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Improvement of Traffic Performance of Hilla City Roads Networks

A Thesis

Submitted to the Department of Civil Engineering, College of Engineering, University of Babylon in Partial Fulfilment of the Requirements for the Master Degree in Engineering / Civil Engineering / Transportation

By

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بسم الله الرحمن الرحيم

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2 / 6 / 2021

Dedication

Great thank Almighty Allah for his blessings and all the achievements in my life. I am grateful to my family for their support and patience throughout my studies and provided me with motivation and financial support. Without them, none of this achievement would be possible.

To:

My Mum and Dad

My brothers and my sisters.

Every person supported me during my entire life.

Fatima Kareem Obayes

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Abstract

Hilla city roadway network suffers from frequent and traffic congestions due to the increase in population density, the increase in car ownership with a constant roadway capacity, this study was conducted to evaluate traffic volumes and improvement Hilla city road networks. To implement the traffic assignment model, a database of the study area roadways must be created, and this was implemented by ArcMap GIS 10.7 software, the majority of roadway network data was collected from the field, and the rest was provided by the governmental directorates concerned, the arterial network of Hilla city consists of 31 links, and 26 nodes. The traffic volumes in the study area were assigned on arterials network by using user equilibrium assignment model by using software designed especially for this study programmed by Visual Basic language and Microsoft Excel Solver, to find links that suffer from congested, estimate the link travel times for evaluation the overall condition of the study area in the base year (2020), and the target years (2025, 2030, 2035). Several suggestion improvements were implemented at several different stages of time (long term & short term), including (suggestion new arterials & addition of new lanes). For showing the difference in level of service for Hilla arterials network, four cases were done for the base year (2020) and future years (2025, 2030, and 2035), Hilla arterial network's overall evaluations for (2020, 2025, 2030, 2035) are between (C – E), respectively. A random destination point was chosen, which representing higher education center of colleges to finding the shortest paths in the study, travel times, V/C and LOS. The overall evaluations of the assigned shortest paths LOS are between (D – F). Two cases for suggested improvements in the long term with adopting suggested major & minor arterials roadways, the overall evaluations for long-term suggestions are (C, B), respectively. Two cases for suggested improvements in the short term, in case 1, the addition of new lanes by reducing the width of the median islands from (6 and 5 m) to become (1 m). The overall evaluation of case 1 is (B). In case 2, assign traffic volumes from the centers of all sectors to each other to find the optimum paths. The overall evaluation of the assigned optimum paths before improvement LOS are between (B – F), and after improvement LOS are between (A – C), respectively.

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List of Abbreviations and Symbols

Abbreviations and Symbols	Details
CBD	Central Business District
E	The number of links (edges)
GIS	Geographic Information System
L	Length of link
LOS	Level of service
M	The total length of the network
P	Represents the number of discrete graphs that are not connected
S	Speed
T	Travel time
V	The number of nodes (vertices)
$\boldsymbol{\beta}$	(Beta) index
$\boldsymbol{\alpha}$	(Alpha) index
$\boldsymbol{\gamma}$	(Gamma) index
$\boldsymbol{\varepsilon}$	(Eta) index

Chapter One

Introduction

Chapter One

Introduction

1.1 Introduction

Roads transportation accounts for a significant proportion of both goods and passengers traffic, especially in every metropolis, heavy traffic releases toxic, traffic congestions, and traffic accidents (Chow, 2007), as poor transportation infrastructure in many developing countries caused heavy traffic congestion, all these infrastructures were often congested due to poor management and poor planning (Scellato et al., 2010).

Traveling congestion and delays are also exacerbated by heavy traffic on the roads, automobiles crawling gradually along congested city roads are becoming commonplace, and heavy traffic can make managing unexpected events more difficult. These rather occurrences, combined with heavy traffic levels, cause severe congestion and, as a result, delay for thousands of people (Cheng et al., 2016).

Transportation designers and engineers must formulate and implement strategies to manage transportation facilities and infrastructure and accommodate new traffic demands, a dependable traffic flow controlling/assignment must be implemented to accomplish this, in which travelers respond to traffic management measures and assessments to manage congested roads on congested highways (Kelly, 1994; Murchland, 1970). The processing of defining the flow pattern in a network with a specific traveling request between pairs of origin-destination may be termed as traffic assignment, the goal of the optimization assignment is to discover flow patterns such that the overall trip time expense in the network is as low as possible, traffic assignment had long been an important part of transport infrastructure (Jayakrishnan et al., 1994).

Traffic assignment is used to evaluate traffic density on roadway systems based on some functional and physical characteristics and the expected traffic that can be used. This process consists of two phases. First, who must define the expected traffic flow that can be used by the transportation networks, which is usually expressed in terms of current and future origin/destination matrix based on this data, in the second stage of the process, the expected traffic will be allocated to each section of the road network (Bagdasar et al., 2020).

The main benefit of traffic assignment to roadway network designers is obtaining the design movement estimates for the entire facility. The traffic assignment process tests the facility as part of the transportation system to estimate the assigned traffic on the roadway network (Witheford, 1963).

A traffic assignment model attempts to predict how traffic flows through a road system and the impact on the system, several criteria may be used to quantify these impacts, include environmental pollution, fuel consumption, delay, travel time, and distance traveled. Changes in travel demand, travelers' knowledge, road capacity, signal timings, and road tolls may all be investigated using traffic assignment models (Witheford, 1963).

1.2 Problem Definition

The arterial roadway network in Hilla city suffers of many problems such as low speed, increasing congestion, long time of travel, the low level of services; increase the level of accident rates, low road network management. Most of the traffic studies are still dealing with individual cases without the existence of a comprehensive strategy to deal with transportation problems. For this reason, the urban road network is used to increase efficiency that can be achieved through the flow of traffic sound management and this requires a great deal of travel times, travel speed and data delay. So, Al-Hilla needs to improvement roadway the network with efficient movement of traffic and minimal traffic congestion problems, for these reasons, forecasts traffic demand for current and future scenarios.

1.3 Aim and Objectives

- Evaluating of the measured performance of the arterials network in the study area.
- Determine the actual links that will be used in the roadways network according to roadways capacity by utilizing user equilibrium assignment.
- Estimating services level of the arterial network in Hilla city for both base year (2020) and target years (2025, 2030, and 2035) and finding the best path (shortest path) from (origin point) to the random destination (education centers).
- Suggesting an improvement to the network within the study area.

1.4 Thesis Structure

Five chapters are included in this thesis as described below:

Chapter One: gives an idea, definition of the problem, and the objectives of the study and the study structure.

Chapter Two: shows the related literature of the previous work.

Chapter Three: contains the background of Hilla city, its location and the required data to achieve the study objectives.

Chapter Four: consists of three sections:

- First section deals with the data set of links and nodes within the arterial network, its measured performance. All these are done as the main requirements of functional assessment of the network.
- Second section deals with the fourth step in the traditional travel-demand forecasting process (traffic assignment). These are done to assign traffic volumes for Hilla arterials network for the current and future scenarios.
- Third section deals with suggested improvements for achieving optimization of Hilla arterials network for the long and short terms before and after suggested improvements.

Chapter Five: shows conclusions, recommendations, and recommendations for the future work.

Chapter Two

Literature Review and Basic Concepts

Chapter Two

Literature Review and Basic Concepts

2.1 Introduction

This chapter presents a literature review on planning of urban transportation. It describes urban roadway networks, urban roadway network attributes, O-D matrix, traffic assignment with their types, levels of service, traffic islands, their types. Furthermore, the selected computer programs including (Arc Map GIS).

2.2 Background of Urban Transportation Planning (UTP)

Urban traffic congestion is widely regarded as one of the most significant problems facing cities and urban areas worldwide. Cities require urban transportation networks on a national and international scale. This particular requirement comes with its difficulties, affecting cities and other urban systems. Cities are experiencing increased urban transportation problems as their populations grow and urban development expands (Rodrigue, 2020). Some of these problems arise as a result of increasing urbanization, some are caused by inadequate infrastructure, inconsistencies in urban design, or poor traffic control management (Zeng et al., 2019). Changes in urban layouts or densities, such as the transition from low-to-high rises or changes in land use via urban redevelopment, are instances of this (Cheshmehzangi, 2018). The relationship between these changes and increasing urban traffic is shown in various ways, which could eventually lead to better urban land use assignment (Silveira & Dentinho, 2018),through networked-based location-sensing or location-based information (Campbell et al., 2006). The evaluation and transportation selection of infrastructures to serve present and future planning is part of urban transportation planning (Garber & Hoel, 2014). Two distinct periods are involved in the process, the first focuses on the short term, intending to select initiatives that could be realized in 1-3 years, the second time horizon considers an area's long–term transportation requirements of an area and identifies the projects to be constructed over a 20 year period (Garber & Hoel, 2014).

The process could be performed in terms of the procedures described, as follows (Meyer, 2016):

- Existing inventory traveling and facilities.
- Establishing objectives and goals.
- Alternatives' generation.
- Guess the time of traveling demand and project budget.
- Alternatives' assessment.
- Selecting of project.

