid waste generated by each individual in the study area were calculated as shown in Figure (4.2).

Table (4.5): Solid Waste Quantities of Karbala District Center Sectors [Karbala Municipality Directorate, 2020]

District	Yearly Quantity (ton/year)
First sector	79580
Second sector	28065
Third sector	75149
Fourth sector	42346
Fifth sector	46783
Sixth sector	41779
Total	313702

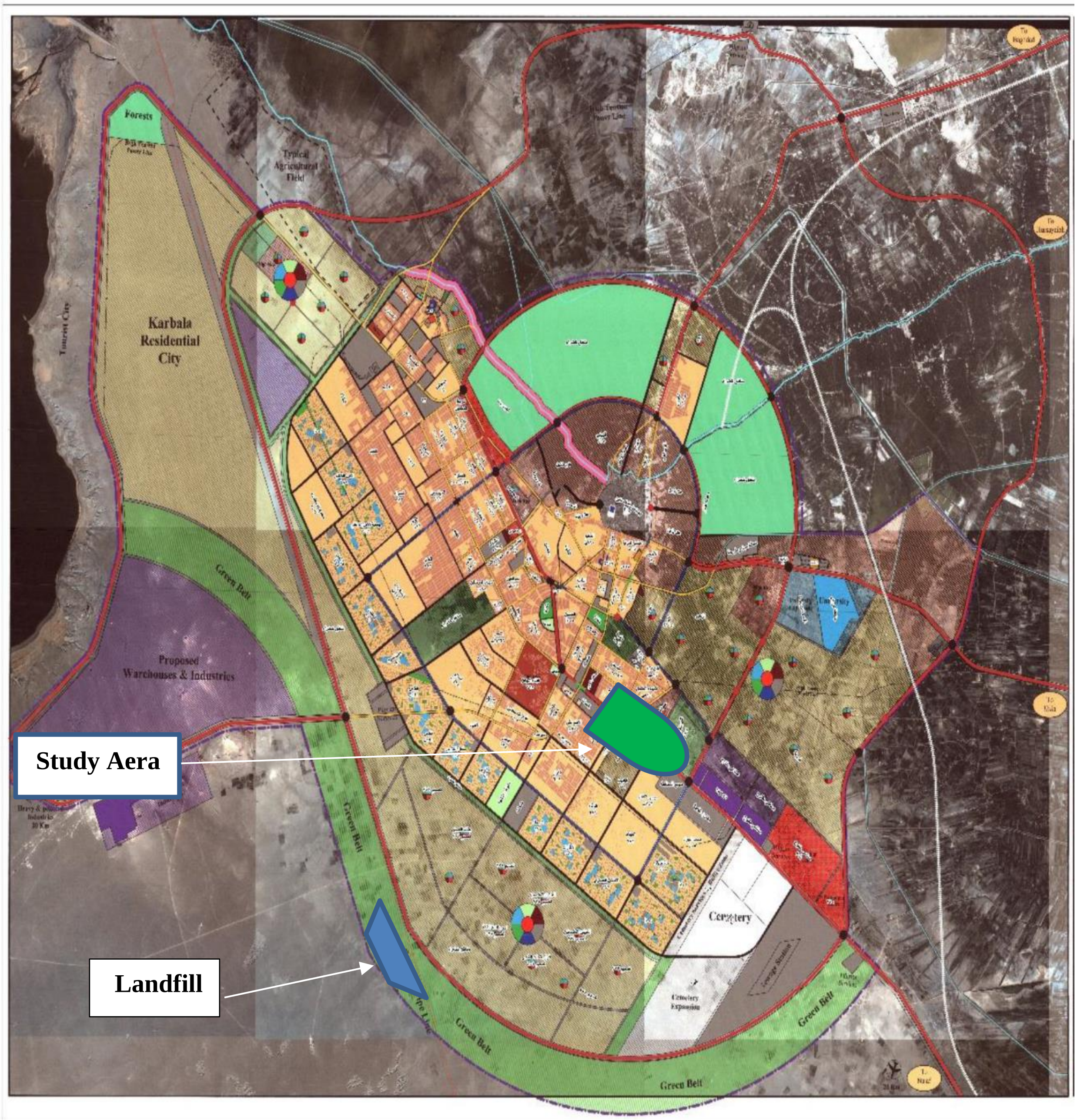

Fig (4.2): Digital Map of Karbala District Center [Karbala Municipality Directorate,2020]

4.4 Equipment and Manpower

Equipment and manpower have a major effect on collection operation, fleet size, crew size, and work day time, all these factors affect productivity, in addition to other factors that affect an efficiency of the collection which has been mentioned earlier, Fuel cost (FC): it is the price of fuel that consumed to move solid waste per kilometer. Baghdad municipality determines half a liter of fuel therefor the fuel cost calculation for each one kilometer as fallowing.

Fuel Cost = 0.5 liter * Pf…………..(4.1)

Pf = price of fuel Price of one liter fuel = 400 Iraq dinar (ID) therefor **Fuel cost of each kilometer** = **0**. **5 liter** ∗ **400** = **200 I**D. (Amjad, 2020). The total cost can also be calculated from the following equation:

Cost (Total cost) =Operation cost +Maintenance cost + (Depreciation cost) will be estimated as (ID/Km)…………(4.2)(Karbala Municipality Directorate)

As shown in Table (4.6).

Table (4.6): Compactor Costs (ID/Km)
[Karbala Municipality Directorate, 2020]

Compactor Costs	2010	2020	Increase%
Operation Cost	205 ID/Km	230 ID/Km	12%
Maintenance Cost	510 ID/Km	620 ID/Km	21%
Depreciation cost	20 ID/Km	30ID/Km	1.5%
Total Cost	735 ID/Km	880 ID/Km	4%

4.5 Collection Frequency and Waste Density

Urban solid waste is one of the most significant environmental issues of our time, especially in developing nations where it is one of the major sources of pollution. Trash is a direct contributor to environmental contamination, which has detrimental effects on production and human health.

Due to the convergence of living standards, the proportions of the solid waste components in Karbala city were comparable to those of other cities in developing countries, and the proportions of food waste contain high levels of organic matter. Solid waste contributes to the spread of disease, increased mortality, and decreased levels of wellbeing (Issa, 2017).

4.6 Routing

Three maps of the study area were taken from the municipality of Karbala and the arterial streets were identified and the amount of solid waste was calculated for them, boundaries are already defined for each district in Karbala city, The following has been determined:

- Location of refuse collection points.

Solid waste collection points are at the end of each branch, as shown in Table (A-1), (A-3), and (A-5) in Appendix A

- Streets in the collection area requiring service.

All streets were assumed to need service, except some which don't contain any waste generation source, which was excluded from the network, those streets generally are very few, short in distance.

- Solid waste generated on each street requiring service.

Solid waste generation rates were taken from Table (4.7).

- Location of garage and disposal area.

Proper distances from the garage to the district were determined, also a proper distance from district to disposal site

was determined, (as shown in Table 4.7)

- Available truck fleet and capacities.

Available truck was determined. Capacities are known to be between 3.88 and 4 tons, a capacity of 4 tons will be taken with 97% allowance, as mentioned (Al-Ali, 1995).

- Collection crew rates.

Collection crews were also determined for each district.

- Frequency of service for each collection point.

Frequency of collection was assumed six times a week in summer and winter, the simulation program will consider the two situations.

Table (4.7): Districts Information (Karbala Municipality Directorate)

Property	Al-Mulhaq (1,2)	Shohadaa Al-Mulhaq & Dhubat Al-Usra	Al-Usra
Area(m^2)	513963	377722	351569
Estimated census (Year 2020)	14009	6745	6276
No. of residential. Units	1068	766	431
Avg. area of residential. Unit(m^2)	100-450	80-400	150-600
Population Density (capita/km^2)	27257	17857	17851
Populations per residential unit (capita/unit)	13.117	8.805	14.561
Collection vehicles	3	2	2
Working crews (Driver)	1	1	1
Working crews (Worker)	2	2	2
Distance from garage to neighborhood (Km)	7	5	6
Distance from district to disposal site (Km)	52	32	42
Estimated waste quantity per day (kg/day)	21014	10118	9414
Frequency of service per week	6	6	6

The Streets Priorities Estimation Table (4.8) displays the number of nodes, number of links, and street lengths for the study area and type of residential street.

Ease of work: which includes ease of maneuvering of the truck due to street width, ease of access to a street or to waste containers, with the maximum degree of 10 which was used (Karbala Municipality Directorate).

Table (4.8): Streets Priorities Estimation

Property	Districts		
	Al-Mulhaq (1,2)	Shohadaa Al-Mulhaq & Dhubat Al-Usra	Al-Usra
Nodes Number	167	110	66
Streets number	233	167	95
Street’s kind	R	R	R
Ease of work (Waste handling) and maneuvering (Street width)	10	10	10
Total street lengths(m)	15610	13353	3829
Total waste quantity generated per day (Ton/day)	20	10	8

R= Residential

A tour should never utilize all of the other links touching one of the endpoints of this street without first using one of the links representing this street. If this rule is violated, the result is a U-turn in the tour, because one of the two links representing the street is finally used, the only exit from the node entered on this link is the other link representing the same street. At this juncture, it is possible to resort to the method of inserting cycles. All that is necessary is to find a node already in the tour which is touched by links not yet in tour. The tour can be broken at this node, and a new cycle of links can be inserted into it. This procedure may be continued until all links of the network have been included in the tour (Cordasco et al., 2010).

4.7 Win QSB Program Work

There are many data required for the computer to find solutions for the optimal path for the movement of the compactor when collecting waste from one locality to another, specifically for two types of solutions are the following:

1-The shortest possible path between two nodes, one representing the starting point and the other representing the endpoint.

2-The least possible number of connections between the beginning and end nodes for each residential neighborhood in the study area.

From the observation of Table (A-1) in Appendix A, it is possible to determine those data for Al-Mulhaq (1,2), where the existing streets were covered with 223 ties of different lengths. The lengths of the ties ranged from (15 - 450) m. This disparity in the lengths of the ties depends on the nature of the main or secondary streets. It is worth noting that as the connections were at great distances, the number of nodes covering the area decreased, as these nodes represent waste collection points and the compactor must stop at them, and that the density of collection points in crowded areas with many sub-streets is more than in the main streets.

Table (A-2) in Appendix A shows the information about Dhubat AL-Usra & Shohadaa Al-Mulhaq as input to the program to find the path of the collection compactor that achieves the collection of the largest possible amount of solid waste generated in it.

From the observation of the general structure of this table, we find that it includes the bundle number and its symbol and a coding for the beginning and end nodes, as well as the amount of waste generated weekly at the beginning and end nodes, measured in kilograms, using the following relationship: (Shamshir, 2001).

The amount of waste generated for a particular bundle (kg) = the average waste generated along the bundle (kg/m.l /day) * bundle length (m.l) * number of days of the week…..(4.3)

Amount of waste generated along each bundle calculated from the above relationship was distributed to both ends of the bundle and as shown in the table and that this distribution was not equal, but with different weights at each node in line with what was observed in the field of solid waste distribution.

Table (A-3) in Appendix A represents the information required to find solutions (the shortest path and the least number of ties) for the residential neighborhood, Shohadaa Al-Mulhaq & Dubat Al-Usra, through 110 bundles ranging in length from 18 to 400 m.

The short distance ties represent the sub streets in the region, while the long distance ties represent the main streets of the region, and each tie has been identified with the beginning and end nodes. For example, the link No. 33 was given within the QSB program the symbol (B33) and is specified by knots No. 17 and 20 and a length of 75 m.

The rest of the links in the mentioned residential neighborhood can be defined.

Table (A-4) in Appendix A presents the data related to Shohadaa Al-Mulhaq & Dubat Al-Usra area, which are required as input to the calculator to find a solution that achieves the collection of the largest possible amount of waste generated from the mentioned residential neighborhood.

The structure of this Table is similar to Table (A-2) for finding the same solution for Al-Mulhaq (1,2) as it also includes the amount of waste generated at the beginning and end nodes of each bundle.

The required information as input to find solutions (the shortest path, the least number of ties) for Al-Usra area is shown in Table (A-5) in Appendix A, where the streets were covered through 67 nodes of varying lengths. The lengths of these ties ranged from 33 m to 393 meters depending on the location of the ties within the streets of the region.

Table (A-6) in Appendix A, represents the data for Al-Usra neighborhood, which is required to find the path that represents the collection of the largest possible amount of solid waste. Prepare the table in the same way you prepared the Tables (A-2) and (A-4).

All the information referred to in the tables from (A1-A6), as shown in Appendix A was prepared through a field survey of the study area, as well as making use of the horizontal plans of the site and as indicated in the above paragraphs by finding the length of each tie based on the scale of the horizontal plans and verifying these lengths by measuring Field some randomly selected streets.

4.8 Win QSB Program Output

A ready-made program has been adopted to deal with the data referred to in the above-mentioned tables and by entering each type of this information separately for the residential neighborhoods within the study area. This information was stored on the calculator's memory in 6 different files.

The program processes each file's special processing depending on the type of the solution required which is governed by a particular target function. For example, to find the shortest possible path in AL-Mulhaq (1,2) between node No. 1 which represents the first collection point (the entry point of the compactor), and node No. (167) which represents the last collection point (the exit point of the compactor). There are several possible paths in front of the assembly mechanism, so the program calculates all the distances achieved from the movement of all possible paths and determines the path that achieves the least possible distance and thus the solution is reached (the shortest path). The outputs are in the form of a path expressed by writing the sequence of nodes that the assembly mechanism passes through. The program follows the same treatment method to find the shortest path with the data of the Martyrs of (Shohada AL-Mulhaq and Dhubat AL-Usra) and AL-Usra.

As shown in Tables (4.9), (4.10), and (4.11).

Table (4.9) Solution for Shortest Path Problem AL-Mulhaq (1,2)

03-22-2021	From	To	Distance/Cost	Cumulative Distance/Cost
1	Node1	Node3	110	110
2	Node3	Node5	250	360
3	Node5	Node7	100	460
4	Node7	Node8	38	498
5	Node8	Node9	125	623
6	Node9	Node77	30	653
7	Node77	Node78	140	793
8	Node78	Node165	243	1036
9	Node165	Node166	450	1486
10	Node166	Node167	425	1911

Table (4.10) Solution for Shortest Path Problem ShohadaaAL-Mulhaq & Dhubat AL-Usra

02-26-2021	From	To	Distance/Cost	Cumulative Distance/Cost
1	Node1	Node4	63	63
2	Node4	Node6	50	113
3	Node6	Node32	63	176
4	Node32	Node33	130	306
5	Node33	Node37	400	706
6	Node37	Node38	125	831
7	Node38	Node56	88	919
8	Node56	Node60	118	1037
9	Node60	Node62	63	1100
10	Node62	Node64	63	1163
11	Node64	Node66	50	1213
12	Node66	Node67	30	1243
13	Node67	Node68	100	1343
14	Node68	Node110	63	1406

Table (4.11) Solution for Shortest Path Problem AL-Usra

02-26-2021	From	To	Distance/Cost	Cumulative Distance/Cost
1	Node1	Node17	340	340
2	Node17	Node18	65	405
3	Node18	Node19	75	480
4	Node19	Node20	125	605
5	Node20	Node28	55	660
6	Node28	Node29	75	735
7	Node29	Node30	128	863
8	Node30	Node64	58	921
9	Node64	Node65	68	989
10	Node65	Node66	65	1054

(The source is the results of the electronic calculator using the Win QSB program)

To find the solution that represents the least number of connections, the program adopts different treatment, where the same required information is used as input to the previous solution (the shortest path) with a different goal function, where the program has several options for the movement of the mechanism between the start and end nodes for each residential neighborhood within the study area.

The program calculates the number of links that make up each possible path and then chooses the path that gives the least number of links, and this is represented by writing the contract numbers of the aforementioned solution. Finding these solutions is done by setting the goal function subject to certain determinants and this goal functions towards reducing the distance between the first and last node in the network and it can be formulated as follows: (Shamshir, 2001).

$$\text{Min } Z = \sum_{i=1}^{m} Xi \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.4)$$

Subjected to:
$t \leq T$
$f = 2\text{-}3$

Z= Objective function.

Xi = The length of the street within the network between the start and endpoint (m).

M = The number of streets between the beginning and end nodes.

t = Time period for solid waste collection (hr).

T = The number of daily working hours available.

N = Volume of labor currently available (m^3).

f = Frequency of waste collection per week.

The program also processes a number of the aforementioned files to find the solution that achieves the collection of the largest amount of solid waste, where this solution needs to know the amount of waste generated at each node. As for the lengths of the ties, they are not necessary because they are not included in the objective function.

The program calculates the total solid waste generated for all possible paths and selects the path that records the highest total solid waste, represented by the contract numbers that make up that path. Mathematically, this can be done by the following relationship: (Shamshir, 2001).

$$\text{Max } Z = \sum_{i=1}^{n} Li \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.5)$$

Subjected to:

$\sum Li \leq Vc$ for one trip

Where as:

Z = Objective function.

Li = The amount of waste generated on the street between the start and endpoint that needs to be collected within the network (kg/day.cap.).

Vc = Compactor Capacity (m^3).

n = The number of streets between the start and endpoints.

4.9 Output Graphic Representation

The program outputs were represented by graphing them on the horizontal plans of the study area, using the AutoCAD program. Figures (4.3), (4.4), (4.5) represent the solution presented by the program for solid waste collection from Al-Mulhaq (1,2). Figures (4.6), (4.7), (4,8) represent the solutions provided by the program to collect solid waste for Shohada AL-Mulhaq and Dhubat AL-Usra. While figures (4.9), (4.10), (4.11) represent the alternatives suggested by the program as solid waste collection paths from Al-Usra neighborhood.

When observing each of the alternatives referred to above, it can be seen that the single alternative is not an efficient process for solid waste collection, because each alternative has been identified in the light of a specific objective function.

For example, Figure (4.3), which represents the shortest possible path to AL-Mulhaq (1,2). This path starts with Node No. 1 and ends with Node No. 167, and this path does not serve all nodes that cover the study area.

Figure (4.6), which represents the least possible number of ties for AL-Mulhaq (1, 2). Where this path begins with node number 1 and ends with node number 167 also, but it differs in its nature from the path referred in Figure (4.3), and so on for the rest of the solutions.

4.10 Specifications of Initial and Final Solutions

4.10.1 Shortest Path

Figure (4.3) shows the scheme for AL-Mulhaq (1,2), showing the shortest possible path, the path begins with node No. 1 and passes through a number of nodes that represent street intersections, which are a non-sequential node, and then ends with node No. 167 and this path does not pass in all the main or secondary streets, as it does not achieve the process of collecting waste. The solids generated in the streets within the aforementioned residential neighborhood.

Figure (4.4) shows the plan for Shohada AL-Mulhaq and Dhubat AL-Usra showing the shortest possible path, as the path begins at node No. 1 passing through the node (1, 4, 6, ... to the last node No. 110) located at the other end of the mentioned residential neighborhood. The length of the proposed path is (1406) m, and it serves 11% of the total area, as the total length of the streets in it is (13353) m.

Figure (4.5) shows the plan for AL-Usra residential neighborhood, showing the path that represents the shortest possible path, as the path starts at node No. 1 through the node (1, 17, 18, ... to the last node number 66). The length of the proposed path according to this solution is (1054) m, and thus constitutes (11%) of the total lengths of the streets in the mentioned locality, which is (9382) m. It is a very small percentage.