The objective of the transportation planning process is to provide the information necessary for decision-making on when and where improvements should be made in the transportation system (Khisty & Lall, 1998).

2.3 Urban Roadway Network

The increasing expansion of the urban scale leads to enormous pressure on the traffic on urban roadways, so traffic congestion is now widespread in almost every place in urban areas. Traffic congestion does not affect the movement of travelers only, but it also has other effects such as increasing the cost of the trip, pollution, noise, and it also affects the safety of road users (William & Martin, 1998). Therefore, traffic management is most important to effective ways to relieve traffic congestion, and it is necessary to analyze traffic on the urban roadway network, urban roadway network consist of many nodes and links, the nodes indicate intersections and links refer to sections of the roadway (William & Martin, 1998). Several researchers (Jiang et al., 2008) have analyzed the urban roadway network topology. In most cases, the links in the network represent real physical constructs (Jiang & Claramunt, 2004). (De Montis et al., 2007) utilized a weighted network model to study the roadway network structure representing the traffic between cities and quantitatively analyzed the weighted and topological characteristics for the resulting network.

2.4 Urban Roadway Network Attributes

Many attributes are assigned to roadways links that represent the level of service provided by the section and the other sections associated with it, for example, the link distance is determined based on the actual roadway shape (curvature and terrain are in consideration) and travel times, link capacities, speed, and any delays that influence traveling time (William & Martin, 1998). Characteristics should be considered, including the effects of traffic signals on traveling time (Brusewitz et al., n.d.). The following are some of the important attributes to the traffic assignment process on the roadway network:

2.4.1 Link Speed

Link speeds are one of the most important inputs to modeling process, the traffic assignment process to roadways is related to travel times and speeds on links, their size, and capacity. This process requires what are commonly referred to as "free-flow speeds," which means the average passenger speed measured during low to moderate flows (approximately 1300 passenger vehicles per hour/lane) (William & Martin, 1998).

It is important to correctly estimate free-flow speed in the field since this factor is utilized in models for transportation system design, operational analysis, and performance assessment. Field measurement of Free-Flow Speed, on the other hand, is time-consuming since it requires collecting a large specimen size of vehicle speeds at the right period, most transportation authority's utilize modeling methods to estimate free-flow speed to overcome field data collecting difficulties because the speed of free flow is influenced by various variables (Moses & Mtoi, 2013). The FFS estimates the segment's running time and determines the urban roadway class. The FFS in urban roadways is the speed at which vehicles travel under low traffic volumes and when all the signs on the roadway are green throughout the journey.The best location for measuring the FFS for urban roadways is in the middle of the block and as far away as possible from the nearest signaled intersection (Manual–HCM, 2000).

2.4.2 Link Capacity

The highest hourly flow rate at which people or automobiles may properly be anticipated to pass a point or uniform portion of a lane or a roadway over a particular period under prevailing roadway and traffic conditions is described as the capacity of a highway facility (Council, 2010; Manual, 2010; Molander et al., 2012). Even though capacity has a common meaning, a magnitude is determined by different traffic and highway factors. As a result, many nations have devised their standards for estimating the traffic carrying capacity of their roads (Jayaratne & Pasindu, 2020). Link capacity is an important function of lanes' number in the roadways. Nevertheless, the type of area and the type of facilities can determine the lane capacity; therefore, several factors are used for calculating the variance in lane capacity in roadway networks (William & Martin, 1998).

2.4.3 Link Distance

Link distance represents the length of the link, the length of each link can be measure through the software's, or the length of each link can be measure from the map, an alternative to manually measuring length is to use the x and y coordinates of the two nodes that define each link and the estimation of correlation distances (William & Martin, 1998).

2.4.4 Link Volume

Daily average traffic or design loads per hour are two ways to represent traffic volumes. The rate of service flow, often utilized to assess engineering design options, is calculated using traffic volumes (Welde & Qiao, 2020). Traffic volume studies are performed to evaluate the quantity, movement, and classification of highway vehicles at a particular location, because most vehicles have varied speeds and body dimensions, estimating traffic volume in the setting of heterogeneous traffic has always been challenging. This problem was solved by devising a method of turning a wide range of vehicles into equal passenger cars, known as the passenger car unit, and expressing volume in passenger car units per hour. Because traffic volume does not always remain constant, a continuous technique of estimating traffic volume is critical for the proper operation of transport vehicles (A. U. H. Bhat & Gupta, 2018).

2.5 Origin-Destination matrix

The matrix of origin and destination is essential in transportation analysis. The matrix contains information on the number of travelers who commute from one region to another, or it expresses the number of traffic volumes moving from one region to another, often it is obtained by several methods including (during home interviews, direct surveys, etc.), by defining the OD matrix of the transport network, the demand for paths connecting pairs of regions are defined (Abrahamsson, 1998). Most transport models include (OD) matrices and travel patterns as essential inputs for long-term strategic planning and short-term traffic management and controlling. The OD flows' distribution between various OD pairings reveals the OD matrix's intrinsic structural information, which must be considered when comparing OD matrices (Behara, 2019). On the other hand, optimization models rely on point-based traffic count data to update and forecast the outdated prior OD matrix and cannot thus characterize the distribution of trips (or "structure" of travel patterns) throughout the network. The chosen techniques usually depend on traffic survey-based restrictions, including trip productions/attractions, the OD flows' proportion, etc. (Behara, 2019).

2.6 Traffic Assignment

The final stage of the traditional process of modeling traveling demand is in determining the true roadway, to be utilized and estimated assigned volume for each section of the highway (Abedali & Qasim, 2017). A traffic assignment procedure aims to determine how traffic flows through a highway system and its impacts. Distance traveled, traveling time, delaying, fuel consumption, and environmental degradation are all factors that may be used to quantify these consequences. Three types of data are required to formulate and solve a traffic assignment procedure, the two of these are the demand for traveling and the features of the transportation system, the travel demand which is predicted throughout the phases leading up to the traffic assignment process for traveling demand modeling, indicates the most probable travel choices that people would make based on the performances of the transportation system (Chow, 2007).

The travel decisions considered include frequency of trip, choices of destination mode (Janson, 1991). The traditional planning models take into account the travel demand during a certain period only. Therefore, a proposed system of transport system features is the second element of traffic assignment formulations (Janson, 1991). The third type of information is a technique of assessing the proportional distribution of travel demand across the transportation system, given the demand for travel and the system's features (Chow, 2007).

The main objectives of the traffic assignment procedure are:

- Estimates the volume of traffic on roadway network links.
- Estimates of travel costs between origin and trip destinations to be used to distribute trips.
- Obtains reasonable link flows in terms of traffic volumes distributed to it, as well as to identify connections that suffer from high congestion.
- Estimates the paths to be utilized between every pair from origin to destination (O-D).
- Analyzing O-D pairs that use a specific path or correlation.

Travelers will select a path that leads to the shortest time and covers the least distance, depending on traffic on the road. The models listed below are some of the most often utilized traffic assignment models (Modi et al., 2011):

2.6.1 User- Equilibrium Assignment

User Equilibrium (UE) assignment is one of the most widely used methods in practical fields. In the (UE) condition, it is assumed that each traveler will seek to reduce the time/cost associated with the routes chosen (Bar-Gera, 1999). Travelers cannot reduce their travel time on one side by switching to another roadway. This means that the travel time on each route used between any origins (O-D) is the same under this condition, therefore, UE condition naturally exists in every roadway network (Mamun et al., 2015).

2.6.2 All-or-Nothing Assignment

In this model, the trips between any production and attraction zones are located on a single path between them, which is called the shortest path model. This model can be used in small and uncrowded networks where there are few paths, and there is a significant variance in travel cost. However, this model is unrealistic because it uses one single route between all pairs (O-D) even though there is another route at the same or nearly as expensive as travel. In addition, traffic in this model assigned on paths is without considering whether or not there is a sufficient capacity or heavy crowded; fixed input is travel time and does not vary based on the congestion links (Martin & McGuckin, 1998).

2.6.3 Multiple Route Assignment

Travelers might not use the same criteria to determine which way is the shortest. This model acknowledges that numerous pathways between two nodes may have almost identical impedance and, as a result, be used equally. As a result, there is a chance that some tourists may take an even longer path (Abedali & Qasim, 2017).

2.6.4 Stochastic User Equilibrium Assignment

The common framework for modeling and analyzing a transport system was limited to representing the average state of the transport network, such as average travel flows and average correlation flows. For example, in common traffic assignment models, it is possible to obtain predictions of flows in a network on a specific path based on the average flow of the origin (O-D), as well as the ability to correlate, and one of the forms of path selection models is the equilibrium stochastic user (Uchida & Kato, 2017).

SUE models assume that not all travelers have sufficient knowledge of the traffic system because every driver is assuming to be taking the shortest route. In addition, some sophisticated algorithms were used to solve the problems of this model (Huang & Gu, 1994).