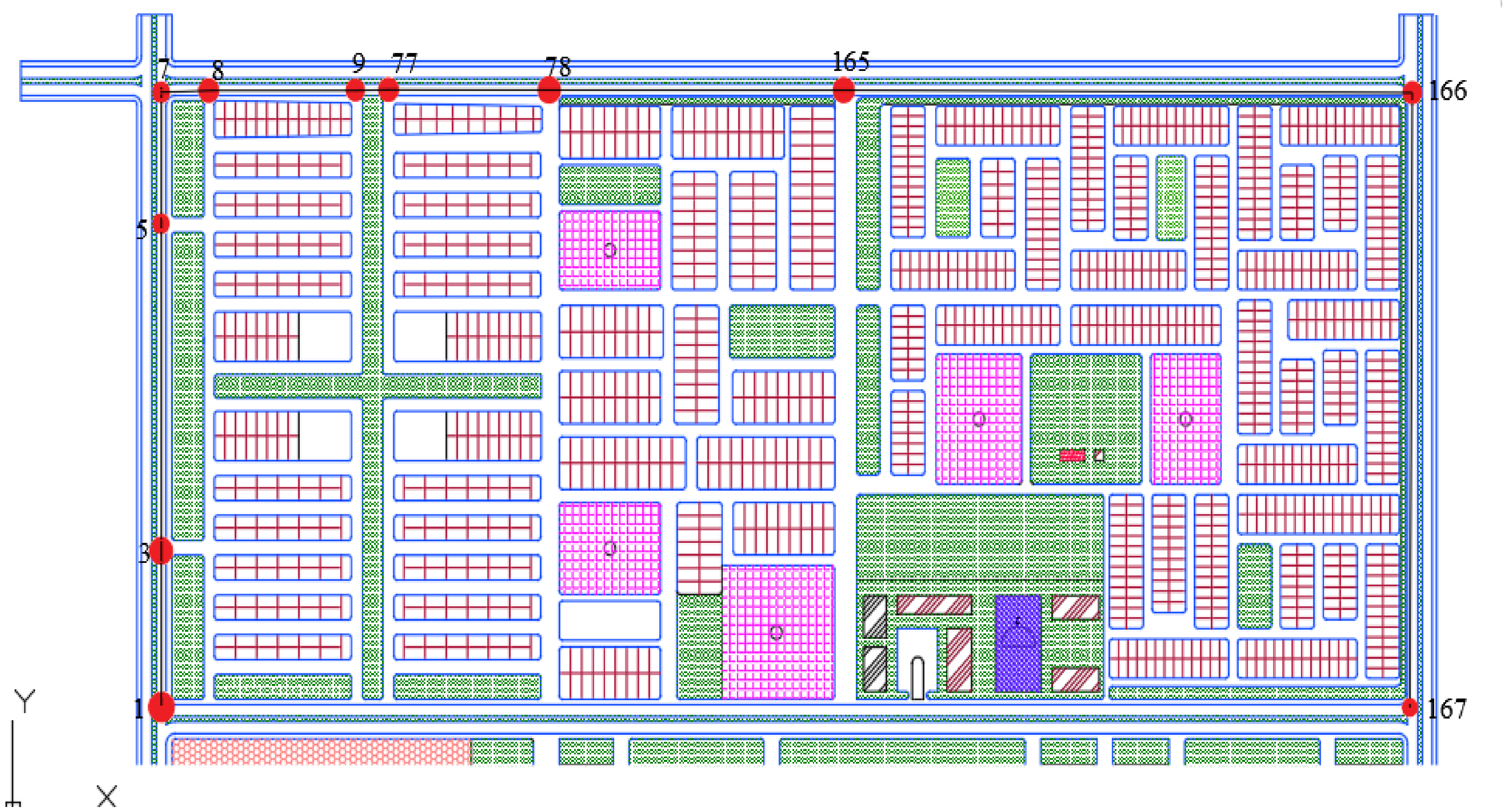

Figure (4.3): The plan for AL-Mulhaq (1,2) showing the shortest possible path using AutoCAD.

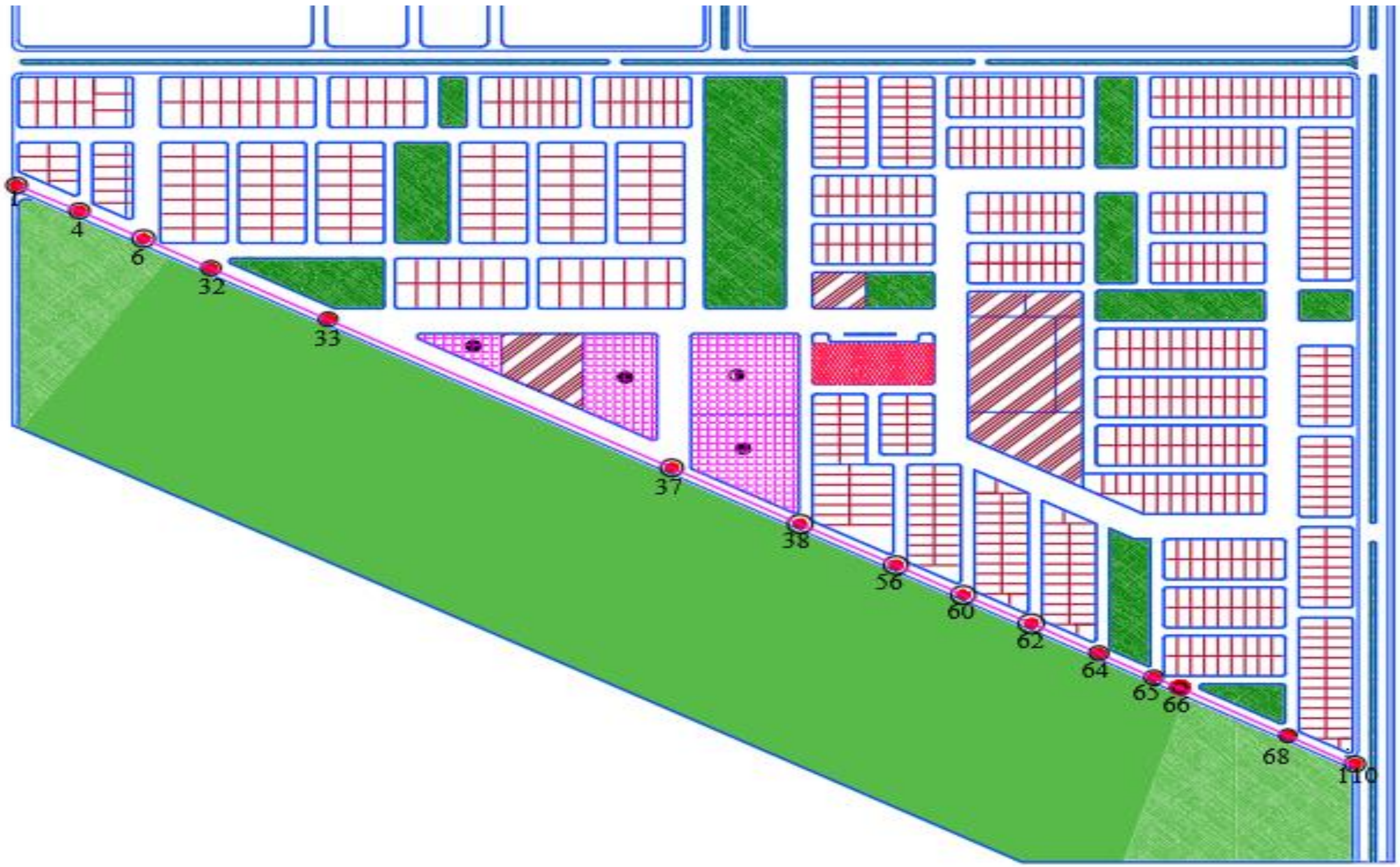

Figure (4.4): The plan for Shohada AL-Mulhaq & Dhubat AL-Usra showing the shortest possible path using AutoCAD

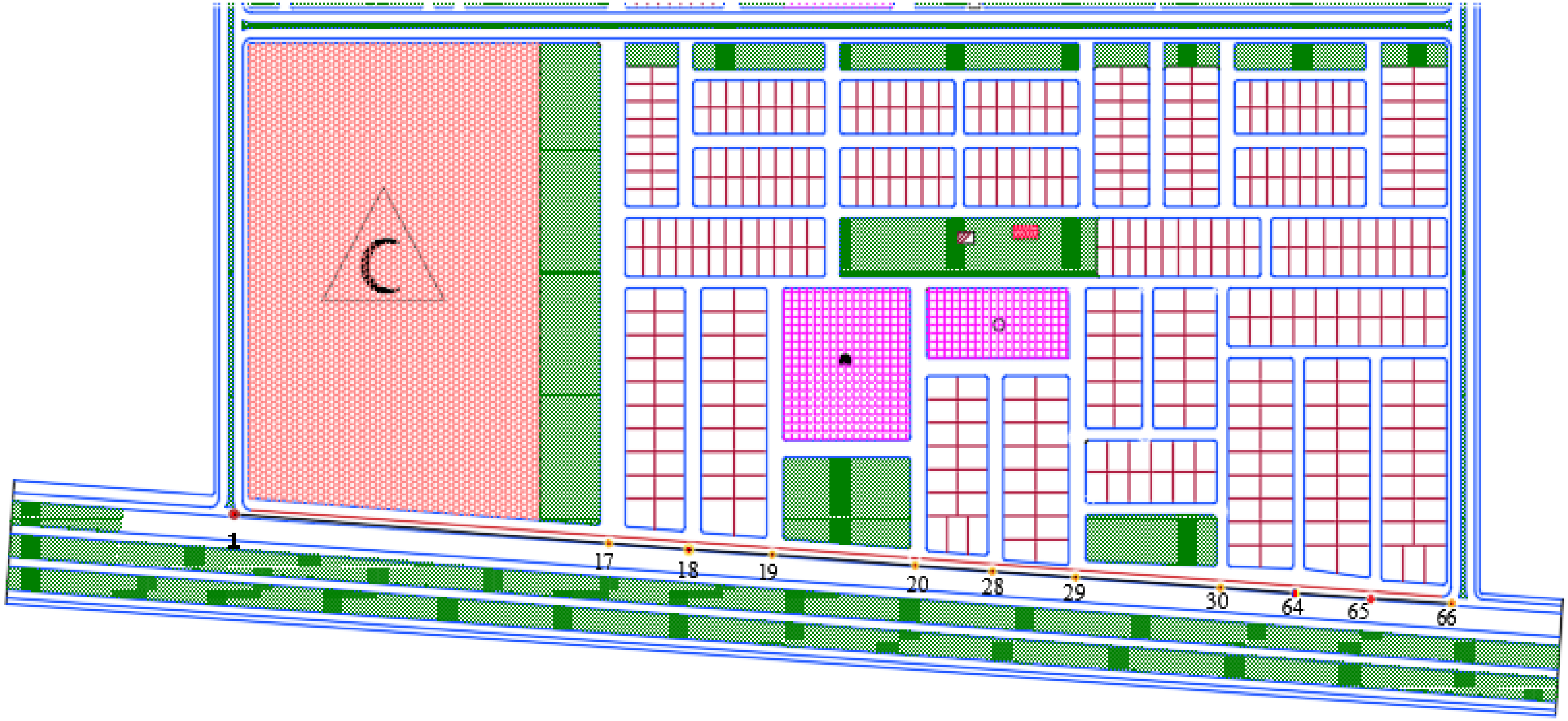

Figure (4.5): The plan for AL-Usra showing the shortest possible path using AutoCAD.

Table (4.12) gives the specifications of this path, as consists of (11) nodes, any waste collection point, and the length of the path (1911) m. The proposed path according to this solution constitutes a service (12%) of the area, because the total lengths of the streets for the mentioned area, from which waste collection is required (15610) m, and this reinforces mentioned earlier that a single solution does not achieve the required efficiency in solid waste collection.

Table (4.12) General Specifications of the Proposed Solutions Shortest Path to Study Area

District Name	Route	Collection Points Number	Route Length (m)
AL-Mulhaq	1, 3, 5, 7, 8, 9, 77, 78, 165, 166, 167	11	1911 %12
Shohadaa Al-Mulhaq & Dhubat Al-Usra	1, 4, 6, 32, 33, 37, 38, 56, 60, 62, 64, 66, 67, 68, 110	15	1406 11%
AL-Usra	1, 17, 18, 19, 20, 28, 29, 30, 64, 65, 66	11	1054 11%

4.10.2 Minimum number of links

Figure (4.6) shows the plan for the residential neighborhood in AL-Mulhaq 1 and 2, showing the path that represents the least number of links. This path begins with node No. 1 through knots (1, 2, 34, and then ends with the last node No. 167), which is located at the other end of AL-Mulhaq (1,2).

This path took another group of streets that differed from the path in the previous solution (the shortest path), despite the use of the same inputs for both solutions, but the results (paths) differed due to the difference in the target function. Also, the length of the proposed path under this solution is (2510) m, which constitutes serving the area by 16%, this path alone also does not cover the efficiency required for solid waste collection.

Figure (4.7), shows the scheme of Shohada AL-Mulhaq and Dhubat AL-Usra, explaining the path that represents the least number of links, as the path begins at node No. 1 through the node (1, 2, 3, ... to the last node No. 110) and the length of the proposed path It is (2799) m, which constitutes about 21% of the total area.

Figure (4.8), which shows the plan for the residential neighborhood of AL-Usra, explaining the path that represents the least number of connections, this path has taken a different path from the previous path, as it included a number of internal streets that mediate the mentioned residential neighborhood and starts with Node No. 1 through a number of the contract (1, 17, 18, ... and ends with node No. 66) and the length of the proposed path under this solution is (1799) m, and thus constitutes (19) % of the total lengths of the streets in the mentioned residential neighborhood.

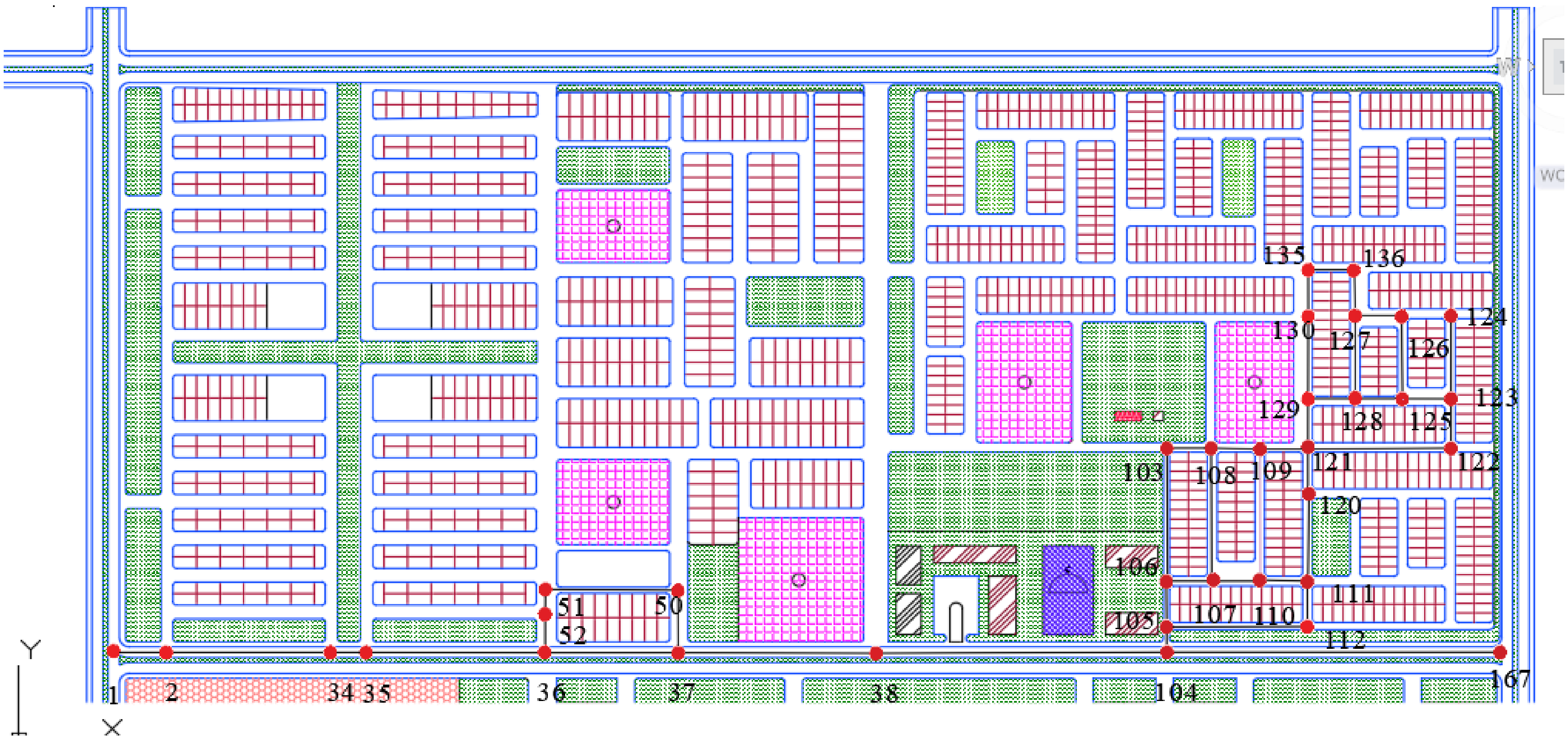

Figure (4.6): The plan for AL-Mulhaq (1,2) showing the minimum links using AutoCAD.

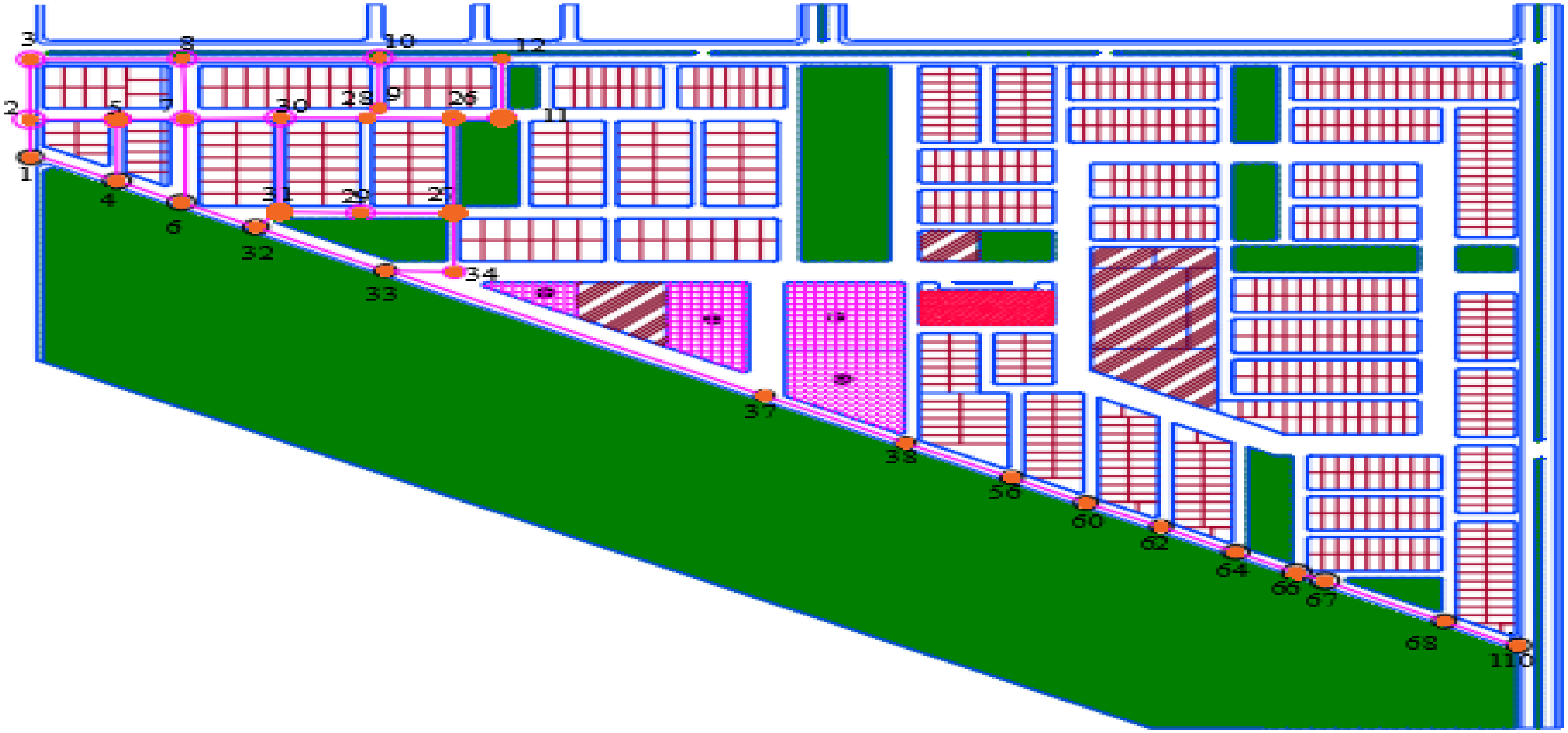

Figure (4.7): The plan for Shohada AL-Mulhaq & Dhubat AL-Usra showing the minimum links using AutoCAD.

Figure (4.8): The plan for AL-Usra showing the minimum links using AutoCAD.

These solutions are shown in Table (4.13).