2.6.5 Capacity Restraint Assignment

By iterating between all or nothing loading conditions and then predetermining traveling times on links depending on the congestion functional representing the link's capacity, this model seeks to approach the equilibrium solution (Mathew & Krishna Rao, 2007). The travel resistance of a link is increased according to a relation between the practical capacity of the link and the volume assigned to the link in this process, the capacity restraint relationship is (Garber & Hoel, 2014):

$$T_c = T_f * \left(1 + \alpha * \left[\frac{v}{c}\right]^{\beta}\right) \qquad (2-1)$$

Whereas:

T_c = traveling time of congested link (min)

T_f= travel time of free-flow link (min)

v = assigned link traffic volume (vehicles),

c = capacity of a link (pcph), and

α, β= coefficients of volume and delay.

2.6.6. System Optimum Assignment

Wardrop suggested another alternative method for assigning traffic in roadway networks. This is called the second principle of Wardrop as it is stated, "Under conditions of equilibrium, traffic should be arranged in congested networks so that the total cost (of all trips) is minimized." Thus, he reversed Wardrop's first principle, which had always sought to model the behavior of individual drivers. The second principle concerns traffic regulation to reduce travel costs and thus achieve an optimal balance (C. R. Bhat, 2000). System optimum assignment assumes constant capacity on each link. Accidents, weather, and other phenomena lead to wide variation in congestions and road capacity (Unnikrishnan & Hebert, 2008).

2.7. Roadway Service's Level

The notion of service level (LOS) for roads was initially established in the highway capacity handbook (Manual, 1965). Following its debut, a slew of research focused on determining LOS as a method to assess the roadway service's quality as experienced by users. LOS has been defined in this edition of the manual by six groups ranging from 'A' to 'F,' which represented a range of operating circumstances based on a combination of traveling time and the proportion of traffic flow rate to roadway section capacity (Manual, 1985a), this term was revised in connection to various traffic situations. For each road, the HCM used LOS metrics such as traveling speed, traffic flow rate, and traffic density(Manual, 1985b).

LOS is described as "a qualitative metric reflecting operating circumstances within a traffic stream, generally in terms of these service measures as speed and traveling time, freedom of movement, traffic disruptions, comfort, and convenience (Manual–HCM, 2000). Every facility is assigned six LOS, ranging from 'A' to 'F,' with 'A' indicating the best operational circumstances and 'F' representing the worst. There are numerous methods to assess the performance of a transportation facility or service (Manual, 2010), and different points of view to consider when deciding which measures to make (Bhuyan & Nayak, 2013). According to (Manual–HCM, 2000), the service's degree is an indicator of success since it defines operating circumstances within traffic flows in terms of service indicators, including traffic interruptions, traveling time, speed, maneuverability, and convenience and comfort. Other variables, such as slow development, higher traffic volumes, and improper signal timing, drastically decrease the quality of service (Shalaan & Ewadh, 2019). The quality of service in urban regions or regulated regions differs significantly from rural or uncontrolled regions. For example, peak-hour factors, load-factor at junctions, average overall traveling speed, flow situations, and service volume capacity proportion have influenced the quality of service on arterial highways in metropolitan areas (Babit et al., 2016).

2.8 Traffic Islands

They are physical structures, drawn objects that reside on the roads or the side of the road, traffic islands are used for many different purposes according to their types. It is defined as an elevated area extending along the roads to get better traffic flow in an orderly fashion or as a pedestrian rest/stop, it is consist of physical or concrete structures in the shape of panels, barriers, cones' traffic, etc. (Staplin et al., 1997).

2.8.1 Islands of traffic's Categorization and Types

Three basic classes are included depending on the purposes its work, traffic islands may have more than one goal, depending on the location, geometry, and size (Staplin et al., 1997):

- Channelizing Island: It acts as a channel finder, and it provides directions to automobiles. Among the most protuberant uses for this kind at turn-points, it allows for easy-smooth turns, traffic facilitates and avoids interferences with other automobiles.
- Divisional Islands: These are utilized on the side of the road. These are long, extended constructions serve as a divider or median for vehicles traveling in similar directions. Again, these are not designed to assist in turning, but they assist with vehicle movement in a more ordered manner.
- Middle/Refuge Islands: These are huge, and they are intended for walkers rather than automobiles. These are given as safe zones for pedestrians and to make road crossing easier. These elevated constructions may hold a person or people's group. These may be placed in the middle of a road at a pedestrian crossings location because they offer a safe and elevated surface where drivers could see them and stay attentive.

2.9 Geographical Information Systems (GIS)

The GIS program represents a geographic system consisting of program data, computers, and personalities contributing to the spatial analysis of the site's information, display, and process. It also helps to integrate information in a way that contributes to solving problem, as it works to store the data of objects that are in reality in databases and from then it links them to maps in a dynamic way, these maps will change with any change in the databases (Goodchild, 2000). It is consider one of the important tools in the sciences concerned with society, medicine, economics, nature, engineering, planning fields, and even business, because it contains many materials, cultural, demographic, biological, or even economic information (Falih, 2016). This program has been used in transportation fields because it contains data sites, which is essential in transportation applications such as intermodal facilities management, payments management, and also accident analysis, as well as transportation service planning, modeling of bridges, etc. (Al-jazzar, 2012). The GIS system used in the field of transportation (GIS-T) is defined as a system that depends on GIS systems for transportation purposes, as it combines the techniques of a geographic information system and an information system used in transport (TIS) to be integrated systems. The transport data structures that the GIS-T system supports contain paths, links, arrays, nodes, original destination grids, and arrays to use in traffic customization (Alwash, 2019).

2.10 Summary

This work studied traffic assignment modelling by the user equilibrium assignment model for allocating volumes on the roadway network (major and minor), the user equilibrium assignment process were implemented by utilizing software designed specifically for this study program by visual basic language & Microsoft Excel Solver. The outputs of that process were estimate travel times, traffic volumes and level of service in the base year (2020) and the target years (2025, 2030, and 2035) and suggesting an improvement to the network within the study area such as (suggesting new arterials and addition of new lanes). Depending on the previous literature review this thesis will cover the issue of traffic volume within Hilla city, but with the following differences:

- This work was used (visual basic language & Microsoft Excel Solver and using GIS for drawing only) as a software.

- And the target years was three years (2025, 2030, and 2035).
- The implemented process was user equilibrium assignment process.
- The outputs of that process were estimate travel times, traffic volumes and level of service in the base year (2020) and the target years.
- Make suggestion and improvement for the network within the study area such as (suggesting new arterials and addition of new lanes).

The other researchers (Al-jazzar, 2012; Alwash, 2019; Qasim et al., 2018) that study the same issue was used TransCAD & GIS as a software programms. They select one year as a target year which is not give an accurate indication about the estimation of the issue.

Chapter Three

Methodology

Chapter Three

Methodology

3.1. Geographical Location of Hilla City

Hilla city is located 32.46367 degrees latitude north of the equator and 44.41963 degrees longitude east of Greenwich. Hilla city is surrounded from the north by the capital city Baghdad, from the west by Karbalah governorate, from the northwest by Ambar governorate, from the east and northeast by Wasit governorate, and the southwest and the southeast by Najaf and Diwaniyah governorates respectively, as shown in Figure (3 – 1).

Several districts and counties, including Abi-Garaq, Al-kifil, Al-Nil, Al-Mithatiyah, Al-Mahawil, and Sadat Al-Hindiyah as shown in figure (3 – 2), surrounds Hilla city. The city's population reached 473000 unit in 2018, representing around 21.9% of the total Hilla city population according to the update of the statistic directorate (Plan, 2007) , and the population in (2020) reached 485593 unit with an average population growth of 2.66% (2020).

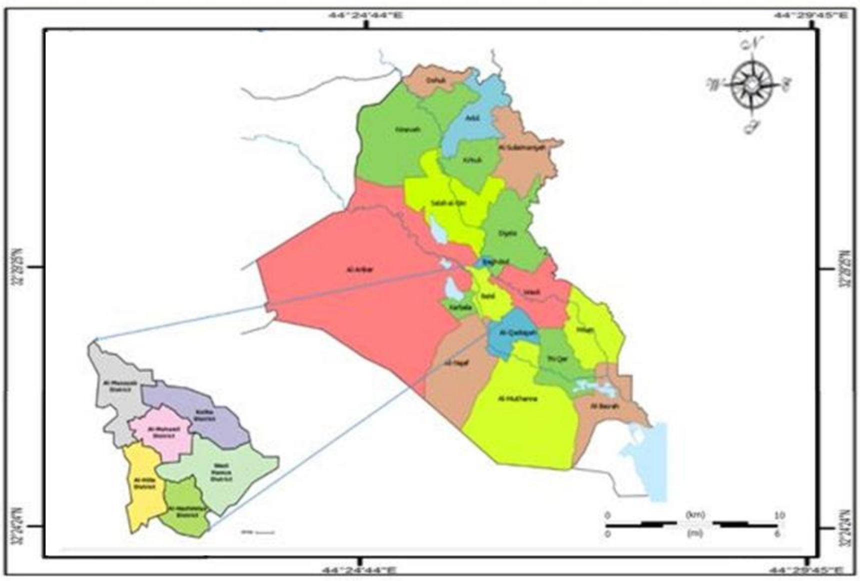

Figure (3 – 1) The Location of Hilla City from Iraq.

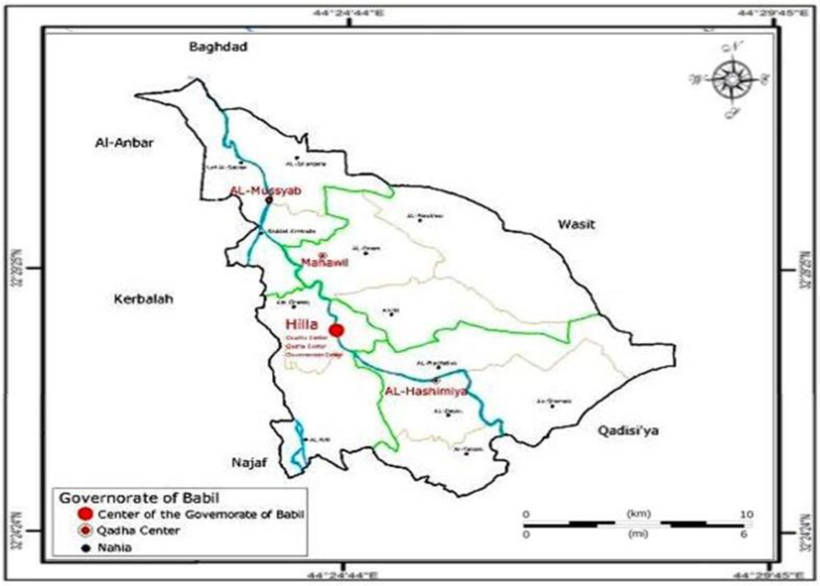

Figure (3 – 2) Location of Hilla city Between Districts and Counties.

3.2 Distribution of Arterials within Study Area

Usually, Hilla city arterial network can be classified into two groups related to highway requirements.

Major arterials: These are usually two-ways 3-lane roads, it serves districts within the city, which would normally be long-distance traffic, and they have some bus routes along with them, with major roads having a free flow speed of 80 (km/hr) and a lane capacity of 1600 (PCU/hr) (Plan, 2007).

It is responsible for connecting city sectors and with external roads. In addition to its traffic function, it is designated place for commercial function, open services, and housing. Therefore, it is an important part of the urban network that includes the city, characterized by the freedom, speed of the vehicles therein, and is provided with a number of traffic signs, with a total length of (77.412 km) (Plan, 2007).

Minor Arterials: These are usually 2-lane dual carriageways, they link between major arterials, they have a free flow speed of 60 (km/hr) and a roadway capacity of 1200 (PCU/hr) (Plan, 2007). They represent the main distribution network of the main roadways, they are dedicated to serving the different sectors of the city and sometimes to the residential neighborhoods and providing commercial, industrial, and recreational services, with a total length of 35,082 km (Plan, 2007).

Traffic intersections form a part of the arterials network and are similar to the centers of the nerves in the human body, if there is a defect in these intersections, the transport network is broken, the intersections consist of the intersection of two or more arterials, for Hilla city, it is characterized by frequent intersections, which are not distributed regularly (Alwash, 2019).

Many intersections lead to many traffic accidents as for the traffic signals, which in turn play a vital role and are very important in the organization and facilitation of the movement of vehicles, and for ensuring the safety of traffic and pedestrian (Alwash, 2019).

3.3 Selection of Study Area

Al-Hilla city has been chosen as a study area to optimize Al-Hilla arterial roadway's network due to traffic congestion during peak hours (7:30-9:30) A.m. & (1:30-3:30) p.m. The study area consists of five sectors as shown in figure (3 – 3) according to Al-Hilla city's master planning map demonstrated, in which the arterial road network consists of 31 links and 26 nodes as shown in Figure (3 – 4), as shown in Table (3 – 1). The daily trips such as students or employees are one reason for traffic congestion because it has consisted of a high percentage of total trips of the case study. These trips are dependent on an arterial roadway's network during peak hours. Therefore, that makes the performance of daily activities worsen day after day.

3.4 Methodology of Data Collection

Effective strategies are used to collect important data within the selected study area. The results represent a key to achieving the research objectives mentioned in Chapter 1, illustrates the data collection stages used in the research:

- Selection of the investigated area’s limits.
- The data needed for the selected programs (volumes, capacity, speed, travel time, number of lanes).
- Identifying the peak duration for the network of traffic.
- Inspecting and setting up the collected data needed with the aid of selected programs characteristics.

The data collection stage, which aims to collect the necessary data within the research field, was designed to illustrate well; database of arterials network in the study area and the main geometric characteristics concerned. The summary of different types of traffic data, which can be collected and use as follow:

- Geometric characteristics (the width of median islands, intersection lane's number per approach, the lane's width for every approach, etc.)
- Speed for each arterial link in the roadway network.
- Database of each links in a roadway network.
- Database of each nodes in a roadway network.

3.4.1 Geometric Data

The geometry data were obtained utilizing field measurements that are done for geometric characteristics of roadways, such as length of each section, no. of lanes per approach, lane width, and width of median islands, and all necessary data of roadways in the study area. A field survey and the satellite pictures are utilized to acquire spatial properties for the roadway network in the selected area; also, most of the roads' geometric data's are utilized, available in Al-Hilla municipality, which represented the key inputs in the process of traffic assignment.

Table (3.1) Details of Roadways in the Study Area.

Link – ID	Between Nodes	Link Name
L1	1 – 2	Old Baghdad Roadway 1
L2	2 – 3	Old Baghdad Roadway 2
L3	2 – 4	Algeria Roadway 1
L4	3 – 4	Hilla-Kish Roadway
L5	4 – 5	Hilla-Kish Roadway
L6	4 – 6	Algeria Roadway 2
L7	3 – 26	Baghdad Roadway
L8	6 –7	Babel Neighborhood Roadway
L9	7 – 8	Bab Al Hussein Bridge
L10	8 –9	Corniche Roadway
L11	24 – 9	Mashhad Al-Shams Roadway
L12	26 – 25	Bell Bridge
L13	24 – 25	60 Roadway 1
L14	23 – 24	Karbala Roadway 1
L15	22 – 23	Karbala Roadway 2
L16	9 – 10	40 Roadway 1
L17	10 – 11	Al-Qaqyad Roadway
L18	10 – 12	40 Roadway 2
L19	13 – 12	Imam Ali Roadway
L20	24 – 21	60 Roadway 2
L21	23 – 20	80 Roadway 1
L22	12 – 21	Al-Jamia Roadway
L23	20 – 21	Al-Tahmazia Roadway 1
L24	19 – 20	Al-Tahmazia Roadway 2
L25	12 – 14	40 Roadway 3
L26	14 – 17	Nader Roadway
L27	21 – 17	60 Roadway 3
L28	19 – 15	80 Roadway 2
L29	17 – 16	60 Roadway 4
L30	17 – 15	Al-Najaf Roadway 1
L31	15 – 18	Al-Najaf Roadway 2