Table (4.13) General Specifications of the Proposed Solutions Minimum Number of links Study Area

District Name	Route	Collection Points Number	Route Length (m)
AL-Mulhaq (1,2)	1, 2, 34, 35, 36, 37, 38, 50, 51, 52, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 135, 136, 167	34	2510 %16
Shohadaa Al-Mulhaq & Dhubat Al-Usra	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 26, 27, 28, 29, 30, 31, 32, 33, 34, 37, 38, 56, 60, 62, 64, 66, 67, 68, 110	31	2799 21%
AL-Usra	1, 17, 18, 19, 20, 25, 26, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 64, 65, 66	21	1799 19%

4.10.3 Maximum Load of Solid Waste

Figure (4.9) shows the path that achieves the collection of the largest possible amount of solid waste, starting with node No. 1, passing through the node (1, 2, 3, 5, ... to the last node No. 167). It is clear from this table that this path includes (62) A node, i.e., (62) solid waste collection points on a number of streets with a total length of (4,310) m, meaning that the proposed route under this route covers (28%) of AL-Mulhaq (1,2).

Figure (4.10) shows the plan for Shohada AL-Mulhaq and Dhubat AL-Usra explaining the path that achieves the collection of the largest possible amount of solid waste. We note that the path followed in this solution differs from the other two paths (the shortest path and the least number of connections) in terms of the number of collection points that pass through It has (66) nodes and in terms of the path length of (4,076) m, which constitutes about (31%) of the area to be serviced.

As for Figure (4.11), it shows the path that achieves the collection of the largest possible amount of solid waste from AL-Usra. This path took peripheral and central streets. The total number of nodes covered by this path reached (41) nodes extending on the streets, total length is (2825) m. Traffic on this aforementioned path means that about (31%) of the mentioned residential neighborhood is served.

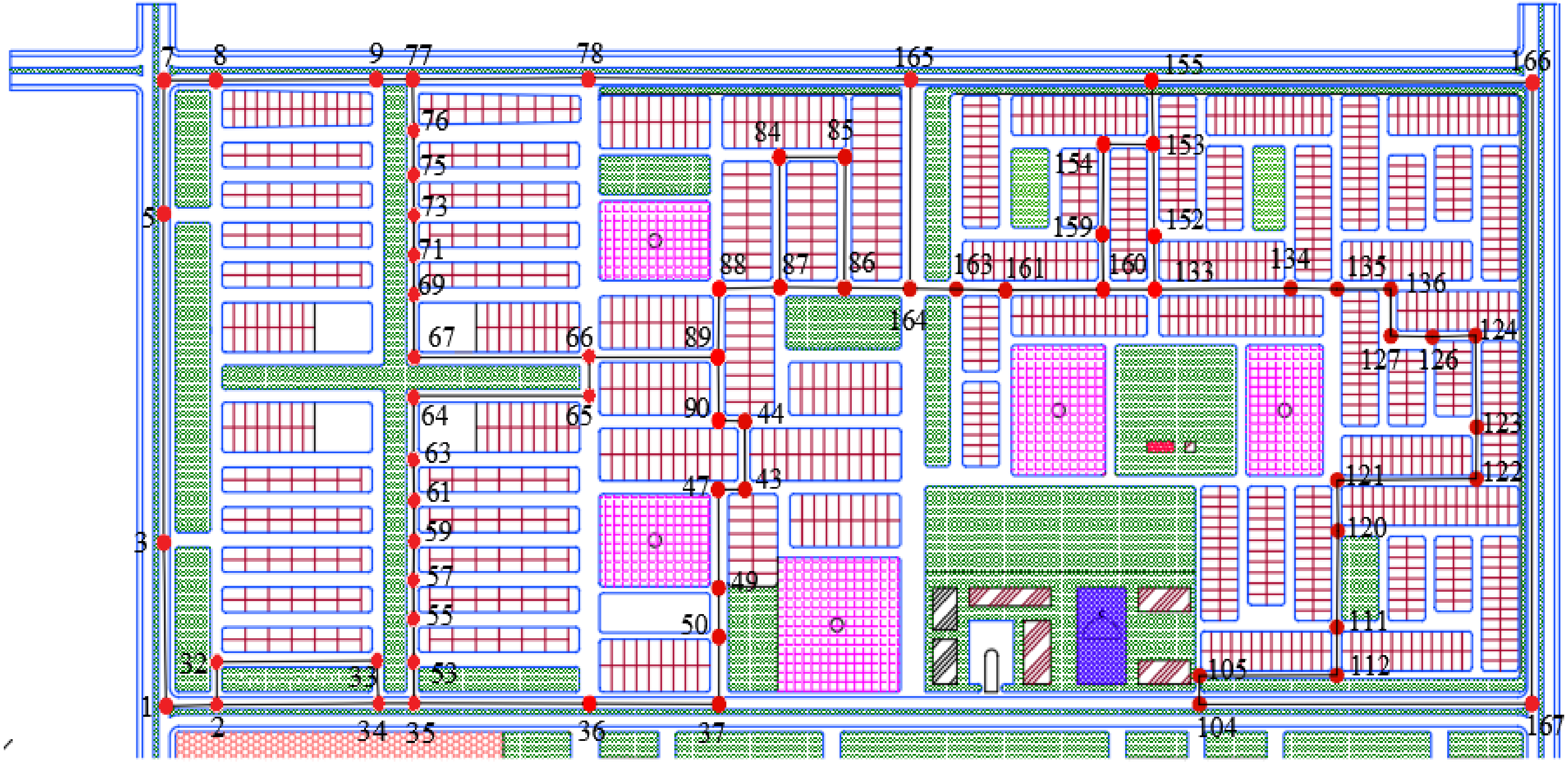

Figure (4.9): The plan for AL-Mulhaq (1,2) showing the maximization using AutoCAD.

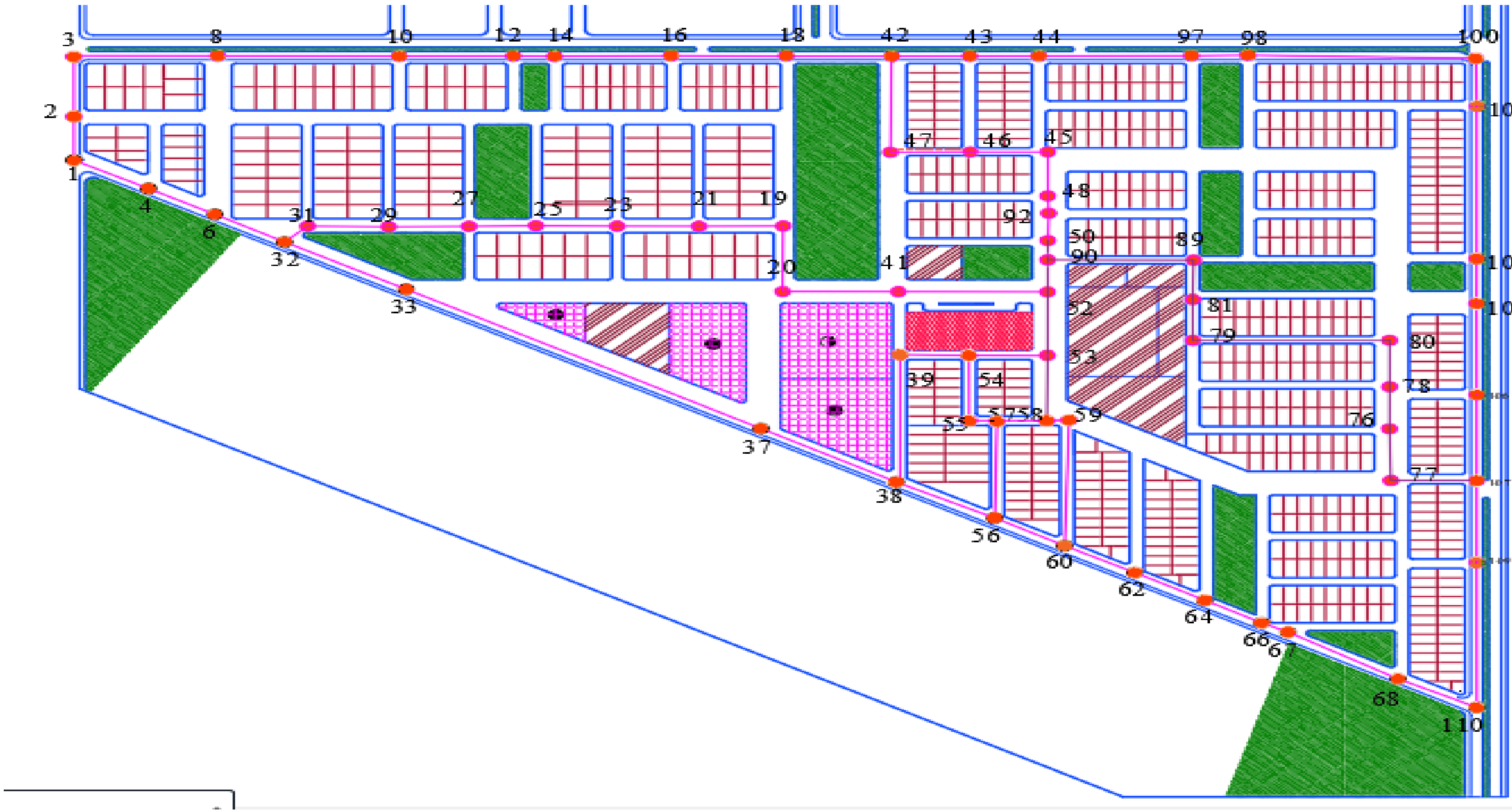

Figure (4.10): The plan for Shohada AL-Mulhaq & Dhubat AL-Usra showing the maximization using AutoCAD.

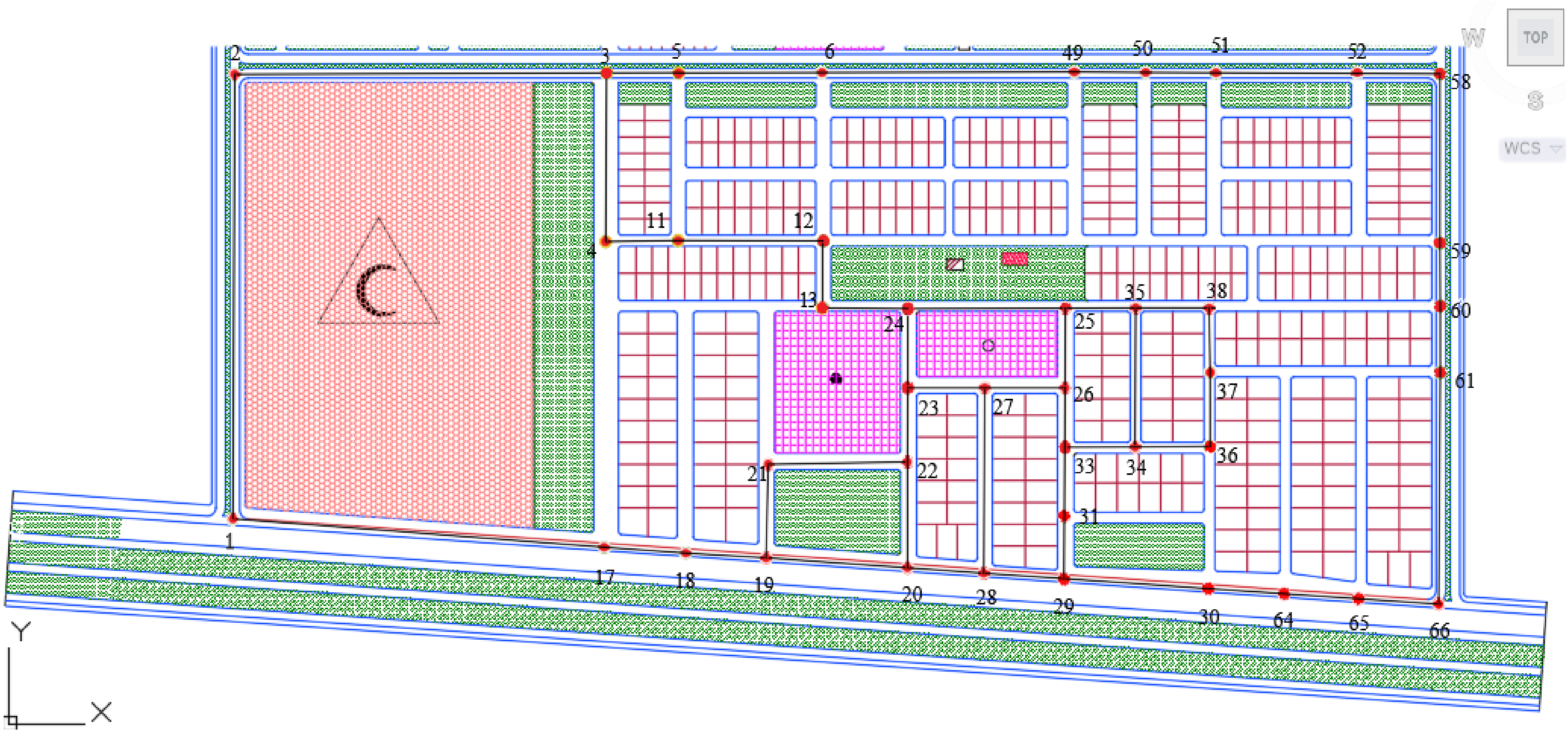

Figure (4.11): The plan for AL-Usra showing the maximization using AutoCAD.

Table (4.14) shows a summary of the proposed solutions to collect the largest amount of solid waste.

Table (4.14) General Specifications of the Proposed Solutions

Maximum Load of Solid Waste to Study Area

District Name	Route	Collection Points Number	Route Length (m)
AL-Mulhaq (1,2) 167	1, 2, 3, 5, 7, 8, 9, 32, 33, 34, 35, 36, 37, 47, 48, 49, 50, 53, 55, 57, 59, 61, 63, 64, 65, 66, 67, 69, 71, 73, 75, 76, 77, 78, 84, 85, 86, 87, 88, 89, 121, 122, 123, 124, 126, 127, 133, 134, 135, 136, 152, 153, 154, 155, 159, 160, 161, 163, 164, 165, 166, 167	62	4310 %28
Shohadaa Al-Mulhaq & Dhubat Al-Usra 110	1, 2, 3, 4, 6, 8, 10, 12, 14, 16, 18,19, 20, 21, 22, 23, 25, 27, 29, 31, 32, 33, 37, 38, 39, 41, 42, 43, 44, 45, 46, 47, 50, 52, 53, 54, 55, 56, 57, 58, 59, 60, 62, 64, 65, 66, 67, 68, 76, 77, 78, 79, 80, 81, 90, 92, 97, 98, 100, 102, 103, 104, 106, 107, 109, 110	66	4076 31%
AL-Usra 67	1, 2, 3, 4, 5, 6, 11, 12, 13, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 33, 34, 35, 36, 37, 38, 39, 49, 50, 51, 52, 58, 59, 60, 61, 63, 64, 65, 66	41	2825 30%

4.11 GIS Program Outputs

The specifications of this solution are shown in Table (4.15), where the final solution includes (81) nodes, i.e. (81) solid waste collection points and covers a length of (12130) m without dead tracks, which constitutes 78% of the total streets in AL-Mulhaq (1,2).

The proposed path in the final solution to the residential neighborhood mentioned above, it is noted that it is not possible to achieve continuity in the movement of solid waste collection mechanisms on the mentioned path without the presence of dead paths. In this regard, the mechanisms can pass in other sub-streets that are not installed in the path of the final solution to compensate for the dead paths, knowing that this traffic does not represent a dead path, but rather is a collection of solid waste in sub-streets that were not included in the path proposed in the final solution.

Noted that the single solutions are inefficient in collecting solid waste for the residential neighborhood mentioned above, so use the GIS program to apply the three solutions and produce the final solution shown in the scheme shown in Figure (4.13) that covers streets with a length of (9100) m, which is equivalent to serving 68 % of total area

The individual solutions do not achieve efficiency in the solid waste collection if each solution is adopted alone. The GIS program provides an implementation of the three solutions that resulted in the scheme shown in Figure (4.14), which represents the proposed path under the final solution to AL-Usra residential neighborhood. Where the total length of the streets is (6300) m, and thus constitutes (67) % of the mentioned residential neighborhood.

Table (4.15) General Specifications of the Proposed Solutions in the Selected Districts from Fourth Municipal Sector within the Study Area

District Name	Route	Collection Points Number	Route Length (m)	The amount of waste collected
Al-Molhaq (1)(2)	1, 2, 3, 5, 7, 8, 9, 32, 33, 34, 35, 36, 37, 38, 43, 44, 47, 49, 50, 51, 52, 53, 55, 57, 59, 61, 63, 64, 65, 66, 67, 69, 71, 73, 75, 76, 77, 78, 84, 85, 86, 87, 88, 89, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 133, 134, 135, 136, 152, 153, 154, 155, 159, 160, 161, 163, 164, 165, 166, 167	81	12130 78%	12 Ton/d
Shohadaa Al-Molhaq & Dubat Al-Usra	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 16, 18,19, 20, 21, 22, 23, 25, 26, 27, 28, 29, 31, 32, 33, 34, 37, 38, 39, 41, 42, 43, 44, 45, 46, 47, 50, 52, 53, 54, 55, 56, 57, 58, 59, 60, 62, 64, 65, 66, 67, 68, 76, 77, 78, 79, 80, 81, 90, 92, 97, 98, 100, 102, 103, 104, 106, 107, 109, 110	73	9100 68%	5 Ton/d
Al-Usra	1, 2, 3, 4, 5, 6, 11, 12, 13, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 49, 50, 51, 52, 58, 59, 60, 61, 64, 65, 66	41	6300 67%	4 Ton/d

From the Catalog Arc we create a Geodatabase File folder and inside this folder create a Layers container, Dataset Feature and within it, we create the required layers. To number the nodes, added a layer to the nodes of type Point, and entered them in a table, The area to which the nodes belong (Wazan, 2010).

The direction of the streets is described as follows:

- On two-way streets, you don't write any descriptive information in the < Null> one-way field.
- On the painted streets with their true direction F.

- On the painted streets opposite their true direction T.
- The speeds were entered by taking the speed values from the Karbala traffic police and they were determined as follows:
- On the main streets:60 h/km.
- On minor streets:40 h/km.
- Time: is calculated by entering an equation into the calculator field (time = distance / the speed), (Shahin et al, 2015).

As shown in Tables (4.16), (4.17), and (4.18).

Table (4.16) Descriptive Information for the Street Layer of Al-Mulhaq (1,2)

line

OBJECTID *	SHAPE *	line	SHAPE_Length	speed	Time_	one_way
1	Polyline	<Null>	3163.80876	60	0.052	F
2	Polyline	<Null>	194.049567	40	0.0048	T
3	Polyline	<Null>	757.462837	60	0.0126	<Null>
4	Polyline	<Null>	610.01784	40	0.0153	F
5	Polyline	<Null>	37.04422	40	0.0009	F
6	Polyline	<Null>	303.282005	40	0.0076	T
7	Polyline	<Null>	338.738862	60	0.0057	F
8	Polyline	<Null>	109.222046	60	0.0018	<Null>
9	Polyline	<Null>	109.433742	40	0.0027	F
10	Polyline	<Null>	71.805634	40	0.0018	F
11	Polyline	<Null>	72.11806	40	0.0018	F
12	Polyline	<Null>	853.40027	40	0.0213	T
13	Polyline	<Null>	98.030072	40	0.0025	<Null>
14	Polyline	<Null>	251.912185	40	0.0063	F
16	Polyline	<Null>	155.041082	40	0.0039	F
17	Polyline	<Null>	154.538705	40	0.0039	F
18	Polyline	<Null>	146.079437	40	0.0037	F
21	Polyline	<Null>	154.422565	40	0.0039	F

Table (4.17) descriptive information for the street layer of the Shohadaa Al-Mulhaq & Dhubat AL-Usra.

lin

OBJECTID *	SHAPE *	line	SHAPE_Length	on_way	speed	Time_
3	Polyline	<Null>	3165.26169	F	60	0.0527
4	Polyline	<Null>	161.527729	F	40	0.0041
5	Polyline	<Null>	60.211072	F	40	0.0015
6	Polyline	<Null>	66.46898	<Null>	40	0.0015
7	Polyline	<Null>	44.279201	T	40	0.0011
8	Polyline	<Null>	76.899226	F	40	0.0019
9	Polyline	<Null>	103.505581	F	60	0.0017
10	Polyline	<Null>	139.902114	T	40	0.0035
11	Polyline	<Null>	280.836343	<Null>	60	0.0047
12	Polyline	<Null>	59.48189	F	40	0.0015
13	Polyline	<Null>	46.106466	F	40	0.0012
15	Polyline	<Null>	136.064705	F	40	0.0034
16	Polyline	<Null>	325.406909	F	40	0.0081
17	Polyline	<Null>	119.886979	F	40	0.003
18	Polyline	<Null>	108.710181	<Null>	40	0.0027
19	Polyline	<Null>	70.352769	F	40	0.00175
28	Polyline	<Null>	101.380089	F	40	0.0025
29	Polyline	<Null>	102.094518	T	40	0.0026
31	Polyline	<Null>	306.993493	F	40	0.0077

Table (4.18) descriptive information for the street layer of the Al-Usra.

line

OBJECTID *	SHAPE *	line	SHAPE_Length	speed	time_	one_v
1	Polyline	<Null>	2992.010195	60	0.0498	F
2	Polyline	<Null>	638.676904	60	0.0106	T
3	Polyline	<Null>	848.536161	60	0.0142	F
4	Polyline	<Null>	142.483983	40	0.0035	F
5	Polyline	<Null>	248.264761	40	0.0062	F
6	Polyline	<Null>	200.499426	40	0.005	F
7	Polyline	<Null>	94.300646	40	0.0024	F

(The source is the results of the electronic calculator using the ArcGIS program)

From Tool Analyst Spatial, which provides a network based on spatial analysis and using a network data model that enables the user to easily build networks based on GIS data, and this extension chooses the optimal path by calculating the minimum topological distance that the vehicle can traverse. A new route was chosen for each section of the area, which was followed by the identification of the principal garbage collecting hubs and solution. This allowed the program to select the best course for the process plan for the collection and deportation of waste.

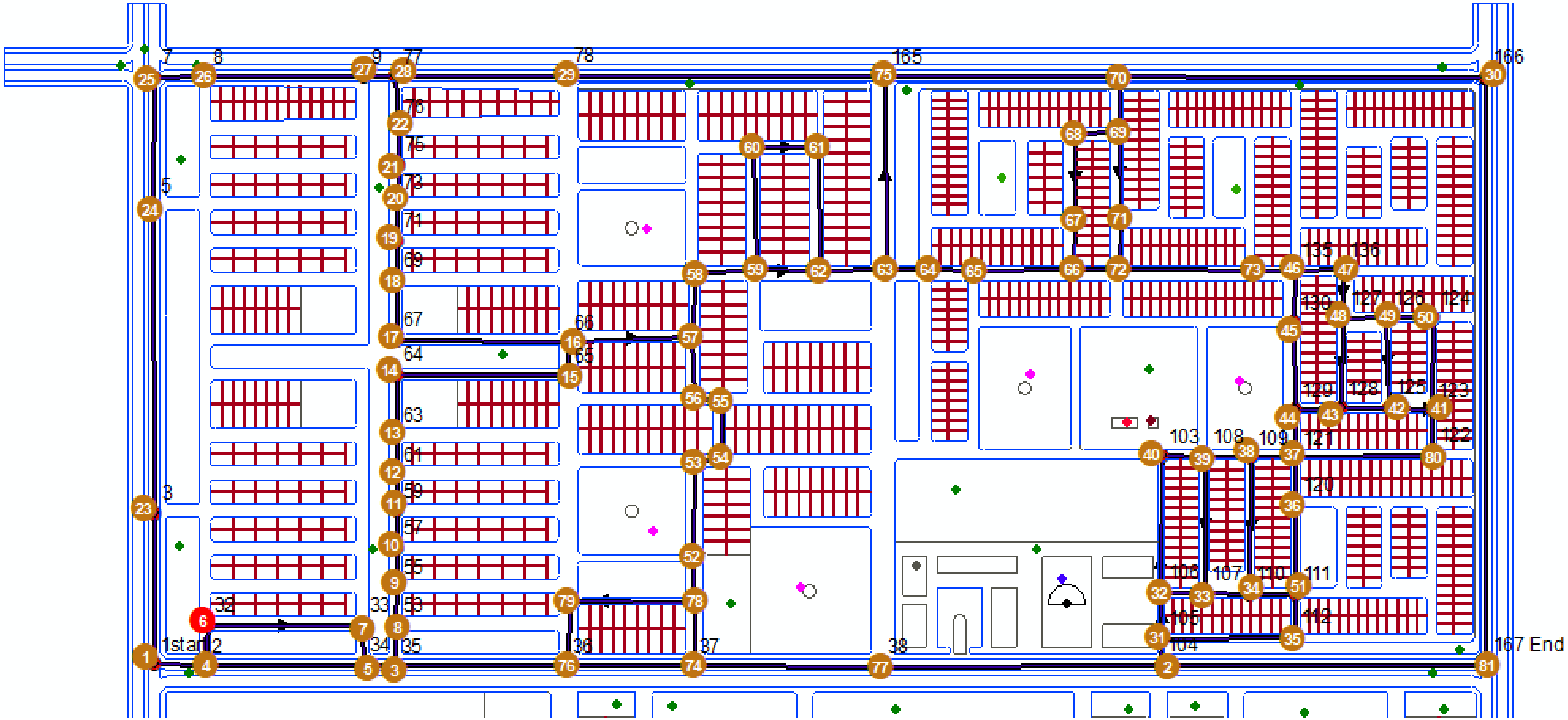

Figure (4.12): The plan for AL-Mulhaq (1,2) showing the path that represents the final solution using Arc GIS.

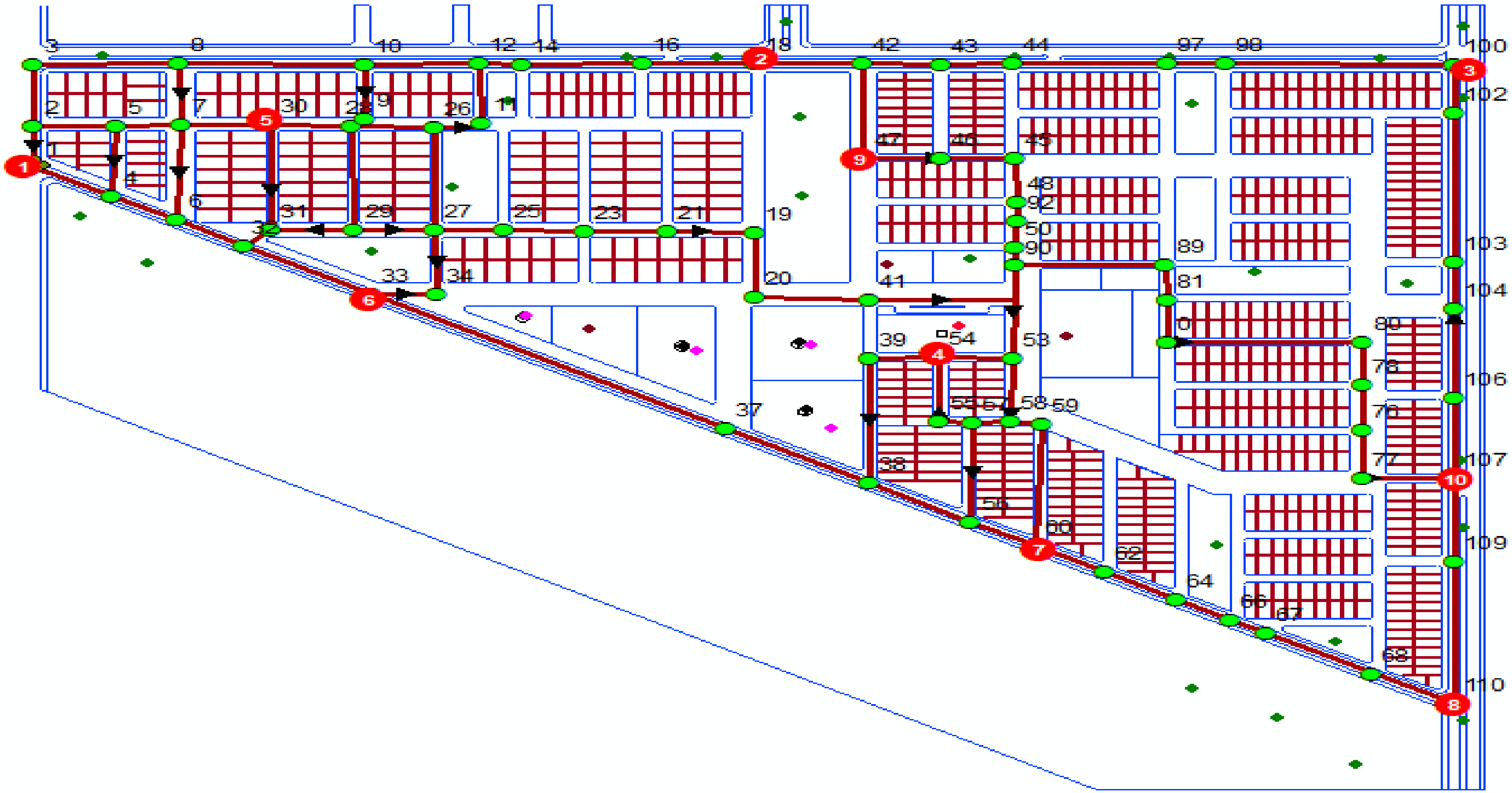

Figure (4.13): The plan for Shohadaa AL-Mulhaq & Dhubat AL-Usra showing the path that represents the final solution using Arc GIS.

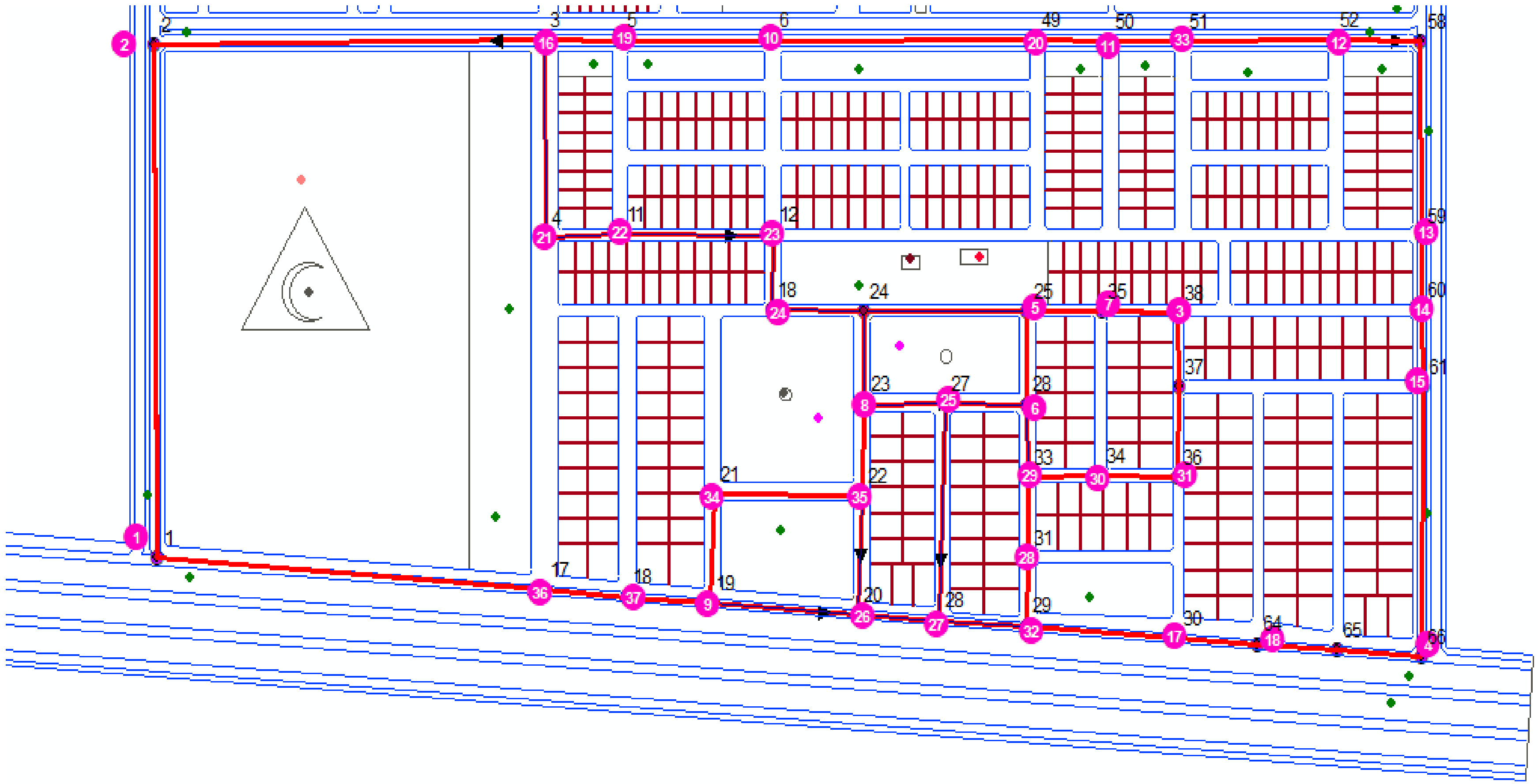

Figure (4.14): The plan for AL-Usra showing the path that represents the final solution using Arc GIS.

4.12 Movement Timing Tables

The movement schedules for the daily cleaning campaigns, including the number of compactors, tippers, flaps, workers, and solid waste collection for the study area (AL-Mulhaq (1,2), Shohadaa AL-Mulhaq & Dhubat Al-Usra, and AL-Usra), are determined according to the material and human capabilities available to the Karbala Municipality Directorate at present, and as shown below:

Table (4.19) shows the movement of the proposed waste collection mechanisms during the winter season. It is noted from the mentioned table that the AL-Mulhaq (1,2) is divided into three equal sectors in terms of collection points, and thus we assumed that each sector is passed twice a week (waste collection frequency). For example, the collection mechanisms pass through the sector that includes the nodes from (1-55) on Saturday and Tuesday of each week, while the same mechanisms for solid waste collection pass from the sector that includes the contract from (56-110) on Sunday and Wednesday. As for the third sector, which includes the nodes (111-167) passes on Monday and Thursday of every week.

The Machines type used to collect waste within AL-Mulhaq (1,2) are 1 tipper, 2 shffels and 3 compactors, where the load of the tipper is estimated at 8 tons, the load of shffel 4 ton, and the load of the compactor is 4 tons (Karbala Municipality Directorate). Therefore, the total load collected per day is 24 tons of solid waste, and this is assuming the implementation of one trip per day for each machine during working hours because there is one shroud that loads all these machines, and in the event of providing another shroud, the number of trips can be increased and a greater amount of solid waste is lifted.

As for Shohadaa AL-Mulhaq & Dhubat Al-Usra, it is noted in Table (4.20) that the area has been divided into three equal sectors in terms of collection points. The sector that includes the nodes (1-43) is passed on Saturday and Tuesday of each week, while solid waste collection passes through the sector that includes the nodes (44-75) on Sunday and Wednesday of every week, while the sector that includes the nodes (76-110) is passed on Monday and Thursday of every week, and the same is true in Table (4.21) for AL-Usra. The snaps were used to collect the solid waste of these two neighborhoods because the waste generated is less than what it is in AL-Mulhaq (1,2) and the load of the press per trip is 4 tons. As for Table (4.22), which shows the movement of the proposed mechanisms during the summer, it is clear from it that each neighborhood within the study area is divided into two equal sectors in terms of the number of waste collection points for the neighborhood. Each sector is passed through three times a week. For example, the collection mechanisms pass over the sector that includes the nodes (1 - 83) In AL-Mulhaq (1,2) on Saturdays, Mondays, and Wednesdays of each week, as well as the collection mechanisms pass on the second sector, which includes the nodes (84-167) on Sundays, Tuesdays, and Thursday's weekly. Therefore, the frequency of waste collection during the summer is six times a week to avoid the damage caused by the decomposition of solid waste as a result of high temperatures, as well as the case for the rest of the residential neighborhoods. The same applies to Shohadaa AL-Mulhaq, Dhubat Al-Usra, and AL-Usra as shown in Table (4.23) and (4.24).

The compactor made one trip per day, which means providing one compactor for all days of the week to benefit from it in collecting solid waste from other areas outside the study area or increasing the efficiency of collection in the neighborhoods that fall within the study area by passing on some streets that were not covered by the final solution (the optimal path).

Table (4.19) The Movement of Machinery and Cleaning Campaigns for the Winter Season AL-Mulhaq(1,2)

Day	AL-Mulhaq(1,2)	Daily cleaning campaigns		Machine type	Lifted load (tons)
		Compactor	No. of workers		
Saturday	From 1-55	3	6	1 Shffel+1Tippe	24
Sunday	From 56-110	2	4	1Shffel+1Tipper	20
Monday	From 111-167	3	6	1 Shffel or (1Tippe)	16
Tuesday	From 1-55	2	4	1 Shffel+1 Tipp	20
Wednesday	From 56-110	1	4	1Shffel+1Tipper	16
Thursday	From 111-167	2	6	1 Shffel+1 Tipp	20

Table (4.20) The Movement of Machinery and Cleaning Campaigns for the Winter Season Shohadaa AL-Mulhaq & Dhubat Al-Usra

Day	Shohadaa AL-Mulhaq & Dhubat Al-Usra	Daily cleaning campaigns		Machine type	Lifted load (tons)
		Compactor	No. of workers		
Saturday	From 1-43	2	6	1 Shffel+1Tipper	20
Sunday	From 44-75	1	4	1 Shffel+1Tipper	16
Monday	From 76-110	2	4	1 Shffel+1Tipper	20
Tuesday	From 1-43	2	5	1Shffel or 1Tipper	12
Wednesday	From 44-75	1	2	1 Shffel+1Tipper	16
Thursday	From 76-110	2	4	1 Shffel+1Tipper	20

Table (4.21) The Movement of Machinery and Cleaning Campaigns for the Winter Season AL-Usra

Day	AL-Usra	Daily cleaning campaigns		Machine type	Lifted load (tons)
		Compactor	No. of workers		
Saturday	From 1-23	2	6	1 Shffel+1Tipper	20
Sunday	From 24-50	2	5	1 Shffel or 1Tipper	12
Monday	From 44-66	2	4	1 Shffel+1Tipper	20
Tuesday	From 1-23	1	2	1 Shffel or 1Tipper	8
Wednesday	From 24-50	2	4	1 Shffel+1Tipper	20
Thursday	From 44-66	1	2	1 Shffel or 1Tipper	12

Table (4.22) The Movement of Machinery and Cleaning Campaigns for the Summer Season AL-Mulhaq(1,2)

Day	AL-Mulhaq(1,2)	Daily cleaning campaigns		Machine type	Lifted load (tons)
		Compactor	No. of workers		
Saturday	From 1-83	3	6	1 Shffel+1Tipper	24
Sunday	From 84-167	2	4	1 Shffel+1 Tipper	20
Monday	From 1-83	2	6	1 Shffel or 1Tipper	12
Tuesday	From 84-167	2	4	1 Shffel+1 Tipper	20
Wednesday	From 1-83	2	6	1 Shffel or 1Tipper	12
Thursday	From 84-167	1	6	1 Shffel+1 Tipper	16

Table (4.23) The Movement of Machinery and Cleaning Campaigns for the Summer Season Shohadaa AL-Mulhaq & Dhubat Al-Usra

Day	Shohadaa AL-Mulhaq & Dhobat Al-Usra	Daily cleaning campaigns		Mechanism type	Lifted load (tons)
		Compactor	No. of workers		
Saturday	From 1-55	2	6	1 Shffel+1Tipper	20
Sunday	From 56-110	2	4	1 Shffel or 1Tipper	16
Monday	From 1-55	1	4	1 Shffel or 1Tipper	8
Tuesday	From 56-110	2	5	1Shffel+1Tipper	20
Wednesday	From 1-55	1	2	1 Shffel+1Tipper	16
Thursday	From 56-110	2	4	1 Shffel or 1Tipper	12

Table (4.24) The Movement of Machinery and Cleaning Campaigns for the Summer Season AL-Usra

Day	AL-Usra	Daily cleaning campaigns		Machine type	Lifted load (tons)
		Compactor	No. of workers		
Saturday	From 1-33	3	6	1 Shffel or1Tipper	20
Sunday	From 34-66	2	5	1 Shffel+1Tipper	20
Monday	From 1-33	1	4	1 Shffel+1Tipper	16
Tuesday	From 34-66	2	4	1 Shffel+1Tipper	20
Wednesday	From 1-33	2	4	1 Shffel or 1Tipper	12
Thursday	From 34-66	1	6	1 Shffel+1Tipper	16

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Chapter Five

Conclusions and Recommendations

Chapter Five

Conclusions and Recommendations

5.1 Introduction

In this chapter, the conclusions are drawn from the findings, as well as some suggestions for future research, which are presented for study route optimization for solid waste collection vehicles for sample districts in Karbala City.