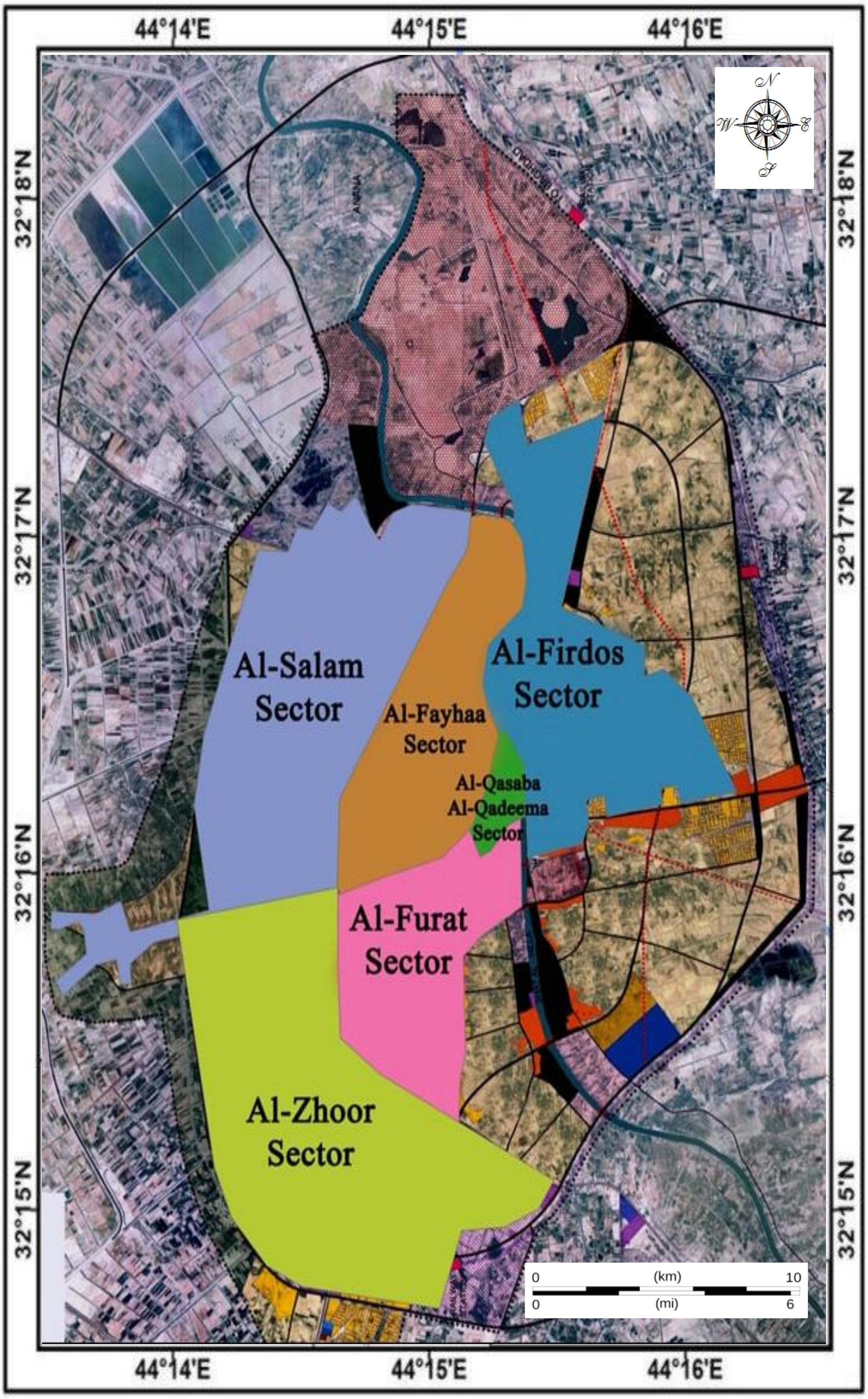

Figure (3 – 3) Sectors of Hilla City.

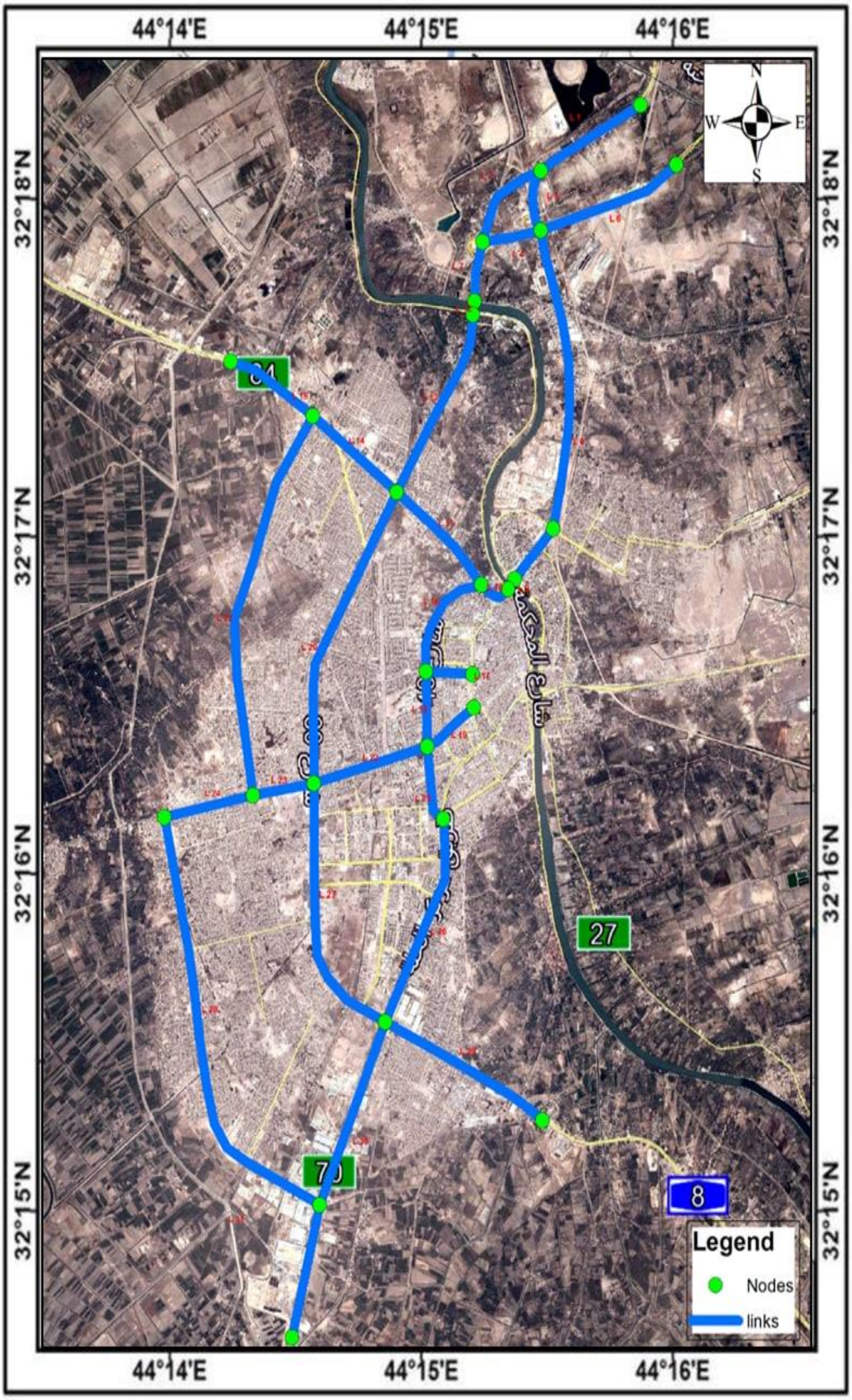

Figure (3 – 4) The Layers of Link and Node for Hilla Arterials Network.

3.5 Traffic Assignment Process

The traffic assignment process consists of several stages:

- First stage: creating a database for the arterials network of Al-Hilla city to make network analysis by using Arc map GIS 10.7 software and measured the performance of the arterial network by using (Beta, Alpha, Gamma, Eta) indexes.
- Second stage: creating an O-D matrix, representing the number of trips distributed between sectors of the study zone, the purpose of the distribution of those trips is to estimate the number of those trips generated from all sectors into every other in the study area.
- Third stage: the user equilibrium assignment is used to assign traffic volumes on the study area network.
- Fourth stage: traffic assignment processes for the study area will be implemented using software designed especially for this study program by Visual Basic language & Microsoft Excel Solver.

3.6 Database of the Arterial Network

3.6.1 The Shapefiles of Arterial Network

The roadway network is represented as shapefiles to perform the network analysis process; these shapefiles were built according to Al-Hilla city's master planning map demonstrated in Figure (3 – 5). By Arc map GIS; two shapefiles were built of roadways networks (nodes & links).

3.6.2 The Network Topology

Arc map GIS 10.7 was used to create a topology network, which was then applied to the layer of links and nodes with two criteria (must be one part, not self-intersection). After applying the topology network, the total of mistakes in the drawing should equal zero part, not self-intersection).