5.2 Conclusions

The following conclusions were formed based on the results obtained:

1. Complete general information about solid waste management, waste generation rate, collection and transportation methods, number of vehicles and workers for the study area from the Karbala Municipality Directorate
2. The lengths of the streets were calculated for the study area, depending on the horizontal plans and the scale of the drawing from the Directorate of Statistics of Karbala. They were (15.610) Km for AL-Mulhaq(1,2), (13.353)Km for Shohadaa AL-Mulhaq, and (9.382)Km for AL-Usra and entered into the QSB program
3. The (WinQSB) program used to find three alternatives for the paths of solid waste collection mechanisms from the study area, and that each alternative achieves a specific objective function, noting that the only alternative does not achieve good efficiency in solid waste collection.
4. The following percentages were obtained for the shortest path for the solid waste collection and transportation vehicle for residential

neighborhoods: AL-Mulhaq (1, 2) 12%, Shohadaa AL-Mulhaq and Dhubat AL-Usra 11% and AL-Usra 11% when using the (WinQSB) program.

5. In the realm of solid waste management and environmental planning, geographic information systems (GIS) technology plays a critical role in aiding the planning process and designing the tracks used by cars to collect solid trash and transport it to sanitary landfills.
6. The GIS program achieved high rates for the optimal path of solid waste collection and transportation vehicles for the study area, which were 78% AL-Mulhaq (1, 2), 68% for Shohadaa AL-Mulhaq and Dhubat AL-Usra, and 67% AL-Usra.
7. The results showed that, the GIS program did not treat the remaining path, which is 22% AL-Mulhaq, 32% Shohdaa AL-Mulhaq and Dhubat AL-Usra, and 33% AL-Usra.
8. Effective directing of solid waste collection and transportation vehicles would reduce costs by reducing the number of workers, reduce working hours, and vehicle fuel consumption by obtaining the optimal path found in this study.
9. The ArcGIS program needs a high level of training in order to give the outputs with high accuracy and speed.
10. Collecting the largest possible amount of waste for the neighborhood of Al-Mutlaq (1,2), which amounts to 24 tons per day, when using the ArcGIS program.

5.3 Recommendations

The following recommendations are suggested for future work for Karbala Municipality: -

1. Holding seminars and programs to increase the environmental awareness of the population through educational and religious institutions so that they can be properly dealt with by using special bags to collect solid waste and throw it into the containers designated for it.
2. Adopting well-studied scientific methods in distributing containers and solid waste collection bags, taking into account the number of dwelling households in each housing unit to meet their need of containers and solid waste collection bags.
3. Establishing committees to supervise the solid waste collection and street cleaning process by environmental requirements.
4. Distributing special containers to be placed at the end of the street, and educating families to sort solid waste in them, along with setting up transfer stations to take advantage of the waste because of the energy it contains that can be used.
5. The possibility of adopting the movement tables prepared in this study for the two periods of the year (summer and winter), knowing that these tables provide a number of mechanisms that can be used to serve other areas of the holy city of Karbala.
6. Recommendation for studies recommends research in the areas of cost reduction, citizen services, citizen engagement, and environmental impact. However, improving the performance of solid waste collection systems is a major challenge for most developing economies.

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Appendix A

Data Entry Tables for The Study Area

Table (A-1): Input Data for Al-Mulhaq (1)(2) (Shortest, Min)

Branch Number	Branch Name	Start Node	End Node	Distance (m)
1	<B1>	<1>	<2>	<+38.000>
2	<B2>	<1>	<3>	<+110.000>
3	<B3>	<2>	<32>	<+30.000>
4	<B4>	<2>	<34>	<+125.000>
5	<B5>	<3>	<4>	<+38.000>
6	<B6>	<3>	<5>	<+250.000>
7	<B7>	<4>	<25>	<+30.000>
8	<B8>	<4>	<27>	<+128.000>
9	<B9>	<5>	<6>	<+38.000>
10	<B10>	<5>	<7>	<+100.000>
11	<B11>	<6>	<12>	<+30.000>
12	<B12>	<6>	<14>	<+125.000>
13	<B13>	<7>	<8>	<+38.000>
14	<B14>	<8>	<9>	<+125.000>
15	<B15>	<9>	<11>	<+38.000>
16	<B16>	<9>	<77>	<+30.000>
17	<B17>	<10>	<11>	<+125.000>
18	<B18>	<10>	<12>	<+30.000>
19	<B19>	<11>	<13>	<+30.000>
20	<B20>	<12>	<13>	<+125.000>
21	<B21>	<13>	<14>	<+30.000>
22	<B22>	<14>	<15>	<+30.000>
23	<B23>	<15>	<16>	<+125.000>
24	<B24>	<15>	<17>	<+30.000>
25	<B25>	<16>	<18>	<+30.000>
26	<B26>	<17>	<18>	<+125.000>
27	<B27>	<17>	<19>	<+45.000>
28	<B28>	<18>	<20>	<+45.000>
29	<B29>	<19>	<20>	<+125.000>
30	<B30>	<20>	<21>	<+30.000>
31	<B31>	<21>	<22>	<+125.000>
32	<B32>	<21>	<23>	<+48.000>
33	<B33>	<22>	<24>	<+48.000>
34	<B34>	<23>	<24>	<+125.000>
35	<B35>	<23>	<25>	<+30.000>
36	<B36>	<24>	<26>	<+30.000>

Branch Number	Branch Name	Start Node	End Node	Distance (m)
37	<B37>	<25>	<26>	<+125.000>
38	<B38>	<26>	<27>	<+30.000>
39	<B39>	<27>	<28>	<+30.000>
40	<B40>	<28>	<29>	<+125.000>
41	<B41>	<28>	<30>	<+30.000>
42	<B42>	<29>	<31>	<+30.000>
43	<B43>	<30>	<31>	<+125.000>
44	<B44>	<30>	<33>	<+30.000>
45	<B45>	<31>	<32>	<+30.000>
46	<B46>	<32>	<33>	<+125.000>
47	<B47>	<33>	<34>	<+30.000>
48	<B48>	<34>	<35>	<+30.000>
49	<B49>	<35>	<36>	<+138.000>
50	<B50>	<35>	<53>	<+30.000>
51	<B51>	<36>	<37>	<+105.000>
52	<B52>	<36>	<52>	<+30.000>
53	<B53>	<37>	<38>	<+150.000>
54	<B54>	<37>	<50>	<+45.000>
55	<B55>	<38>	<39>	<+110.000>
56	<B56>	<38>	<104>	<+110.000>
57	<B57>	<39>	<40>	<+103.000>
58	<B58>	<40>	<42>	<+45.000>
59	<B59>	<41>	<42>	<+103.000>
60	<B60>	<41>	<95>	<+8.000>
61	<B61>	<42>	<43>	<+30.000>
62	<B62>	<43>	<44>	<+50.000>
63	<B63>	<43>	<47>	<+20.000>
64	<B64>	<44>	<90>	<+20.000>
65	<B65>	<44>	<91>	<+28.000>
66	<B66>	<45>	<65>	<+18.000>
67	<B67>	<45>	<90>	<+103.000>
68	<B68>	>45<	>62<	<+38.000>
69	<B69>	<46>	<47>	<+100.000>
70	<B70>	<46>	<62>	<+20.000>
71	<B71>	>46<	>60<	<+8.000>
72	<B72>	<47>	<49>	<+75.000>
73	<B73>	<48>	<49>	<+103.000>
74	<B74>	<48>	<54>	<+15.000>
75	<B75>	<49>	<50>	<+38.000>

Branch Number	Branch Name	Start Node	End Node	Distance (m)
76	<B76>	<50>	<51>	<+103.000>
77	<B77>	<51>	<52>	<+15.000>
78	<B78>	<51>	<54>	<+15.000>
79	<B79>	<52>	<53>	<+138.000>
80	<B80>	<53>	<55>	<+30.000>
81	<B81>	<54>	<55>	<+138.000>
82	<B82>	<55>	<57>	<+30.000>
83	<B83>	<56>	<57>	<+138.000>
84	<B84>	<56>	<58>	<+30.000>
85	<B85>	<57>	<59>	<+30.000>
86	<B86>	<58>	<59>	<+138.000>
87	<B87>	<58>	<60>	<+30.000>
88	<B88>	<59>	<61>	<+30.000>
89	<B89>	<60>	<61>	<+140.000>
90	<B90>	<61>	<63>	<+30.000>
91	<B91>	<62>	<63>	<+140.000>
92	<B92>	<63>	<64>	<+38.000>
93	<B93>	<64>	<65>	<+138.000>
94	<B94>	<65>	<66>	<+33.000>
95	<B95>	<66>	<67>	<+140.000>
96	<B96>	<66>	<68>	<+50.000>
97	<B97>	<66>	<89>	<+100.000>
98	<B98>	<67>	<69>	<+45.000>
99	<B99>	<68>	<69>	<+140.000>
100	<B100>	<68>	<70>	<+30.000>
101	<B101>	<69>	<71>	<+30.000>
102	<B102>	<70>	<71>	<+140.000>
103	<B103>	<70>	<72>	<+30.000>
104	<B104>	<71>	<73>	<+30.000>
105	<B105>	<72>	<81>	<+13.000>
106	<B106>	<73>	<75>	<+30.000>
107	<B107>	<74>	<75>	<+140.000>
108	<B108>	<74>	<80>	<+13.000>
109	<B109>	<75>	<76>	<+30.000>
110	<B110>	<76>	<77>	<+30.000>
111	<B111>	<76>	<79>	<+140.000>
112	<B112>	<77>	<78>	<+140.000>
113	<B113>	<78>	<79>	<+30.000>

Branch Number	Branch Name	Start Node	End Node	Distance (m)
114	<B114>	<78>	<165>	<+243.000>
115	<B115>	<79>	<80>	<+15.000>
116	<B116>	<80>	<83>	<+103.000>
117	<B117>	<81>	<82>	<+103.000>
118	<B118>	<82>	<83>	<+30.000>
119	<B119>	<83>	<84>	<+50.000>
120	<B120>	<84>	<85>	<+53.000>
121	<B121>	<85>	<86>	<+103.000>
122	<B122>	<86>	<87>	<+53.000>
123	<B123>	<86>	<164>	<+53.000>
124	<B124>	<87>	<88>	<+50.000>
125	<B125>	<87>	<92>	<+53.000>
126	<B126>	<88>	<89>	<+53.000>
127	<B127>	<89>	<90>	<+50.000>
128	<B128>	<91>	<92>	<+50.000>
129	<B129>	<91>	<94>	<+103.000>
130	<B130>	<92>	<93>	<+103.000>
131	<B131>	<93>	<94>	<+50.000>
132	<B132>	<94>	<95>	<+45.000>
133	<B133>	<95>	<96>	<+38.000>
134	<B134>	<96>	<97>	<+73.000>
135	<B135>	<96>	<98>	<+38.000>
136	<B136>	<97>	<99>	<+73.000>
137	<B137>	<97>	<163>	<+75.000>
138	<B138>	<98>	<99>	<+75.000>
139	<B139>	<98>	<102>	<+85.000>
140	<B140>	<99>	<100>	<+28.000>
141	<B141>	<100>	<101>	<+85.000>
142	<B142>	<100>	<161>	<+38.000>
143	<B143>	<101>	<102>	<+103.000>
144	<B144>	<101>	<132>	<+33.000>
145	<B145>	<102>	<103>	<+70.000>
146	<B146>	<103>	<106>	<+108.000>
147	<B147>	<103>	<108>	<+35.000>
148	<B148>	<104>	<105>	<+38.000>
149	<B149>	<104>	<167>	<+265.000>
150	<B150>	<105>	<106>	<+38.000>
151	<B151>	<105>	<112>	<+110.000>
152	<B152>	<106>	<107>	<+38.000>

Branch Number	Branch Name	Start Node	End Node	Distance (m)
153	<B153>	<107>	<108>	<+100.000>
154	<B154>	<107>	<110>	<+38.000>
155	<B155>	<108>	<109>	<+38.000>
156	<B156>	<108>	<131>	<+103.000>
157	<B157>	<109>	<110>	<+110.000>
158	<B158>	<109>	<121>	<+38.000>
159	<B159>	<110>	<111>	<+40.000>
160	<B160>	<111>	<112>	<+38.000>
161	<B161>	<111>	<118>	<+38.000>
162	<B162>	<111>	<120>	<+70.000>
163	<B163>	<112>	<113>	<+103.000>
164	<B164>	<113>	<114>	<+38.000>
165	<B165>	<114>	<115>	<+70.000>
166	<B166>	<114>	<116>	<+38.000>
167	<B167>	<115>	<117>	<+38.000>
168	<B168>	<116>	<117>	<+70.000>
169	<B169>	<117>	<119>	<+38.000>
170	<B170>	<118>	<119>	<+70.000>
171	<B171>	<119>	<120>	<+38.000>
172	<B172>	<120>	<121>	<+38.000>
173	<B173>	<121>	<122>	<+113.000>
176	<B176>	<122>	<123>	<+38.000>
175	<B175>	<123>	<124>	<+70.000>
176	<B176>	<123>	<125>	<+38.000>
177	<B177>	<124>	<126>	<+38.000>
178	<B178>	<125>	<126>	<+73.000>
179	<B179>	<125>	<128>	<+38.000>
180	<B180>	<126>	<127>	<+38.000>
181	<B181>	<127>	<128>	<+73.000>
182	<B182>	<127>	<136>	<+40.000>
183	<B183>	<128>	<129>	<+38.000>
184	<B184>	<129>	<130>	<+70.000>
185	<B185>	<130>	<131>	<+70.000>
186	<B186>	<130>	<135>	<+43.000>
187	<B187>	<131>	<132>	<+68.000>
188	<B188>	<132>	<133>	<+38.000>
189	<B189>	<133>	<134>	<+108.000>
190	<B190>	<133>	<152>	<+38.000>
191	<B191>	<133>	<160>	<+38.000>

Branch Number	Branch Name	Start Node	End Node	Distance (m)
192	<B192>	<134>	<135>	<+38.000>
193	<B193>	<134>	<147>	<+38.000>
194	<B194>	<135>	<136>	<+38.000>
195	<B195>	<135>	<144>	<+38.000>
196	<B196>	<136>	<137>	<+70.000>
197	<B197>	<137>	<138>	<+38.000>
198	<B198>	<138>	<139>	<+70.000>
199	<B199>	<138>	<140>	<+38.000>
200	<B200>	<139>	<141>	<+38.000>
201	<B201>	<140>	<141>	<+70.000>
202	<B202>	<140>	<143>	<+38.000>
203	<B203>	<141>	<142>	<+38.000>
204	<B204>	<142>	<143>	<+70.000>
205	<B205>	<143>	<144>	<+38.000>
206	<B206>	<144>	<145>	<+70.000>
207	<B207>	<145>	<146>	<+38.000>
208	<B208>	<146>	<147>	<+38.000>
209	<B209>	<146>	<148>	<+35.000>
210	<B210>	<147>	<149>	<+38.000>
211	<B211>	<148>	<149>	<+70.000>
212	<B212>	<148>	<150>	<+38.000>
213	<B213>	<149>	<151>	<+38.000>
214	<B214>	<150>	<151>	<+70.000>
215	<B215>	<151>	<152>	<+38.000>
216	<B216>	<152>	<153>	<+70.000>
217	<B217>	<153>	<154>	<+38.000>
218	<B218>	<154>	<155>	<+38.000>
219	<B219>	<154>	<159>	<+70.000>
220	<B220>	<155>	<156>	<+38.000>
221	<B221>	<155>	<158>	<+70.000>
222	<B222>	<156>	<157>	<+75.000>
223	<B223>	<157>	<158>	<+38.000>
224	<B224>	<157>	<162>	<+38.000>
225	<B225>	<158>	<159>	<+38.000>
226	<B226>	<159>	<160>	<+40.000>
227	<B227>	<160>	<161>	<+78.000>
228	<B228>	<161>	<163>	<+38.000>

Branch Number	Branch Name	Start Node	End Node	Distance (m)
229	<B229>	<162>	<163>	<+38.000>
230	<B230>	<163>	<164>	<+30.000>
231	<B231>	<164>	<165>	<+150.000>
232	<B232>	<165>	<166>	<+450.000>
233	<B233>	<166>	<167>	<+425.000>

Total Distance = 15610.000 m= 15.610 km

Table (A-2): Input Data for Al-Molhaq (1)(2) (Max)

Branch Number	Branch Name	Start Node	End Node	Flow Capacity(kg) From Start Node	Flow Capacity(kg) From End Node
1	<B1>	<1>	<2>	<+86.00>	<+94.00>
2	<B2>	<1>	<3>	<+266.00>	<+254.00>
3	<B3>	<2>	<32>	<+143.00>	<+141.00>
4	<B4>	<2>	<34>	<+301.00>	<+290.00>
5	<B5>	<3>	<4>	<+88.00>	<+92.00>
6	<B6>	<3>	<5>	<+1174.00>	<+1189.00>
7	<B7>	<4>	<25>	<+147.00>	<+137.00>
8	<B8>	<4>	<27>	<+618.00>	<+592.00>
9	<B9>	<5>	<6>	<+92.00>	<+88.00>
10	<B10>	<5>	<7>	<+465.00>	<+480.00>
11	<B11>	<6>	<12>	<+147.00>	<+137.00>
12	<B12>	<6>	<14>	<+577.00>	<+604.00>
13	<B13>	<7>	<8>	<+92.00>	<+88.00>
14	<B14>	<8>	<9>	<+607.00>	<+574.00>
15	<B15>	<9>	<11>	<+187.00>	<+172.00>
16	<B16>	<9>	<77>	<+140.00>	<+144.00>
17	<B17>	<10>	<11>	<+574.00>	<+607.00>
18	<B18>	<10>	<12>	<+149.00>	<+135.00>
19	<B19>	<11>	<13>	<+149.00>	<+135.00>
20	<B20>	<12>	<13>	<+574.00>	<+607.00>
21	<B21>	<13>	<14>	<+135.00>	<+149.00>
22	<B22>	<14>	<15>	<+135.00>	<+149.00>
23	<B23>	<15>	<16>	<+605.00>	<+576.00>
24	<B24>	<15>	<17>	<+135.00>	<+149.00>
25	<B25>	<16>	<18>	<+135.00>	<+149.00>
26	<B26>	<17>	<18>	<+605.00>	<+576.00>
27	<B27>	<17>	<19>	<+222.00>	<+203.00>
28	<B28>	<18>	<20>	<+222.00>	<+203.00>
29	<B29>	<19>	<20>	<+574.00>	<+607.00>
30	<B30>	<20>	<21>	<+140.00>	<+144.00>
31	<B31>	<21>	<22>	<+607.00>	<+574.00>
32	<B32>	<21>	<23>	<+221.00>	<+204.00>
33	<B33>	<22>	<24>	<+218.00>	<+207.00>
34	<B34>	<23>	<24>	<+574.00>	<+607.00>
35	<B35>	<23>	<25>	<+135.00>	<+149.00>
36	<B36>	<24>	<26>	<+149.00>	<+135.00>
37	<B37>	<25>	<26>	<+607.00>	<+574.00>

Branch Number	Branch Name	Start Node	End Node	Flow Capacity(kg) From Start Node	Flow Capacity(kg) From End Node
38	<B38>	<26>	<27>	<+135.00>	<+149.00>
39	<B39>	<27>	<28>	<+135.00>	<+149.00>
40	<B40>	<28>	<29>	<+607.00>	<+574.00>
41	<B41>	<28>	<30>	<+135.00>	<+149.00>
42	<B42>	<29>	<31>	<+149.00>	<+135.00>
43	<B43>	<30>	<31>	<+607.00>	<+574.00>
44	<B44>	<30>	<33>	<+135.00>	<+149.00>
45	<B45>	<31>	<32>	<+135.00>	<+149.00>
46	<B46>	<32>	<33>	<+605.00>	<+576.00>
47	<B47>	<33>	<34>	<+144.00>	<+140.00>
48	<B48>	<34>	<35>	<+73.00>	<+69.00>
49	<B49>	<35>	<36>	<+321.00>	<+331.00>
50	<B50>	<35>	<53>	<+140.00>	<+144.00>
51	<B51>	<36>	<37>	<+510.00>	<+482.00>
52	<B52>	<36>	<52>	<+137.00>	<+147.00>
53	<B53>	<37>	<38>	<+717.00>	<+701.00>
54	<B54>	<37>	<50>	<+151.00>	<+133.00>
55	<B55>	<38>	<39>	<+510.00>	<+530.00>
56	<B56>	<38>	<104>	<+252.00>	<+268.00>
57	<B57>	<39>	<40>	<+475.00>	<+498.00>
58	<B58>	<40>	<42>	<+221.00>	<+204.00>
59	<B59>	<41>	<42>	<+500.00>	<+473.00>
60	<B60>	<41>	<95>	<+37.00>	<+39.00>
61	<B61>	<42>	<43>	<+138.00>	<+146.00>
62	<B62>	<43>	<44>	<+245.00>	<+228.00>
63	<B63>	<43>	<47>	<+97.00>	<+92.00>
64	<B64>	<44>	<90>	<+97.00	<+92.00>
65	<B65>	<44>	<91>	<+124.00>	<+141.00>
66	<B66>	<45>	<65>	<+81.00>	<+89.00>
67	<B67>	<45>	<90>	<+501.00>	<+472.00>
68	<B68>	<45>	<62>	<+187.00>	<+172.00>
69	<B69>	<46>	<47>	<+462.00>	<+483.00>
70	<B70>	<46>	<62>	<+99.00>	<+90.00>
71	<B71>	<46>	<60>	<+37.00>	<+39.00>
72	<B72>	<47>	<49>	<+364.00>	<+345.00>
73	<B73>	<48>	<49>	<+494.00>	<+479.00>
74	<B74>	<48>	<54>	<+69.00>	<+73.00>
75	<B75>	<49>	<50>	<+172.00>	<+187.00>

Branch Number	Branch Name	Start Node	End Node	Flow Capacity(kg) From Start Node	Flow Capacity(kg) From End Node
76	<B76>	<50>	<51>	<+489.00>	<+284.00>
77	<B77>	<51>	<52>	<+67.00>	<+75.00>
78	<B78>	<51>	<54>	<+73.00>	<+69.00>
79	<B79>	<52>	<53>	<+665.00>	<+652.00>
80	<B80>	<53>	<55>	<+149.00>	<+135.00>
81	<B81>	<54>	<55>	<+652.00>	<+668.00>
82	<B82>	<55>	<57>	<+135.00>	<+149.00>
83	<B83>	<56>	<57>	<+668.00>	<+636.00>
84	<B84>	<56>	<58>	<+149.00>	<+135.00>
85	<B85>	<57>	<59>	<+135.00>	<+149.00>
86	<B86>	<58>	<59>	<+668.00>	<+636.00>
87	<B87>	<58>	<60>	<+158.00>	<+126.00>
88	<B88>	<59>	<61>	<+135.00>	<+149.00>
89	<B89>	<60>	<61>	<+678.00>	<+645.00>
90	<B90>	<61>	<63>	<+135.00>	<+149.00>
91	<B91>	<62>	<63>	<+645.00>	<+678.00>
92	<B92>	<63>	<64>	<+174.00>	<+185.00>
93	<B93>	<64>	<65>	<+676.00>	<+647.00>
94	<B94>	<65>	<66>	<+161.00>	<+151.00>
95	<B95>	<66>	<67>	<+638.00>	<+666.00>
96	<B96>	<66>	<68>	<+245.00>	<+227.00>
97	<B97>	<66>	<89>	<+454.00>	<+491.00>
98	<B98>	<67>	<69>	<+207.00>	<+218.00>
99	<B99>	<68>	<69>	<+678.00>	<+645.00>
100	<B100>	<68>	<70>	<+135.00>	<+149.00>
101	<B101>	<69>	<71>	<+149.00>	<+135.00>
102	<B102>	<70>	<71>	<+678.00>	<+645.00>
103	<B103>	<70>	<72>	<+137.00>	<+147.00>
104	<B104>	<71>	<73>	<+149.00>	<+135.00>
105	<B105>	<72>	<81>	<+63.00>	<+60.00>
106	<B106>	<73>	<75>	<+135.00>	<+149.00>
107	<B107>	<74>	<75>	<+645.00>	<+678.00>
108	<B108>	<74>	<80>	<+59.00>	<+64.00>
109	<B109>	<75>	<149>	<+149.00>	<+135.00>
110	<B110>	<76>	<149>	<+149.00>	<+135.00>
111	<B111>	<76>	<678>	<+678.00>	<+645.00>

Branch Number	Branch Name	Start Node	End Node	Flow Capacity(kg) From Start Node	Flow Capacity(kg) From End Node
112	<B112>	<77>	<78>	<+645.00>	<+678.00>
113	<B113>	<78>	<79>	<+149.00>	<+135.00>
114	<B114>	<78>	<165>	<+604.00>	<+544.00>
115	<B115>	<79>	<80>	<+70.00>	<+72.00>
116	<B116>	<80>	<83>	<+475.00>	<+498.00>
117	<B117>	<81>	<82>	<+492.00>	<+481.00>
118	<B118>	<82>	<83>	<+137.00>	<+147.00>
119	<B119>	<83>	<84>	<+247.00>	<+226.00>
120	<B120>	<84>	<85>	<+240.00>	<+261.00>
121	<B121>	<85>	<86>	<+505.00>	<+468.00>
122	<B122>	<86>	<87>	<+245.00>	<+256.00>
123	<B123>	<86>	<164>	<+245.00>	<+256.00>
124	<B124>	<87>	<88>	<+246.00>	<+227.00>
125	<B125>	<87>	<92>	<+243.00>	<+258.00>
126	<B126>	<88>	<89>	<+262.00>	<+239.00>
127	<B127>	<89>	<90>	<+248.00>	<+225.00>
128	<B128>	<91>	<92>	<+226.00>	<+247.00>
129	<B129>	<91>	<94>	<+470.00>	<+503.00>
130	<B130>	<92>	<93>	<+500.00>	<+473.00>
131	<B131>	<93>	<94>	<+229.00>	<+244.00>
132	<B132>	<94>	<95>	<+220.00>	<+205.00>
133	<B133>	<95>	<96>	<+88.00>	<+92.00>
134	<B134>	<96>	<97>	<+359.00>	<+331.00>
135	<B135	<96>	<98>	<+187.00>	<+172.00>
136	<B136>	<97>	<99>	<+338.00>	<+352.00>
137	<B137>	<97>	<163>	<+340.00>	<+369.00>
138	<B138>	<98>	<99>	<+369.00>	<+340.00>
139	<B139>	<98>	<102>	<+394.00>	<+408.00>
140	<B140>	<99>	<100>	<+129.00>	<+136.00>
141	<B141>	<100>	<101>	<+416.00>	<+387.00>
142	<B142>	<100>	<161>	<+169.00>	<+190.00>
143	<B143>	<101>	<102>	<+494.00>	<+479.00>
144	<B144>	<101>	<132>	<+163.00>	<+149.00>
145	<B145>	<102>	<103>	<+161.00>	<+170.00>
146	<B146>	<103>	<106>	<+129.00>	<+492.00>
147	<B147>	<103>	<108>	<+171.00>	<+160.00>
148	<B148>	<104>	<105>	<+178.00>	<+181.00>

Branch Number	Branch Name	Start Node	End Node	Flow Capacity(kg) From Start Node	Flow Capacity(kg) From End Node
149	<B149>	<104>	<167>	606.00>	<+646.00>
150	<B150>	<105>	<106>	185.00>	<+174.00>
151	<B151>	<105>	<112>	535.00>	<+205.00>
152	<B152>	<106>	<107>	170.00>	<+189.00>
153	<B153>	<107>	<108>	538.00>	<+502.00>
154	<B154>	<107>	<110>	170.00>	<+189.00>
155	<B155>	<108>	<109>	172.00>	<+187.00>
156	<B156>	<108>	<131>	495.00>	<+478.00>
157	<B157>	<109>	<110>	502.00>	<+538.00>
158	<B158>	<109>	<121>	187.00>	<+172.00>
159	<B159>	<110>	<111>	198.00>	<+180.00>
160	<B160>	<111>	<112>	171.00>	<+188.00>
161	<B161>	<111>	<118>	184.00>	<+175.00>
162	<B162>	<111>	<120>	320.00>	<+342.00>
163	<B163>	<112>	<113>	501.00>	<+472.00>
164	<B164>	<113>	<114>	189.00>	<+170.00>
165	<B165>	<114>	<115>	315.00>	<+347.00>
166	<B166>	<114>	<116>	170.00>	<+189.00>
167	<B167>	<115>	<117>	<+189.00>	<+170.00>
168	<B168>	<116>	<117>	<+347.00>	<+315.00>
169	<B169>	<117>	<119>	<+189.00>	<+170.00>
170	<B170>	<118>	<119>	<+320.00>	<+342.00>
171	<B171>	<119>	<120>	<+172.00>	<+187.00>
172	<B172>	<120>	<121>	<+189.00>	<+170.00>
173	<B173>	<121>	<122>	<+552.00>	<+516.00>
174	<B174>	<122>	<123>	<+189.00>	<+170.00>
175	<B175>	<123>	<124>	<+317.00>	<+345.00>
176	<B176>	<123>	<125>	<+171.00>	<+188.00>
177	<B177>	<124>	<126>	<+171.00>	<+188.00>
178	<B178>	<125>	<126>	<+359.00>	<+331.00>
179	<B179>	<125>	<128>	<+171.00>	<+188.00>
180	<B180>	<126>	<127>	<+188.00>	<+171.00>
181	<B181>	<127>	<128>	<+359.00>	<+331.00>
182	<B182>	<127>	<136>	<+181.00>	<+197.00>
183	<B183>	<128>	<129>	<+188.00>	<+171.00>
184	<B184>	<129>	<130>	<+344.00>	<+318.00>
185	<B185>	<130>	<131>	<+344.00>	<+318.00>

Branch Number	Branch Name	Start Node	End Node	Flow Capacity(kg) From Start Node	Flow Capacity(kg) From End Node
186	<B186>	<130>	<135>	<+359.00>	<331.00>
187	<B187>	<131>	<132>	<+181.00>	<197.00>
188	<B188>	<132>	<133>	<+188.00>	<171.00>
189	<B189>	<133>	<134>	<+344.00>	<+318.00>
190	<B190>	<133>	<152>	<+344.00>	<+318.00>
191	<B191>	<133>	<160>	<+194.00>	<+212.00>
192	<B192>	<134>	<135>	<+312.00>	<+331.00>
193	<B193>	<134>	<147>	<+188.00>	<+171.00>
194	<B194>	<135>	<136>	<+527.00>	<+494.00>
195	<B195>	<135>	<144>	<+171.00>	<+188.00>
196	<B196>	<136>	<137>	<+188.00>	<+171.00>
197	<B197>	<137>	<138>	<+187.00>	<+172.00>
198	<B198>	<138>	<139>	<+169.00>	<+190.00>
199	<B199>	<138>	<140>	<+169.00>	<+190.00>
200	<B200>	<139>	<141>	<+190.00>	<+169.00>
201	<B201>	<140>	<141>	<+317.00>	<+345.00>
202	<B202>	<140>	<143>	<+189.00>	<+170.00>
203	<B203>	<141>	<142>	<+345.00>	<+317.00>
204	<B204>	<142>	<143>	<+189.00>	<+170.00>
205	<B205>	<143>	<144>	<+170.00>	<+189.00>
206	<B206>	<144>	<145>	<+318.00>	<+345.00>
207	<B207>	<145>	<146>	<+189.00>	<+170.00>
208	<B208>	<146>	<147>	<+189.00>	<+170.00>
209	<B209>	<146>	<148>	<+318.00>	<+344.00>
210	<B210>	<147>	<149>	<+170.00>	<+189.00>
211	<B211>	<148>	<149>	<+344.00>	<+318.00>
212	<B212>	<148>	<150>	<+189.00>	<+170.00>
213	<B213>	<149>	<151>	<+193.00>	<+166.00>
214	<B214>	<150>	<151>	<+174.00>	<+157.00>
215	<B215>	<151>	<152>	<+171.00>	<+188.00>
216	<B216>	<152>	<153>	<+341.00>	<+321.00>
217	<B217>	<153>	<154>	<+170.00>	<+189.00>
218	<B218>	<154>	<155>	<+189.00>	<+170.00>
219	<B219>	<154>	<159>	<+317.00>	<+345.00>
220	<B220>	<155>	<156>	<+171.00>	<+188.00>
221	<B221>	<155>	<158>	<+341.00>	<+321.00>
222	<B222>	<156>	<157>	<+365.00>	<+344.00>

Branch Number	Branch Name	Start Node	End Node	Flow Capacity(kg) From Start Node	Flow Capacity(kg) From End Node
223	<B223>	<157>	<158>	<+171.00>	<+188.00>
224	<B225>	<157>	<162>	<+189.00>	<+170.00>
225	<B226>	<158>	<159>	<+189.00>	<+170.00>
226	<B227>	<159>	<160>	<+198.00>	<+180.00>
227	<B227>	<160>	<161>	<+352.00>	<+385.00>
228	<B228>	<161>	<163>	<+170.00>	<+189.00>
229	<B229>	<162>	<163>	<+185.00>	<+174.00>
230	<B230>	<163>	<164>	<+140.00>	<+144.00>
231	<B231>	<164>	<165>	<+725.00>	<+693.00>
232	<B232>	<165>	<166>	<+2086.00>	<+2166.00>
233	<B233>	<166>	<167>	<+1034.00>	<+974.00>

Table (A-3): Input Data for Shohadaa Al-Molhaq & Dubat Al-Usra (Shortest, Min)

Branch Number	Branch Name	Start Node	End Node	Distance (m)
1	<B1>	<1>	<2>	<+40.000>
2	<B2>	<1>	<4>	<+63.000>
3	<B3>	<2>	<3>	<+63.000>
4	<B4>	<2>	<5>	<+75.000>
5	<B5>	<3>	<8>	<+113.000>
6	<B6>	<4>	<5>	<+45.000>
7	<B7>	<4>	<6>	<+50.000>
8	<B8>	<5>	<7>	<+40.000>
9	<B9>	<6>	<7>	<+138.000>
10	<B10>	<6>	<32>	<+63.000>
11	<B11>	<7>	<8>	<+63.000>
12	<B12>	<7>	<30>	<+63.000>
13	<B13>	<8>	<10>	<+160.000>
14	<B14>	<9>	<10>	<+63.000>
15	<B15>	<9>	<26>	<+18.000>
16	<B16>	<9>	<28>	<+13.000>
17	<B17>	<10>	<12>	<+100.000>
18	<B18>	<11>	<12>	<+63.000>
19	<B19>	<11>	<24>	<+18.000>
20	<B20>	<11>	<26>	<+40.000>
21	<B21>	<12>	<14>	<+25.000>
22	<B22>	<13>	<14>	<+63.000>
23	<B23>	<13>	<22>	<+50.000>
24	<B24>	<13>	<24>	<+18.000>
25	<B25>	<14>	<16>	<+100.000>
26	<B26>	<15>	<16>	<+63.000>
27	<B27>	<15>	<20>	<+25.000>
28	<B28>	<15>	<22>	<+40.000>
29	<B29>	<16>	<18>	<+100.000>
30	<B30>	<17>	<18>	<+63.000>
31	<B31>	<18>	<42>	<+83.000>
32	<B32>	<17>	<19>	<+138.000>
33	<B33>	<17>	<20>	<+75.000>
34	<B34>	<19>	<21>	<+65.000>
35	<B35>	<19>	<40>	<+65.000>
36	<B36>	<20>	<21>	<+138.000>
37	<B37>	<21>	<23>	<+65.000>
38	<B38>	<22>	<23>	<+138.000>

Appendix A

Branch Number	Branch Name	Start Node	End Node	Distance (m)
39	<B39>	<23>	<25>	<+65.000>
40	<B40>	<23>	<35>	<+68.000>
41	<B41>	<24>	<25>	<+138.000>
42	<B42>	<25>	<27>	<+50.000>
43	<B43>	<26>	<27>	<+138.000>
44	<B44>	<27>	<29>	<+63.000>
45	<B45>	<27>	<34>	<+85.000>
46	<B46>	<28>	<29>	<+138.000>
47	<B47>	<28>	<30>	<+65.000>
48	<B48>	<29>	<31>	<+65.000>
49	<B49>	<30>	<31>	<+138.000>
50	<B50>	<31>	<32>	<+33.000>
51	<B51>	<32>	<33>	<+130.000>
52	<B52>	<33>	<34>	<+50.000>
53	<B53>	<33>	<37>	<+400.000>
54	<B54>	<34>	<35>	<+135.000>
55	<B55>	<35>	<36>	<+133.000>
56	<B56>	<36>	<40>	<+18.000>
57	<B57>	<36>	<37>	<+143.000>
58	<B58>	<37>	<38>	<+125.000>
59	<B59>	<38>	<39>	<+175.000>
60	<B60>	<38>	<56>	<+88.000>
61	<B61>	<39>	<41>	<+63.000>
62	<B62>	<39>	<54>	<+50.000>
63	<B63>	<40>	<41>	<+83.000>
64	<B64>	<41>	<51>	<+50.000>
65	<B65>	<41>	<52>	<+125.000>
66	<B66>	<42>	<43>	<+50.000>
67	<B67>	<42>	<47>	<+125.000>
68	<B68>	<43>	<44>	<+50.000>
69	<B69>	<43>	<46>	<+125.000>
70	<B70>	<44>	<97>	<+138.000>
71	<B71>	<45>	<94>	<+25.000>
72	<B72>	<45>	<96>	<+50.000>
73	<B73>	<45>	<46>	<+50.000>
74	<B74>	<46>	<47>	<+50.000>
75	<B75>	<47>	<49>	<+50.000>
76	<B76>	<48>	<92>	<+125.000>

Branch Number	Branch Name	Start Node	End Node	Distance (m)
77	<B77>	<48>	<94>	<+28.000>
78	<B78>	<48>	<49>	<+125.000>
79	<B79>	<49>	<51>	<+50.000>
80	<B80>	<50>	<90>	<+25.000>
81	<B81>	<50>	<92>	<+28.000>
82	<B82>	<50>	<51>	<+125.000>
83	<B83>	<52>	<53>	<+65.000>
84	<B84>	<52>	<90>	<+25.000>
85	<B85>	<53>	<58>	<+85.000>
86	<B86>	<53>	<54>	<+50.000>
87	<B87>	<54>	<55>	<+80.000>
88	<B88>	<55>	<57>	<+25.000>
89	<B89>	<56>	<60>	<+118.000>
90	<B90>	<56>	<57>	<+118.000>
91	<B91>	<57>	<58>	<+43.000>
92	<B92>	<58>	<59>	<+25.000>
93	<B93>	<59>	<60>	<+163.000>
94	<B94>	<59>	<61>	<+63.000>
95	<B95>	<60>	<62>	<+63.000>
96	<B96>	<61>	<62>	<+163.000>
97	<B97>	<61>	<63>	<+63.000>
98	<B98>	<62>	<64>	<+63.000>
99	<B99>	<63>	<64>	<+163.000>
100	<B100>	<63>	<65>	<+43.000>
101	<B101>	<64>	<66>	<+50.000>
102	<B102>	<65>	<72>	<+50.000>
103	<B103>	<65>	<74>	<+125.000>
104	<B104>	<66>	<67>	<+30.000>
105	<B105>	<66>	<70>	<+50.000>
106	<B106>	<67>	<68>	<+100.000>
107	<B107>	<67>	<69>	<+88.000>
108	<B108>	<68>	<110>	<+63.000>
109	<B109>	<68>	<69>	<+50.000>
110	<B110>	<69>	<71>	<+50.000>
111	<B111>	<70>	<71>	<+125.000>
112	<B112>	<70>	<72>	<+50.000>
113	<B113>	<71>	<108>	<+25.000>
114	<B114>	<72>	<73>	<+125.000>