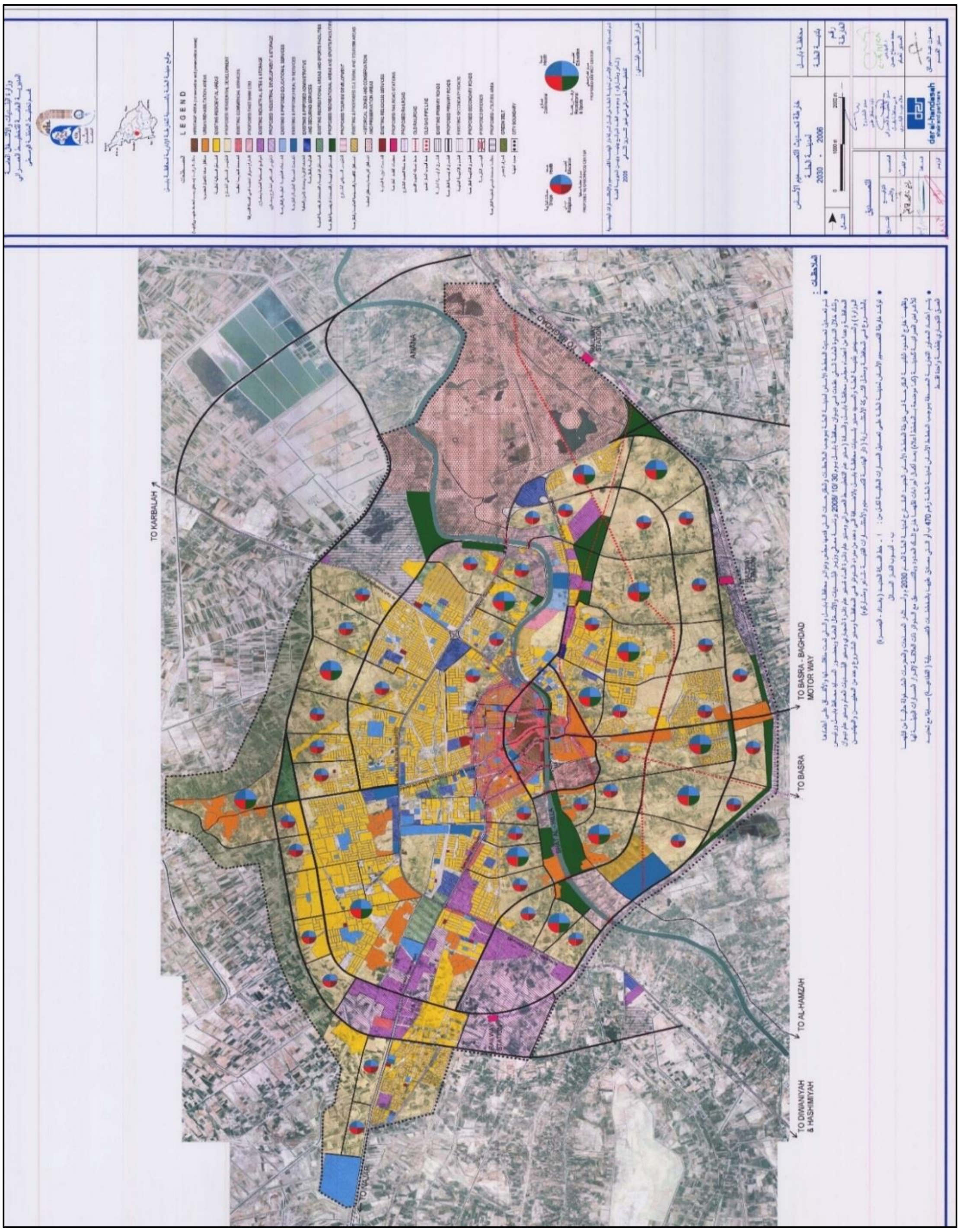

Figure (3 – 5) Study Area Location According to Hilla Municipality Directorate.

3.7 The Database of Links

The Hilla arterials network information was collected from the administration of Hilla Municipality (GIS unit), whereas the rest was gained by observations or measurements. There have been primarily two kinds of characteristic data gained:

- The first data set has been descriptive attributes, including descriptions of roadways such as (ID, link ID, no. of lanes, capacity, speed limit, total width); Table (3.2) illustrates the links attributes. The capacity has been computed by using the following equation (Subramani & Kumaresan, 2012):

Capacity of link = Actual width of carriageway x (1-landuse/ 100)) - Parking space - Encroachment (3.1)

- The second set of data included cost characteristics used to study roadways, such as the roadway length in meters and the cost of time (travel time) in minutes. The following formula has been used to determine the traveling duration (Falih, 2016):

$$Travel\ Time(\text{min.}) = \frac{Link\ Length\ (km) * 60}{Speed\ (km/hr)} \quad (3.2)$$

Table (3.2) Database of Links Attributes.

ID	Link-ID	Length (m)	No. of lanes	Total Width (m)	Speed (Km/hr)	Capacity (pcph)	Travel time (min)
1	L 1	1920.53	6	40	80	6700	1.440
2	L 2	1185.64	4	30	80	3900	0.889
3	L 3	763.63	4	30	80	6700	0.572

ID	Link-ID	Length (m)	No. of lanes	Total Width (m)	Speed (Km/hr)	Capacity (pcph)	Travel time (min)
4	L 4	721.24	4	40	80	6700	0.540
5	L 5	1238.88	4	40	80	3900	0.929
6	L 6	3315.38	6	40	80	6700	1.889
7	L 7	668.09	6	40	80	6700	0.501
8	L 8	186.69	6	30	60	6700	0.135
9	L 9	150.36	4	25	80	3900	0.112
10	L 10	453.26	4	30	60	3900	0.453
11	L 11	1444.5	6	60	80	6700	1.447
12	L 12	105.38	4	30	80	6700	0.079
13	L 13	1614.88	6	60	80	6700	1.211
14	L 14	1325.61	6	60	80	6700	0.994
15	L 15	1833.26	6	60	80	3900	1.374
16	L 16	1305.48	6	40	80	6700	0.979
17	L 17	579.8	4	40	80	3900	0.579
18	L 18	806.52	6	40	80	6700	0.604
19	L 19	698.83	4	30	60	6700	0.698
20	L 20	3382.44	6	60	80	6700	2.536
21	L 21	4235.42	6	60	80	6700	3.213
22	L 22	1494.09	4	30	60	3900	1.494
23	L 23	772.26	4	30	60	3900	0.772
24	L 24	1198.17	6	30	60	6700	1.198
25	L 25	636.42	6	40	80	3900	0.636
26	L 26	2538.57	4	30	60	3900	1.903
27	L 27	3028.24	6	60	80	6700	2.271

ID	Link-ID	Length (m)	No. of lanes	Total Width (m)	Speed (Km/hr)	Capacity (pcph)	Travel time (min)
28	L 28	4957.64	6	60	80	6700	3.718
29	L 29	3006.41	6	60	80	3900	2.258
30	L 30	2076.41	6	60	80	6700	1.557
31	L 31	2302.68	6	60	80	6700	1.727

3.8 The Database of Nodes

The number and geographic location of the nodes were stored in the nodes' layers database (latitude and longitude). Table (3.3) illustrates these attributes, added to the nodes layer's attributed Table. The nodes' property is required for network analysis.

Table (3.3) Database of Nodes Attributes According to Hilla Municipality Directorate.

ID	Node-ID	Y	X
1	1	4,069,383	2,348,108
2	2	3,594,841	2,136,305
3	3	3,090,423	1,891,790
4	4	3,866,039	3,247,558
5	5	4,104,167	1,746,043
6	6	3,798,185	2,672,224
7	7	3,814,595	3,227,849
8	8	4,102,457	2,850,818
9	9	3,691,089	2,936,671
10	10	2,986,453	2,804,515
11	11	2,086,937	2,824,358

ID	Node-ID	Y	X
12	12	3,476,003	3,472,589
13	13	3,092,357	3,895,923
14	14	2,607,557	4,901,343
15	15	5,035,113	3,843,008
16	16	2,553,377	2,850,681
17	17	3,478,235	2,982,774
18	18	4,086,509	1,697,953
19	19	4,106,351	1,559,049
20	20	4,542,913	1,380,454
21	21	4,515,131	1,543,175
22	22	4,350,361	2,380,664
23	23	4,316,695	2,507,583
24	24	4,219,393	2,531,477
25	25	5,054,883	1,622,549
26	26	5,171,895	1,225,757

3.9 The Performance of Arterial Network

To understand roadway networks characteristics, these networks will be simplified into links (represented by numbered straight lines) and nodes (represented by numbered points), which are known as (topological planning drawings). The topology represents one of the quantitative geometric forms representing the relationships between lines and points beside areas (Abood, 2013). The network is simplified by reducing the networks to many graphs, some measures developed in selected graph theories to compare a set of some networks. In the graphs, it is four basic quantities (through the use of some theoretical terms in the diagrams) as follows (Buyong, 2007):

e: The number of links (edges).

v: The number of nodes (vertices).

p: Represents the number of discrete graphs that are not connected.

M: The total length of the network.

The scales that were developed in the graphic theories are represented (Buyong, 2007) by:

- Index of Beta ($\boldsymbol{\beta}$)
- Index of Alpha ($\boldsymbol{\alpha}$)
- Index of Gamma ($\boldsymbol{\gamma}$)
- Index of Eta ($\boldsymbol{\varepsilon}$)

Where:

1. The index of Beta ($\boldsymbol{\beta}$)

Calculates the beta through the following Equation (3.3) (Buyong, 2007):

$$\beta = \frac{\boldsymbol{e}}{\boldsymbol{v}} \qquad (3.3)$$

The Beta indicator is half of the average number of links that would serve every node and represent road networks' circulation. Its magnitude ranges between 0 and 3 for most road networks. A magnitude that is less than 1 indicates that there is no complete connection to networks. A magnitude greater than one indicates that a network is complex (a well-connected network).

2. The index of Alpha ($\boldsymbol{\alpha}$)

The Alpha index is calculated through the following Equation (3.4) (Buyong, 2007):

$$\alpha = \frac{e - v + p}{2v - 5} \qquad (3.4)$$

The index compares the number of circuits that closed in a network, which is represented by $(e - v + p)$, and the largest number of circuits in the network, represented by $(2v - 5)$, it can measure the rotation (which represents the density of roadway network in some regions). The Alpha magnitude ranges between (0 – 1). The highest magnitude of $\boldsymbol{\alpha}$ it will indicate a potentially higher level of connectivity.