Branch Number	Branch Name	Start Node	End Node	Distance (m)
115	<B115>	<73>	<108>	<+40.000>
116	<B116>	<73>	<74>	<+50.000>
117	<B117>	<74>	<107>	<+50.000>
118	<B118>	<74>	<76>	<+50.000>
119	<B119>	<75>	<76>	<+170.000>
120	<B120>	<75>	<77>	<+50.000>
121	<B121>	<76>	<105>	<+35.000>
122	<B122>	<77>	<78>	<+170.000>
123	<B123>	<77>	<79>	<+50.000>
124	<B124>	<78>	<105>	<+15.000>
125	<B125>	<78>	<80>	<+50.000>
126	<B126>	<79>	<80>	<+170.000>
127	<B127>	<79>	<81>	<+50.000>
128	<B128>	<80>	<82>	<+50.000>
129	<B129>	<81>	<82>	<+170.000>
130	<B130>	<81>	<89>	<+38.000>
131	<B131>	<82>	<104>	<+50.000>
132	<B132>	<82>	<83>	<+40.000>
331	<B133>	<83>	<103>	<+50.000>
134	<B134>	<83>	<84>	<+113.000>
135	<B135>	<83>	<85>	<+50.000>
136	<B136>	<84>	<86>	<+50.000>
137	<B137>	<84>	<89>	<+38.000>
138	<B138>	<85>	<87>	<+50.000
139	<B139>	<85>	<86>	<+113.000>
140	<B140>	<87>	<101>	<+50.000>
141	<B141>	<87>	<88>	<+113.000>
142	<B142>	<86>	<88>	<+50.000>
143	<B143>	<88>	<99>	<+50.000>
144	<B144>	<88>	<93>	<+38.000>
145	<B145>	<89>	<90>	<+113.000>
146	<B146>	<89>	<91>	<+50.000>
147	<B147>	<91>	<93>	<+50.000>
148	<B148>	<91>	<92>	<+113.000>
149	<B149>	<93>	<94>	<+113.000>
150	<B150>	<93>	<95>	<+50.000>
151	<B151>	<95>	<97>	<+50.000>
152	<B152>	<95>	<96>	<+138.000>

Branch Number	Branch Name	Start Node	End Node	Distance (m)
153	<B153>	<97>	<98>	<+40.000>
154	<B154>	<98>	<99>	<+50.000>
155	<B155>	<98>	<100>	<+203.000>
156	<B156>	<99>	<101>	<+138.000>
157	<B157>	<100>	<102>	<+50.000>
158	<B158>	<101>	<102>	<+55.000>
159	<B159>	<102>	<103>	<+210.000>
160	<B160>	<103>	<104>	<+40.000>
161	<B161>	<104>	<106>	<+110.000>
162	<B162>	<105>	<106>	<+50.000>
163	<B163>	<106>	<107>	<+110.000>
164	<B164>	<107>	<109>	<+110.000>
165	<B165>	<108>	<109>	<+50.000>
166	<B166>	<109>	<110>	<+188.000>

Total Distance = 13353.000 m =13.353 km

Table (A-4): Input Data for Shohadaa Al-Molhaq & Dubat Al-Usra (Max)

Branch Number	Branch Name	Start Node	End Node	Flow Capacity(kg) From Start Node	Flow Capacity(kg) From End Node
1	<B1>	<1>	<2>	<+114.00>	<+99.00>
2	<B2>	<1>	<4>	<+176.00>	<+160.00>
3	<B3>	<2>	<3>	<+159.00>	<+176.00>
4	<B4>	<2>	<5>	<+160.00>	<+179.00>
5	<B5>	<3>	<8>	<+188.00>	<+211.00>
6	<B6>	<4>	<5>	<+128.00>	<+109.00>
7	<B7>	<4>	<6>	<+126.00>	<+140.00>
8	<B8>	<5>	<7>	<+113.00>	<+98.00>
9	<B9>	<6>	<7>	<+378.00>	<+356.00>
10	<B10>	<6>	<32>	<+173.00>	<+162.00>
11	<B11>	<7>	<8>	<+178.00>	<+157.00>
12	<B12>	<7>	<30>	<+156.00	<+179.00>
13	<B13>	<8>	<10>	<+409.00>	<+442.00>
14	<B14>	<9>	<10>	<+158.00>	<+177.00>
15	<B15>	<9>	<26>	<+57.00>	<+39.00>
16	<B16>	<9>	<28>	<+32.00>	<+37.00>
17	<B17>	<10>	<12>	<+264.00>	<+268.00>
18	<B18>	<11>	<12>	<+175.00>	<+160.00>
19	<B19>	<11>	<24>	<+46.00>	<+50.00>
20	<B20>	<11>	<26>	<+101.00>	<+112.00>
21	<B21>	<12>	<14>	<+36.00>	<+31.00>
22	<B22>	<13>	<14>	<+173.00>	<+162.00>
23	<B23>	<13>	<22>	<+126.00>	<+140.00>
24	<B24>	<13>	<24>	<+46.00>	<+50.00>
25	<B25>	<14>	<16>	<+250.00	<+282.00>
26	<B26>	<15>	<16>	<+176.00>	<+159.00>
27	<B27>	<15>	<20>	<+69.00>	<+64.00>
28	<B28>	<15>	<22>	<+100.00>	<+114.00>
29	<B29>	<16>	<18>	<+282.00>	<+250.00>
30	<B30>	<17>	<18>	<+158.00>	<+177.00>
31	<B31>	<17>	<19>	<+357.00>	<+377.00>
32	<B32>	<17>	<20>	<+211.00>	<+188.00>
33	<B33>	<18>	<42>	<+108.00>	<+113.00>
34	<B34>	<19>	<21>	<+164.00>	<+182.00>
35	<B35>	<19>	<40>	<+182.00>	<+164.00>
36	<B36>	<20>	<21>	<+381.00>	<+353.00>
37	<B37>	<21>	<23>	<+184.00>	<+162.00>

Branch Number	Branch Name	Start Node	End Node	Flow Capacity(kg) From Start Node	Flow Capacity(kg) From End Node
38	<B38>	<22>	<23>	<+353.00>	<+381.00>
39	<B39>	<23>	<25>	<+184.00>	<+162.00>
40	<B40>	<23>	<35>	<+190.00>	<+172.00>
41	<B41>	<24>	<25>	<+358.00>	<+376.00>
42	<B42>	<25>	<27>	<+140.00>	<+126.00>
43	<B43>	<26>	<27>	<+376.00>	<+358.00>
44	<B44>	<27>	<29>	<+162.00>	<+173.00>
45	<B45>	<27>	<34>	<+176.00>	<+186.00>
46	<B46>	<28>	<29>	<+381.00>	<+353.00>
47	<B47>	<28>	<30>	<+162.00>	<+184.00>
48	<B48>	<29>	<31>	<+168.00>	<+178.00>
49	<B49>	<30>	<31>	<+106.00>	<+70.00>
50	<B50>	<31>	<32>	<+87.00>	<+89.00>
51	<B51>	<32>	<33>	<+169.00>	<+177.00>
52	<B52>	<33>	<34>	<+64.00>	<+69.00>
53	<B53>	<33>	<37>	<+1074.00>	<+1054.00>
54	<B54>	<34>	<35>	<+350.00>	<+368.00>
55	<B55>	<35>	<36>	<+364.00>	<+345.00>
56	<B56>	<36>	<37>	<+388.00>	<+373.00>
57	<B57>	<36>	<40>	<+47.00>	<+49.00>
58	<B58>	<37>	<38>	<+326.00>	<+239.00>
59	<B59>	<38>	<39>	<+476.00>	<+455.00>
60	<B60>	<38>	<56>	<+241.00>	<+227.00>
61	<B61>	<39>	<41>	<+173.00>	<+162.00>
62	<B62>	<39>	<54>	<+128.00>	<+138.00>
63	<B63>	<40>	<41>	<+223.00>	<+219.00>
64	<B64>	<41>	<51>	<+128.00>	<+138.00>
65	<B65>	<41>	<52>	<+327.00>	<+338.00>
66	<B66>	<42>	<43>	<+138.00>	<+128.00>
67	<B67>	<42>	<47>	<+344.00>	<+321.00>
68	<B68>	<43>	<44>	<+138.00>	<+128.00>
69	<B69>	<43>	<46>	<+321.00>	<+344.00>
70	<B70>	<44>	<97>	<351.00>	<+383.00>
71	<B71>	<45>	<94>	<+65.00>	<+68.00>
72	<B72>	<45>	<96>	<+141.00>	<125.00>
73	<B73>	<45>	<46>	<+124.00>	<+142.00>
74	<B74>	<46>	<47>	<+142.00>	<+124.00>
75	<B75>	<47>	<49>	<+140.00>	<+126.00>

Branch Number	Branch Name	Start Node	End Node	Flow Capacity(kg) From Start Node	Flow Capacity(kg) From End Node
76	<B76>	<48>	<92>	<335.00>	<+330.00>
77	<B77>	<48>	<94>	<69.00>	<+80.00>
78	<B78>	<48>	<49>	<349.00>	<+316.00>
79	<B79>	<49>	<51>	<129.00>	<+137.00>
80	<B80>	<50>	<90>	<69.00>	<+64.00>
81	<B81>	<50>	<92>	<79.00>	<+70.00>
82	<B82>	<50>	<51>	<323.00>	<+342.00>
83	<B83>	<52>	<53>	<180.00>	<+166.00>
84	<B84>	<52>	<90>	<64.00>	<+69.00>
85	<B85>	<53>	<58>	<233.00>	<+219.00>
86	<B86>	<53>	<54>	<127.00>	<+139.00>
87	<B87>	<54>	<55>	<199.00>	<+227.00>
88	<B88>	<55>	<57>	<69.00>	<+64.00>
89	<B89>	<56>	<60>	<319.00>	<+309.00>
90	<B90>	<56>	<57>	<330.00>	<+298.00>
91	<B91>	<57>	<58>	<123.00>	<+106.00>
92	<B92>	<58>	<59>	<335.00>	<+68.00>
93	<B93>	<59>	<60>	<69.00>	<+452.00>
94	<B94>	<59>	<61>	<+349.00>	<+159.00>
95	<B95>	<60>	<62>	<+161.00>	<+174.00>
96	<B96>	<61>	<62>	<+415.00>	<+452.00>
97	<B97>	<61>	<63>	<+176.00>	<+159.00>
98	<B98>	<62>	<64>	<+176.00>	<+159.00>
99	<B99>	<63>	<64>	<+447.00>	<+420.00>
100	<B100>	<63>	<65>	<+110.00>	<+119.00>
101	<B101>	<64>	<66>	<+64.00>	<+69.00>
102	<B102>	<65>	<72>	<+126.00>	<+140.00>
103	<B103>	<65>	<74>	<+349.00>	<+316.00>
104	<B104>	<66>	<67>	<+79.00>	<+81.00>
105	<B105>	<66>	<70>	<+129.00>	<+137.00>
106	<B106>	<67>	<68>	<+137.00>	<+129.00>
107	<B107>	<67>	<69>	<+223.00>	<+245.00>
108	<B108>	<68>	<110>	<+176.00>	<+159.00>
109	<B109>	<68>	<69>	<+226.00>	<+242.00>
110	<B110>	<69>	<71>	<+122.00>	<+144.00>
111	<B111>	<70>	<71>	<+316.00>	<+348.00>
112	<B112>	<70>	<72>	<+139.00>	<+127.00>

Branch Number	Branch Name	Start Node	End Node	Flow Capacity(kg) From Start Node	Flow Capacity(kg) From End Node
113	<B113>	<71>	<108>	<+71.00>	<+62.00>
114	<B114>	<72>	<73>	<+349.00>	<+316.00>
115	<B115>	<73>	<108>	<+114.00>	<+99.00>
116	<B116>	<73>	<74>	<+120.00>	<+146.00>
117	<B117>	<74>	<107>	<+143.00>	<+123.00>
118	<B118>	<74>	<76>	<+144.00>	<+122.00>
119	<B119>	<75>	<76>	<+434.00>	<+470.00>
120	<B120>	<75>	<77>	<+122.00>	<+144.00>
121	<B121>	<76>	<105>	<+103.00>	<+83.00>
122	<B122>	<77>	<78>	<+434.00>	<+470.00>
123	<B123>	<77>	<79>	<+125.00>	<+141.00>
124	<B124>	<78>	<105>	<+42.00>	<+38.00>
125	<B125>	<78>	<80>	<+142.00>	<+124.00>
126	<B126>	<79>	<80>	<+434.00>	<+470.00>
127	<B127>	<79>	<81>	<+125.00>	<+141.00>
128	<B128>	<80>	<82>	<+140.00>	<+126.00>
129	<B129>	<81>	<82>	<+466.00>	<+438.00>
130	<B130>	<81>	<89>	<+105.00>	<+97.00>
131	<B131>	<82>	<104>	<+129.00>	<+137.00>
132	<B132>	<82>	<83>	<+104.00>	<+109.00>
133	<B133>	<83>	<103>	<+138.00>	<+128.00>
134	<B134>	<83>	<84>	<+310.00>	<+291.00>
135	<B135>	<83>	<85>	<+124.00>	<+142.00>
136	<B136>	<84>	<86>	<+141.00>	<+125.00>
137	<B137>	<84>	<89>	<+48.00>	<+53.00>
138	<B138>	<85>	<87>	<+144.00>	<+122.00>
139	<B139>	<85>	<86>	<+149.00>	<+117.00>
140	<B140>	<86>	<88>	<+126.00>	<+140.00>
141	<B141>	<87>	<101>	<+144.00>	<+122.00>
142	<B142>	<87>	<88>	<+319.00>	<+282.00>
143	<B143>	<88>	<99>	<+125.00>	<+141.00>
144	<B144>	<88>	<93>	<+48.00>	<+53.00>
145	<B145>	<89>	<90>	<+314.00>	<+287.00>
146	<B146>	<89>	<91>	<+128.00>	<+138.00>
147	<B147>	<91>	<93>	<+138.00>	<+128.00>
148	<B148>	<91>	<92>	<+286.00>	<+315.00>

Branch Number	Branch Name	Start Node	End Node	Flow Capacity(kg) From Start Node	Flow Capacity(kg) From End Node
149	<B149>	<93>	<94>	<+315.00>	<+286.00>
150	<B150>	<93>	<95>	<+141.00>	<+125.00>
151	<B151>	<95>	<97>	<+141.00>	<+125.00>
152	<B152>	<95>	<96>	<+347.00>	<+379.00>
153	<B153>	<97>	<98>	<+56.00>	<+51.00>
154	<B154>	<98>	<99>	<+140.00>	<+126.00>
155	<B155>	<98>	<100>	<+516.00>	<+564.00>
156	<B156>	<99>	<101>	<+349.00>	<+385.00>
157	<B157>	<100>	<102>	<+140.00>	<+126.00>
158	<B158>	<101>	<102>	<+138.00>	<+154.00>
159	<B159>	<102>	<103>	<+578.00>	<+538.00>
160	<B160>	<103>	<104>	<+51.00>	<+56.00>
161	<B161>	<104>	<106>	<+281.00>	<+304.00>
162	<B162>	<105>	<106>	<+140.00>	<+126.00>
163	<B163>	<106>	<107>	<+304.00>	<+281.00>
164	<B164>	<107>	<109>	<+283.00>	<+302.00>
165	<B165>	<108>	<109>	<+122.00>	<+144.00>
166	<B166>	<109>	<110>	<+520.00>	<+480.00>

Table (A-5): Input Data for Al-Usra & Tjawz Al-Molhaq (Shortest, Min)

Branch Number	Branch Name	Start Node	End Node	Distance (m)
1	<B1>	<1>	<2>	<+393.000>
2	<B2>	<1>	<17>	<+340.000>
3	<B3>	<2>	<3>	<+340.000>
4	<B4>	<3>	<4>	<+63.000>
5	<B5>	<3>	<5>	<+148.000>
6	<B6>	<4>	<11>	<+63.000>
7	<B7>	<4>	<16>	<+63.000>
8	<B8>	<5>	<6>	<+135.000>
9	<B9>	<5>	<7>	<+43.000>
10	<B10>	<6>	<8>	<+43.000>
11	<B11>	<6>	<49>	<+230.000>
12	<B12>	<7>	<9>	<+55.000>
13	<B13>	<7>	<8>	<+133.000>
14	<B14>	<8>	<10>	<+55.000>
15	<B15>	<9>	<10>	<+133.000>
16	<B16>	<9>	<11>	<+55.000>
17	<B17>	<10>	<12>	<+55.000>
18	<B18>	<10>	<45>	<+118.000>
19	<B19>	<11>	<12>	<+133.000>
20	<B20>	<12>	<13>	<+55.000>
21	<B21>	<12>	<44>	<+118.000>
22	<B22>	<13>	<24>	<+80.000>
23	<B23>	<13>	<14>	<+53.000>
24	<B24>	<14>	<21>	<+145.000>
25	<B25>	<14>	<15>	<+75.000>
26	<B26>	<15>	<18>	<+220.000>
27	<B27>	<15>	<16>	<+68.000>
28	<B28>	<16>	<17>	<+218.000>
29	<B29>	<17>	<18>	<+65.000>
30	<B30>	<18>	<19>	<+75.000>
31	<B31>	<19>	<20>	<+125.000>
32	<B32>	<19>	<21>	<+80.000>
33	<B33>	<20>	<22>	<+85.000>
34	<B34>	<20>	<28>	<+55.000>
35	<B35>	<21>	<22>	<+125.000>
36	<B36>	<22>	<23>	<+55.000>
37	<B37>	<23>	<24>	<+55.000>

Branch Number	Branch Name	Start Node	End Node	Distance (m)
38	<B38>	<23>	<27>	<+55.000>
39	<B39>	<24>	<25>	<+140.000>
40	<B40>	<25>	<35>	<+65.000>
41	<B41>	<25>	<26>	<+65.000>
42	<B42>	<26>	<33>	<+60.000>
43	<B43>	<26>	<27>	<+55.000>
44	<B44>	<27>	<28>	<+163.000>
45	<B45>	<28>	<29>	<+75.000>
46	<B46>	<29>	<30>	<+128.000>
47	<B47>	<29>	<31>	<+50.000>
48	<B48>	<30>	<32>	<+60.000>
49	<B49>	<30>	<64>	<+58.000>
50	<B50>	<31>	<32>	<+128.000>
51	<B51>	<31>	<33>	<+63.000>
52	<B52>	<32>	<36>	<+63.000>
53	<B53>	<33>	<34>	<+63.000>
54	<B54>	<34>	<35>	<+125.000>
55	<B55>	<34>	<36>	<+65.000>
56	<B56>	<35>	<38>	<+68.000>
57	<B57>	<36>	<37>	<+68.000>
58	<B58>	<37>	<38>	<+58.000>
59	<B59>	<37>	<63>	<+65.000>
60	<B60>	<38>	<39>	<+38.000>
61	<B61>	<39>	<40>	<+60.000>
62	<B62>	<39>	<60>	<+163.000>
63	<B63>	<40>	<41>	<+35.000>
64	<B64>	<40>	<57>	<+98.000>
65	<B65>	<41>	<42>	<+63.000>
66	<B66>	<41>	>5<5	<+55.000>
67	<B67>	<42>	<50>	<+150.000>
68	<B68>	<42>	<43>	<+63.000>
69	<B69>	<43>	<44>	<+113.000>
70	<B70>	<43>	<46>	<+60.000>
71	<B71>	<44>	<45>	<+60.000>
72	<B72>	<45>	<46>	<+113.000>
73	<B73>	<45>	<47>	<+53.000>
74	<B74>	<46>	<48>	<+53.000>

Branch Number	Branch Name	Start Node	End Node	Distance (m)
75	<B75>	<47>	<48>	<+113.000>
76	<B76>	<48>	<49>	<+35.000>
77	<B77>	<49>	<50>	<+63.000>
78	<B78>	<50>	<51>	<+63.000>
79	<B79>	<51>	<52>	<+138.000>
80	<B80>	<51>	<53>	<+33.000>
81	<B81>	<52>	<58>	<+63.000>
82	<B82>	<52>	<54>	<+33.000>
83	<B83>	<53>	<54>	<+138.000>
84	<B84>	<54>	<56>	<+55.000>
85	<B85>	<55>	<56>	<+128.000>
86	<B86>	<56>	<57>	<+58.000>
87	<B87>	<57>	<59>	<+68.000>
88	<B88>	<58>	<59>	<+148.000>
89	<B89>	<59>	<60>	<+58.000>
90	<B90>	<60>	<61>	<+58.000>
91	<B91>	<61>	<62>	<+65.000>
92	<B92>	<61>	<66>	<+200.000>
93	<B93>	<62>	<63>	<+70.000>
94	<B94>	<62>	<65>	<+200.000>
95	<B95>	<63>	<64>	<+195.000>
96	<B96>	<64>	<65>	<+68.000>
97	<B97>	<65>	<66>	<+65.000>

Total Distance= 9382.000m = 9.382 km

Table (A-6): Input Data for Al-Usra & Tjawz Al-Molhaq (Max)

Branch Number	Branch Name	Start Node	End Node	Flow Capacity(kg) From Start Node	Flow Capacity(kg) From End Node
1	<B1>	<1>	<2>	<+680.00>	<+700.00>
2	<B2>	<1>	<17>	<+607.00>	<+587.00>
3	<B3>	<2>	<3>	<+615.00>	<+579.00>
4	<B4>	<3>	<4>	<+214.00>	<+228.00>
5	<B5>	<3>	<5>	<+253.00>	<+267.00>
6	<B6>	<4>	<11>	<+232.00>	<+210.00>
7	<B7>	<4>	<16>	<+226.00>	<+216.00>
8	<B8>	<5>	<6>	<+241.00>	<+233.00>
9	<B9>	<5>	<7>	<+155.00>	<+147.00>
10	<B10>	<6>	<8>	<+155.00>	<+147.00>
11	<B11>	<6>	<49>	<+400.00>	<+408.00>
12	<B12>	<7>	<9>	<+460.00>	<+474.00>
13	<B13>	<7>	<8>	<+206.00>	<+180.00>
14	<B14>	<8>	<10>	<+186.00>	<+200.00>
15	<B15>	<9>	<10>	<+478.00>	<+456.00>
16	<B16>	<9>	<11>	<+183.00>	<+203.00>
17	<B17>	<10>	<12>	<+203.00>	<+183.00>
18	<B18>	<10>	<45>	<+427.00>	<+401.00>
19	<B19>	<11>	<12>	<+427.00>	<+401.00>
20	<B20>	<12>	<13>	<+202.00>	<+184.00>
21	<B21>	<12>	<44>	<+422.00>	<+406.00>
22	<B22>	<13>	<24>	<+135.00>	<+152.00>
23	<B23>	<13>	<14>	<+179.00>	<+193.00>
24	<B24>	<14>	<21>	<+517.00>	<+501.00>
25	<B25>	<14>	<15>	<+284.00>	<+243.00>
26	<B26>	<15>	<18>	<+786.00>	<+759.00>
27	<B27>	<15>	<16>	<+222.00>	<+155.00>
28	<B28>	<16>	<17>	<+774.00>	<+757.00>
29	<B29>	<17>	<18>	<+239.00>	<+217.00>
30	<B30>	<18>	<19>	<+774.00>	<+757.00>
31	<B31>	<19>	<20>	<+212.00>	<+227.00>
32	<B32>	<19>	<21>	<+276.00>	<+286.00>
33	<B33>	<20>	<22>	<+290.00>	<+307.00>
34	<B34>	<20>	<28>	<+200.00>	<+186.00>
35	<B35>	<21>	<22>	<+291.00>	<+306.00>
36	<B36>	<22>	<23>	<+185.00>	<+201.00>

Branch Number	Branch Name	Start Node	End Node	Flow Capacity(kg) From Start Node	Flow Capacity(kg) From End Node
37	<B37>	<23>	<24>	<+198.00>	<+18.00>
38	<B38>	<23>	<27>	<+183.00>	<+203.00>
39	<B39>	<24>	<25>	<+502.00>	<+282.00>
40	<B40>	<25>	<35>	<+237.00>	<+219.00>
41	<B41>	<25>	<26>	<+237.00>	<+219.00>
42	<B42>	<26>	<33>	<+197.00>	<+224.00>
43	<B43>	<26>	<27>	<+201.00>	<+185.00>
44	<B44>	<27>	<28>	<+580.00>	<+564.00>
45	<B45>	<28>	<29>	<+274.00>	<+256.00>
46	<B46>	<29>	<30>	<+218.00>	<+232.00>
47	<B47>	<29>	<31>	<+159.00>	<+192.00>
48	<B48>	<30>	<32>	<+220.00>	<+201.00>
49	<B49>	<30>	<64>	<+211.00>	<+196.00>
50	<B50>	<31>	<32>	<+456.00>	<+442.00>
51	<B51>	<31>	<33>	<+210.00>	<+232.00>
52	<B52>	<32>	<36>	<+210.00>	<+232.00>
53	<B53>	<33>	<34>	<+210.00>	<+232.00>
54	<B54>	<34>	<35>	<+450.00>	<+428.00>
55	<B55>	<34>	<36>	<+241.00>	<+215.00>
56	<B56>	<35>	<38>	<+250.00>	<+227.00>
57	<B57>	<36>	<37>	<+250.00>	<+227.00>
58	<B58>	<37>	<38>	<+215.00>	<+192.00>
59	<B59>	<37>	<63>	<+218.00>	<+238.00>
60	<B60>	<38>	<39>	<+122.00>	<+145.00>
61	<B61>	<39>	<40>	<+199.00>	<+222.00>
62	<B62>	<39>	<60>	<+561.00>	<+583.00>
63	<B63>	<40>	<41>	<+143.00>	<+103.00>
64	<B64>	<40>	<57>	<+353.00>	<+335.00>
65	<B65>	<41>	<42>	<+213.00>	<+229.00>
66	<B66>	<41>	<55>	<+215.00>	<+192.00>
67	<B67>	<42>	<50>	<+542.00>	<+511.00>
68	<B68>	<42>	<43>	<+234.00>	<+208.00>
69	<B69>	<43>	<44>	<+380.00>	<+413.00>
70	<B70>	<43>	<46>	<+202.00>	<+219.00>

ranch Number	Branch Name	Start Node	End Node	Flow Capacity(kg) From Start Node	Flow Capacity(kg) From End Node
71	<B71>	<44>	<45>	<+202.00>	<+219.00>
72	<B72>	<45>	<46>	<+406.00>	<+387.00>
73	<B73>	<45>	<47>	<+197.00>	<+175.00>
74	<B74>	<46>	<48>	<+197.00>	<+175.00>
75	<B75>	<47>	<48>	<+409.00>	<+383.00>
76	<B76>	<48>	<49>	<+107.00>	<+139.00>
77	<B77>	<49>	<50>	<+97.00>	<+124.00>
78	<B78>	<50>	<51>	<+97.00>	<+124.00>
79	<B79>	<51>	<52>	<+235.00>	<+250.00>
80	<B80>	<51>	<53>	<+109.00>	<+123.00>
81	<B81>	<52>	<58>	<+120.00>	<+101.00>
82	<B82>	<52>	<54>	<+123.00>	<+109.00>
83	<B83>	<53>	<54>	<+498.00>	<+471.00>
84	<B84>	<54>	<56>	<+202.00>	<+184.00>
85	<B85>	<55>	<56>	<+436.00>	<+463.00>
86	<B86>	<56>	<57>	<+190.00>	<+217.00>
87	<B87>	<57>	<59>	<+254.00>	<+223.00>
88	<B88>	<58>	<59>	<+536.00>	<+503.00>
89	<B89>	<59>	<60>	<+213.00>	<+194.00>
90	<B90>	<60>	<61>	<+219.00>	<+188.00>
91	<B91>	<61>	<62>	<+215.00>	<+241.00>
92	<B92>	<61>	<66>	<+679.00>	<+723.00>
93	<B93>	<62>	<63>	<+227.00>	<+264.00>
94	<B94>	<62>	<65>	<+710.00>	<+692.00>
95	<B95>	<63>	<64>	<+695.00>	<+674.00>
96	<B96>	<64>	<65>	<+257.00>	<+220.00>
97	<B97>	<65>	<66>	<+246.00>	<+210.00>

Table (A-7) Waste generated for each street of the Al-Molhaq (1,2)

Nodes 1 street Node-2 steet Node	Loads kg/week	Nodes 1 st. Node-2 st. Node	Loads kg/week	Nodes 1 st. Node-2 st. Node	Loads kg/week	Nodes 1 st. Node-2 st. Node	Loads kg/week
1-2	180*	17-19	425	37-38	1418	52-53	1304
1-3	520*	18-20	425	37-50	284	53-55	284
2-32	284	19-20	1181	38-39	1040	54-55	1304
2-34	591*	20-21	284	38-104	*520	55-57	284
3-4	180*	21-22	1181	39-40	973	56-57	1304
3-5	2363	21-23	454	40-42	425	56-58	284
4-25	284	22-24	454	41-42	973	57-59	284
4-27	1210	23-24	1181	41-95	76	58-59	1304
5-6	180*	23-25	284	42-43	284	58-60	284
5-7	945	24-26	284	43-44	473	59-61	284
6-12	284	25-26	1181	43-47	189	60-61	1323
6-14	1181	26-27	284	44-90	189	61-63	284
7-8	180*	27-28	284	44-91	265	62-63	1323
8-9	1181	28-29	1181	45-65	170	63-64	359
9-11	359	28-30	284	45-90	973	64-65	1323
9-77	284	29-31	284	45-62	359	65-66	312
10-11	1181	30-31	1181	46-47	945	66-67	1304
10-12	284	30-33	284	46-62	189	66-68	473
11-13	284	31-32	284	46-60	76	66-89	945
12-13	1181	32-33	1181	47-49	709	67-69	425
13-14	284	33-34	284	48-49	142	68-69	1323
14-15	284	34-35	142*	48-54	359	68-70	284
15-16	1181	35-36	652*	49-50	973	69-71	284
15-17	284	35-53	284	50-51	142	70-71	1323
16-18	284	36-37	992	51-52	142	70-72	284
17-18	1181	36-52	284	51-54	1304	71-73	284

Nodes 1 st Node-2 st Node	Loads kg/week	Nodes 1 st Node-2 st Node	Loads kg/week	Nodes 1 st Node-2 st Node	Loads kg/week	Nodes 1 st Node-2 st Node	Loads kg/week
72-81	123	93-94	473	109-110	1040	128-129	359
73-75	284	94-95	425	109-121	359	129-130	662
74-75	1323	95-96	180*	110-111	378	130-131	662
74-80	123	96-97	690	111-112	359	130-135	406
75-76	284	96-98	359	111-118	359	131-132	643
76-77	284	97-99	690	111-120	662	132-133	359
76-79	1323	97-163	709	112-113	973	133-134	1021
77-78	1323	98-99	709	113-114	359	133-152	359
78-79	284	98-102	803	114-115	662	133-160	359
78-165	8411	99-100	265	114-116	359	134-135	359
79-80	142	100-101	803	115-117	359	134-147	359
80-83	973	100-161	359	116-117	662	135-136	359
81-82	973	101-102	973	117-119	359	135-144	359
82-83	284	101-132	312	118-119	662	136-137	662
83-84	473	102-103	331*	119-120	359	137-138	359
84-85	501	103-106	1021	120-121	359	138-139	662
85-86	973	103-108	331	121-122	1068	138-140	359
86-87	501	104-105	359	122-123	359	139-141	359
86-164	501	104-167	1252	123-124	662	140-141	662
87-88	473	105-106	359	123-125	359	140-143	359
87-92	501	105-112	1040	124-126	359	141-142	359
88-89	501	106-107	359	125-126	690	142-143	662
89-90	473	107-108	1040	125-128	359	143-144	359
91-92	473	107-110	359	126-127	359	144-145	662
91-94	973	108-109	359	127-128	690	145-146	359
92-93	973	108-131	973	127-136	378	146-147	359

Nodes 1 street Node-2 st. Node	Loads kg/week	Nodes 1 st. Node-2 st. Node	Loads kg/week	Nodes 1 st. Node-2 st. Node	Loads kg/week	Nodes 1 st. Node-2 st. Node	Loads kg/week
146-148	331	153-154	359	157-162	359	164-165	1418
147-149	359	154-155	359	158-159	359	165-166	2524
148-149	662	154-159	662	159-160	378	166-167	*0082
148-150	359	155-156	359	160-161	737	Total Load kg/week	138896
149-151	359	155-158	662	161-163	359		
150-151	662	156-157	709	162-163	359	Total Load ton/d	19.842
152-153	359	157-158	359	163-164	284		

* = This sign indicates that the quantity has been halved

Table (A-8) Waste generated for each street of the Shohada Al-Mulhaq & Dhubat Al-Usra

Nodes 1 street Node-2 st. Node	Loads kg/week	Nodes 1 street Node-2 st. Node	Loads kg/week	Nodes 1 st. Node-2 st. Node	Loads kg/week
1-2	213	16-18	532	36-40	96
1-4	335	17-18	335	37-38	665
2-3	335	18-42	734	38-39	931
2-5	399	17-19	399	56-38	468
3-8	601	17-20	221	39-41	335
4-5	239	19-21	346	39-54	266
4-6	266	19-40	346	40-41	442
5-7	213	20-21	734	41-51	266
6-7	734	21-23	346	41-52	665
6-32	335	22-23	734	42-43	266
7-8	335	23-25	346	42-47	665
7-30	335	23-35	362	43-44	266
8-10	851	24-25	734	43-46	665
9-10	335	25-27	266	44-97	734
9-26	96	26-27	734	45-94	133
9-28	69	27-29	335	45-96	266
10-12	532	27-34	362	45-46	266
11-12	335	28-29	734	46-47	266
11-24	96	28-30	346	47-49	266
11-26	213	29-31	346	48-92	665
12-14	67	30-31	176	48-94	149
13-14	335	31-32	176	48-49	665
13-22	266	32-33	346	49-51	266
13-24	96	33-34	133	50-90	133
14-16	532	33-37	2128	50-92	149
15-16	335	34-35	718	50-51	665
15-20	133	35-36	708	52-53	346
15-22	213	36-37	761	52-90	133

Nodes 1 street Node-2 st. Node	Loads kg/week	Nodes 1 street Node-2 st. Node	Loads kg/week	Nodes 1 st. Node-2 st. Node	Loads kg/week
53-58	452	71-108	133	87-88	601
53-54	266	72-73	665	87-101	266
54-55	426	73-108	213	88-99	266
55-57	133	73-74	266	88-93	101
56-60	628	74-107	266	89-90	601
56-57	628	74-76	266	89-91	266
57-58	229	75-76	904	91-92	266
58-59	133	75-77	266	91-93	601
59-60	867	76-105	186	93-94	601
59-61	335	-7877	904	93-95	266
60-62	335	77-79	266	95-97	266
61-62	867	78-105	80	95-96	734
61-63	335	78-80	266	97-98	107
62-64	335	79-80	904	98-99	266
63-64	867	79-81	266	98-100	1080
63-65	229	80-82	266	99-101	734
64-66	133	81-82	904	100-102	266
65-72	266	81-89	202	101-102	293
65-74	665	82-104	266	102-103	1117
66-67	160	82-83	213	103-104	107
66-70	266	83-103	266	104-106	585
67-68	266	83-84	601	105-106	266
67-69	468	83-85	266	106-107	585
68-110	335	84-86	266	107-109	585
68-69	468	84-89	133	108-109	266
69-71	266	85-87	665	109-110	1000
70-71	665	85-86	213	**Total Load kg/week**	**66179**
70-72	266	86-88	266	**Total Load ton/d**	**9.45**

Table(A-9): Waste generated for each street of the Al-Usra

Nodes 1 street Node-2 st. Node	Loads kg/week	Nodes 1 street Node-2 st. Node	Loads kg/week	Nodes 1 st. Node-2 st. Node	Loads kg/week	Nodes 1 st. Node-2 st. Node	Loads kg/week
1-2	1380	15-18	1545	31-33	878	48-49	246
1-17	1194	15-16	562	32-36	386	49-50	221
2-3	1194	16-17	597	33-34	442	50-51	221
3-4	442	17-18	386	34-35	878	51-52	485
3-5	520	18-19	878	34-36	456	51-53	232
4-11	442	19-20	386	35-38	477	52-58	221
4-16	442	19-21	386	36-37	477	52-54	232
5-6	474	20-22	386	37-38	407	53-54	969
5-7	302	20-28	983	37-63	456	54-56	386
6-8	302	21-22	456	38-39	267	55-56	899
6-49	808	22-23	456	39-40	421	56-57	407
7-8	934	23-24	421	39-60	1144	57-59	477
7-9	386	23-27	386	40-41	246	58-59	3901
8-10	386	24-25	1144	40-57	688	59-60	074
9-10	934	25-35	527	41-42	442	60-61	074
9-11	386	25-26	450	41-55	407	61-62	456
10-12	386	26-33	351	42-50	1053	61-66	1402
10-45	828	26-27	421	42-43	442	62-63	491
11-12	934	27-28	407	43-44	793	62-65	1402
12-13	386	28-29	899	43-46	421	63-64	1369
12-44	828	29-30	442	44-45	421	64-65	477
13-24	281	29-31	442	45-46	793	65-66	456
13-14	372	30-32	562	45-47	372	Total Load kg/week	57983
14-21	1018	30-64	597	46-48	372		
14-15	527	31-32	386	47-48	793	Total Load ton/d	8.28

Appendix B

Pictures of Containers, Compactors and Waste for The Study Area

Figure (B2.1) Shows a small type of containers that were recently used in the study area

Figure (B2.2) Shows a big type of containers that were recently used in the study area.

Figure (B2.3) Shows one of the types of compressors used in the assembly process in the study area

Figure (B2.4): Shows the solid waste in final landfill for Karbala District Center.

الخلاصـــــة

يعتبر موضوع إدارة النفايات الصلبة من المواضيع المهمة في السنوات الأخيرة نتيجة التحضر السريع وتحسين مستوى المعيشة يستهلك جمع النفايات الصلبة حوالي 60%- 80% من اجمالي تكاليف أنظمة إدارة النفايات الصلبة.

من خلال الجولات الميدانية لمنطقة الدراسة في مدينة كربلاء لوحظ ان جمع ونقل النفايات الصلبة الى مكبات النفايات الصحية يكون بطرق قديمة، كما لا توجد استراتيجية فعالة لأليات جمع النفايات الصلبة، ولتقليل كلفة ووقت جمع ونقل النفايات الصلبة, من هنا تحول تركيز هذه الدراسة لتلبية احتياجات بلدية كربلاء.

تمت الدراسة في (اكتوبر 2020 الى سبتمبر 2021) ناقشت الدراسة جزئين رئيسيين يتعلق بتوجيه الية جمع النفايات الصلبة لمنطقة الدراسة (الملحق 1و 2 , شهداء الملحق وضباط الاسرة، والاسرة). تعامل الجزء الاول مع كميات النفايات الصلبة وطرق التجميع والضاغطات وكفاءة الطاقم، والجزء الثاني مع تقنيات برمجة الكومبيوتر وذلك باستخدام ثلاث برامج هندسية، (ArcGIS, AutoCAD ,WinQSB).

تم ادخال المعلومات في برنامج (WinQSB) الذي قام بإجراء تحليل رياضي نتج عنه ثلاث حلول للحصول على اقصر مسار واقل عدد ممكن من الربطات وجمع اكبر كمية ممكنة من النفايات الصلبة بنسبة 12 %, 16%, 28% الملحق (1,2) , 11 %,21%, 31% شهداء الملحق وضباط الاسرة , 11% , 19%, 30% الاسرة ورسمت النتائج باستخدام برنامج الاوتوكاد , أظهرت النتائج ان هذه النسب لم تحقق الكفاءة المطلوبة, وللحصول على المسار الأمثل وتحقيق نسب اعلى استخدم برنامج نظم المعلومات الجغرافية (ArcGIS) من خلال تطبيق الحلول الثلاثة معا الذي يخدم حوالي 78%من حي الملحق(1,2), و68% لحي شهداء الملحق وضباط الاسرة و67% لحي الاسرة.

تم اقتراح جداول لحركة المركبات خلال الصيف والشتاء للاستفادة منها في مناطق أخرى في مدينة كربلاء. أخيرا يوضح هذا العمل ان الحي السكني الملحق (1و 2) حقق اعلى النتائج من حيث المسار الأمثل واقل كلفة لجمع النفايات الصلبة واقل وقت.

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة بابل
كلية الهندسة
قسم الهندسة البيئية

(تطوير نظام إدارة النفايات الصلبة لبعض احياء مدينة كربلاء)

رسالة

مقدمة الى كلية الهندسة – جامعة بابل

كجزء من متطلبات نيل درجة الماجستير في الهندسة/الهندسة البيئة

من قبل
فدك صلاح صاحب كاظم

اشراف
أ. م. د. نبأ شاكر هادي

1443 هـ 2021 م