3. The index of Gamma ($\boldsymbol{\gamma}$)

The Gamma index is calculated using the following Equation (3.5) (Buyong, 2007):

$$\gamma = \frac{e}{3(v - 2)} \qquad (3.5)$$

The Gamma index compares the real number of edges in the roadway network (e) with the maximum number of circles containing them $(3(v-2))$ Gamma measures roadway network connectivity, the gamma magnitude ranges from (1 – 0). A magnitude close to 0 indicates that a simple network contains a small number of links, while a magnitude close to 1 indicates that a network is well connected and contains more links.

4. The index of Eta (ε)

The Eta magnitude is calculated from the following Equation (3.6) (Buyong, 2007):

$$\varepsilon = \frac{m}{e} \qquad (3.6)$$

The Eta index which calculates the total length introduces some notices of geographic scale. The higher dense a network is packed into a region and the greater the number of links, the shorter will edge length becomes. Therefore, (ε) is expected to be high in developed networks and low in well-developed networks.

This study clarifies are measure performance for Al-Hilla city's roadway network, using the developed measures used in graph theory

- Edges' numbers (e) = 31.
- Vertices' numbers (v) = 26.
- Number of separate non-connecting sub-graphs (p) = 7.
- The total length of the network (m) = 49.946 km.
- From Eq. (3.3) :

$$\beta = \frac{31}{26} = 1.192 > 1$$

According to the β index, the roadway network is somewhat complicated, and since the Beta > 1, this indicates that the length of the links is short (meaning that the network is well connected).

- From Eq. (3.4) :

$$\alpha = \frac{31-26+8}{2*26-5} = 0.276 > 0$$

It turns out that the roadway network is not complicated because the index is not higher than one (not good communication level).

- From Eq. (3.5) :

$$\gamma = \frac{31}{3(26-2)} = 0.430 < 1$$

The network is moderately complex.

- From Eq. (3.6) :

$$\varepsilon = \frac{49.946}{31} = 1.611$$

While according to the ε index (ε= 1.611), the network may be well developed.

3.10 Softwares of Traffic Assignment

The process of traffic assignment were implemented by using software designed especially for this study programmed by Visual Basic & Microsoft Excel Solver. The code was implemented in Visual Basic & Microsoft Excel Solver in Appendix (A).

The inputs to Microsoft Excel are the O-D nodes with free-flow times, while the outputs are the shortest path over which the assigned traffic volumes are distributed. The process in Microsoft Excel Solver iteratively scans the network nodes, tries to find a path between nodes being checked, to be the shortest path between O-D pairs.

The cost function equation is programmed for user equilibrium assignment using Visual Basic software, where the inputs (ID link, capacity, assigned volumes, number of lanes, and free flow time) and the output are the traveling time of congested links in the arterial network.

3.11 User Equilibrium Assignment

(UE) assignment is one of the most widely used methods in practical fields. Wardrop's first concept, equilibrium conditions, is used to assign traffic volumes. Traffic organizes itself in crowded networks under equilibrium conditions in such a manner that no trip maker could lower route costs by switching routes. That means any trip maker in the equilibrium state will not find shorter travel time by changing his road.

The user equilibrium model assigns more than one route according to traffic volumes, but in (all or nothing & capacity restraint) not all links on the road network are used, as for stochastic user equilibrium model that disperses the traffic volumes within the secondary roads to choose one path in the network as the shortest path.

As travel time (cost Z) at the equilibrium flow (Xa) which is a minimum, its differentiation equals zero at (Xa). It can find the value of the equilibrium flow (Xa) by differentiating the following equation and equate it to zero (Al-jazzar, 2012).

Minimize Z=$\sum_a \int_0^{xa} t_a\ (x_{a\ \ dx}\ \ )$ (3.7)

Subject to $\sum_k f_k^{rs} = q_{rs}\ \ : \forall_r, s$

$$x_a = \sum_r \sum_s \sum_k \delta_{a,k}^{rs} f_k^{rs}\ : \forall_a$$

$f_k^{rs} \geq 0: : \forall_{k,r,s}$

$x_a \geq 0: a \in A$

Where k is the path, (Xa) equilibrium flows in link (a), (ta) travel time on the link (a), (f_k^{rs}) flow on path (k) connecting O-D pair(r-s), (q_{rs})trip rate between ® and sand ($\delta_{a,k}^{rs}$) is a definitional constraint and is given by ($\delta_{a,k}^{rs}$)= (1 if link a belongs to path k, 0 otherwise).

In this model, the trips (flow) on the roadways in the network will be assigned according to the time costs affected by the link flows (congestions). This means that the flow will reach to equilibrium state, the following equation is always utilized for estimating links' travel time as a function of the ratio of volume-capacity as shown below (Falih, 2016) :

$$T_c = \left(\left(\frac{L}{S}\right) * 60\right) * \left(1 + 0.71 * \left(\frac{V}{C} * N\right)^{2.1}\right) \quad (3.8)$$

Where:

T_c: travel time of congested link (min).

L: length of links (m).

S: speed (Km/hr).

V: assigned traffic volume (vehicles) on the link.

C: capacity of a link (pcph).

N: number of lanes.

Several algorithms are used in the user equilibrium assignment, including incremental algorithm assignment, which is one of the most common methods used in large networks that suffer from congestion. Figure (3 – 6) shows an incremental algorithm in user equilibrium assignment.

The process of the incremental algorithm in equilibrium assignment:

- Preparing a database of major and minor arterials such as (link ID, no. of lanes, free-flow time, capacity) and O-D traffic flow.
- Give initial traffic volumes for all paths equal to zero, and then determine the shortest path.
- Determining the percentage of traffic volumes to be assigned on the roadway network in the study area, where 10% of those volumes were used, because the use of larger percentages will make the calculation complex (William & Martin, 1998).
- Give an incremental percentage for the shortest path and checking travel time for all paths again.
- Compare the travel time for all paths and give another percentage of incremental flow to the path that has minimum travel time.
- The process, on the whole, is repeated many times until the equilibrium is achieved between the supply and the demand for travel (V_{total} = O-D traffic flow).

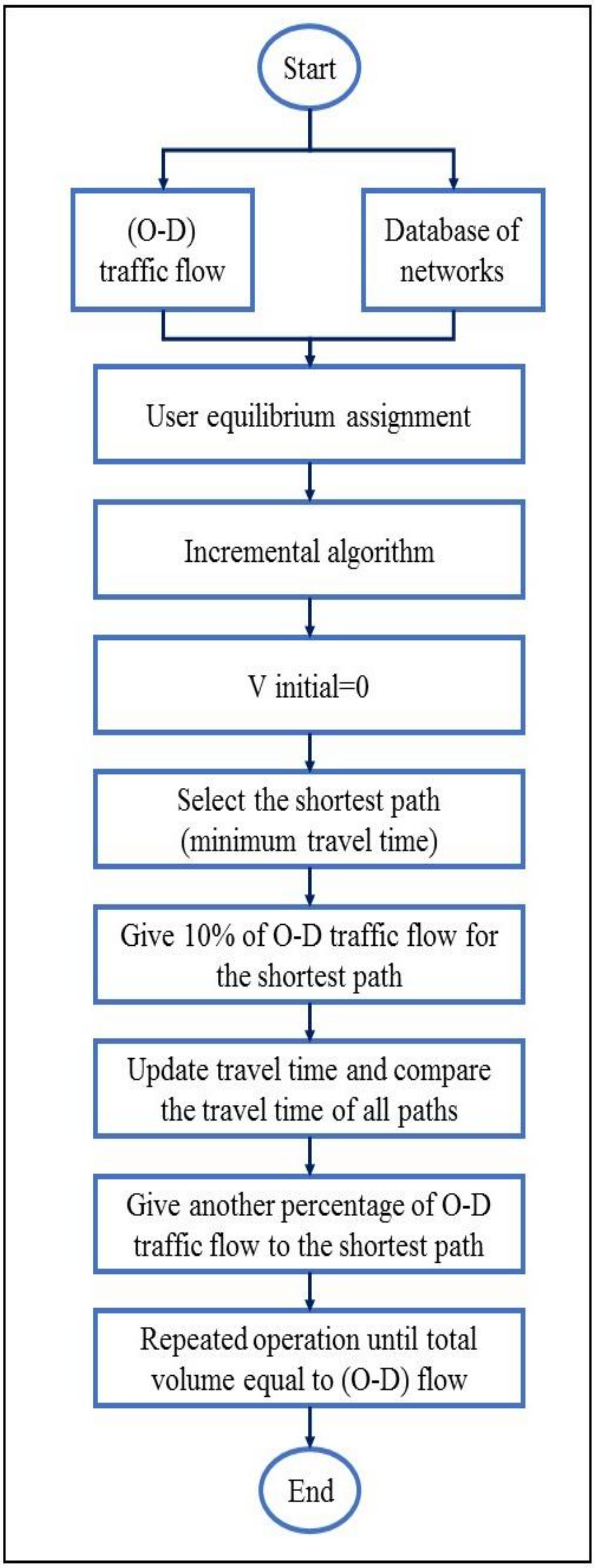

Figure (3 – 6) Incremental Algorithm in User Equilibrium Assignment.

Chapter Four

Result and Discussion

Chapter Four

Result and Discussion

4.1 Introduction

This chapter shows all details' of analyzing the fourth and final step of the four major steps in the traveling response modeling process, usually referred to as (traffic assignment). In addition, some suggestions can be implemented at several different stages of time (long term & short term) that help improve roadway network performance in the study area and raise the level of service, to reach the state of optimization, including (suggesting new arterials & addition of new lanes).

4.2 Origin-Destination Matrix

The origin-destination matrices or travel demand describes people's movement in a certain area. The O-D matric consist of many columns and rows , reflect the origin and destination positions. Modeling the traffic flows needed for all trips begins and ends at some discrete points in the roadway network. The geographic center have been used to solve this issue. The geographic center of a zone is known as the centroid points (Al-jazzar, 2012).

To move between sectors in the study area, specific points are chosen as a centroid point to apply the traffic assignment model for Al-Hilla arterial network, as shown in Figure (4 – 1). The Oigin-Destination matrix (Alwash, 2019) concerning the preparation of a case study on the arterial network of Al- Hilla City, as shown in Table (4.1).

Table (4.1) Hilla City's Peaks Hours Oigin-Destination Matrix (vph).

Sector ID	1	2	3	4	5
1	0	30946	17533	2840	7046
2	18413	0	32680	6153	11986
3	10413	328553	0	5006	15780
4	10466	36933	29866	0	15533
5	13573	40646	47826	8126	0

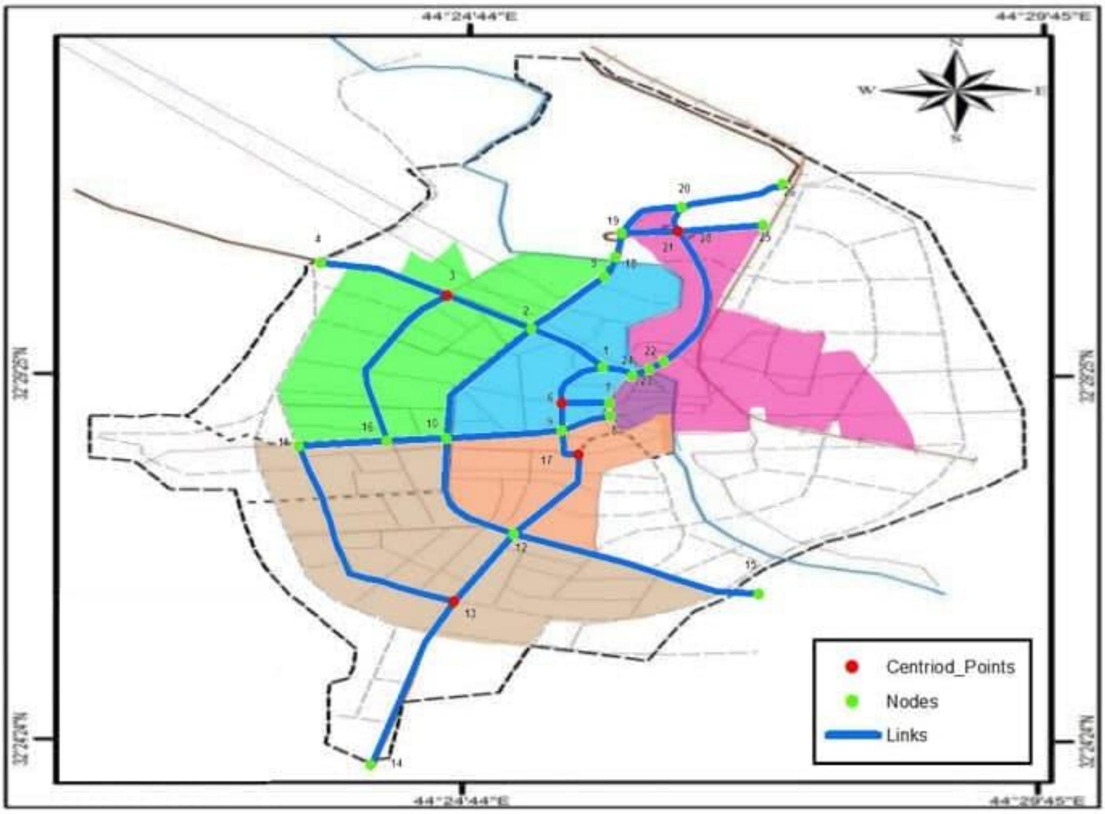

Figure (4 – 1) Centroid Points of the Study Area.

4.3 Traffic Assignment For Base Year

The incremental algorithm is the most used in the user equilibrium model. Therefore, it will be used to assign traffic volumes for the arterial network of Al-Hilla City for the base year 2020. The results of the user equilibrium assignment for current were mentioned in Appendix B. After equilibrium assignment, the comparison is carried out between the assigned volume and the link capacity to find the services level of Hilla City roadway network (Falih, 2016).

LOS indicates the operation condition of arterials based on factors such as speed, travel time, etc. The LOS for the various arterial links in the Al-Hilla network has been estimated following the criteria depicted in Table (4.2) (Falih, 2016).

Table (4.2) Relationship Between Level of Service and Volume/Capacity Proportion for Base Year (2020).

LOS	V/C Ratio	Links ID	Operating condition
A	0.00 – 0.50	L 10, L 16, L 25	Free flow conditions
B	0.51 – 0.70	L 6, L 11, L 12, L 14, L 18	Reasonably unimpeded operations
C	0.71 – 0.80	L 21	Generally stable operations
D	0.81 – 0.90	L 9, L 13, L20, L 22, L 27, L28	Approaching unstable conditions
E	0.91 – 0.99	L 30, L 26	Significant delays and low average speeds
F	≥ 1	L 4, L 7, L 8, L23, L 24	Severe congestion and delays

The level of service for the base year is shown in Figure (4 – 2). The light green color represents the ranging of v/c (0.00-0.50) service's level (A) where the percentage of links in this level is (14%), the gray color represents the ranging of v/c (0.50-0.70) service’s level (B), where the percentage of links in this level is (23%), the yellow color represents the ranging of v / c (0.71-0.8) service’s level (C), where the percentage of links in this level is (5%). The orange color represents the ranging of v / c (0.81-0.99) service level (D), where the percentage of links in this level is (27%), representing majority arterial links in the study area, The blue color represents the ranging of v/c (0.91-0.99) service's level (E), where the percentage of links in this level is (9%), the dark red color represents the v / c ranging of (> = 1) service’s level (F), where the percentage of links in this level is (23%) as shown in Figure (4 – 3). The overall evaluation of the base year (2020) is LOS (D).

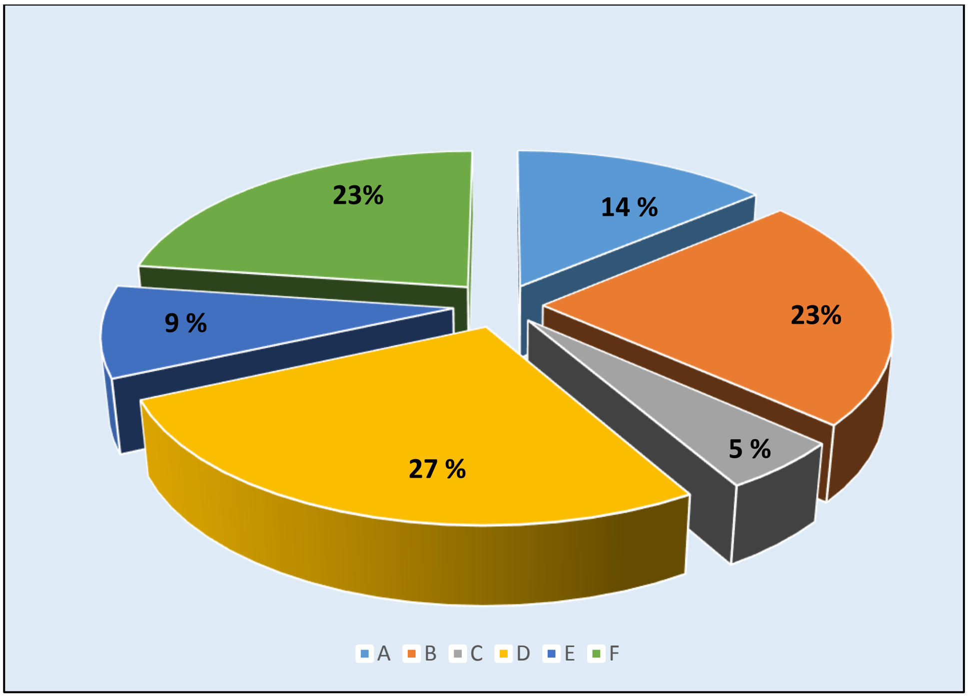

Figure (4 – 3) Percentages of Service Levels in Base Year (2020).

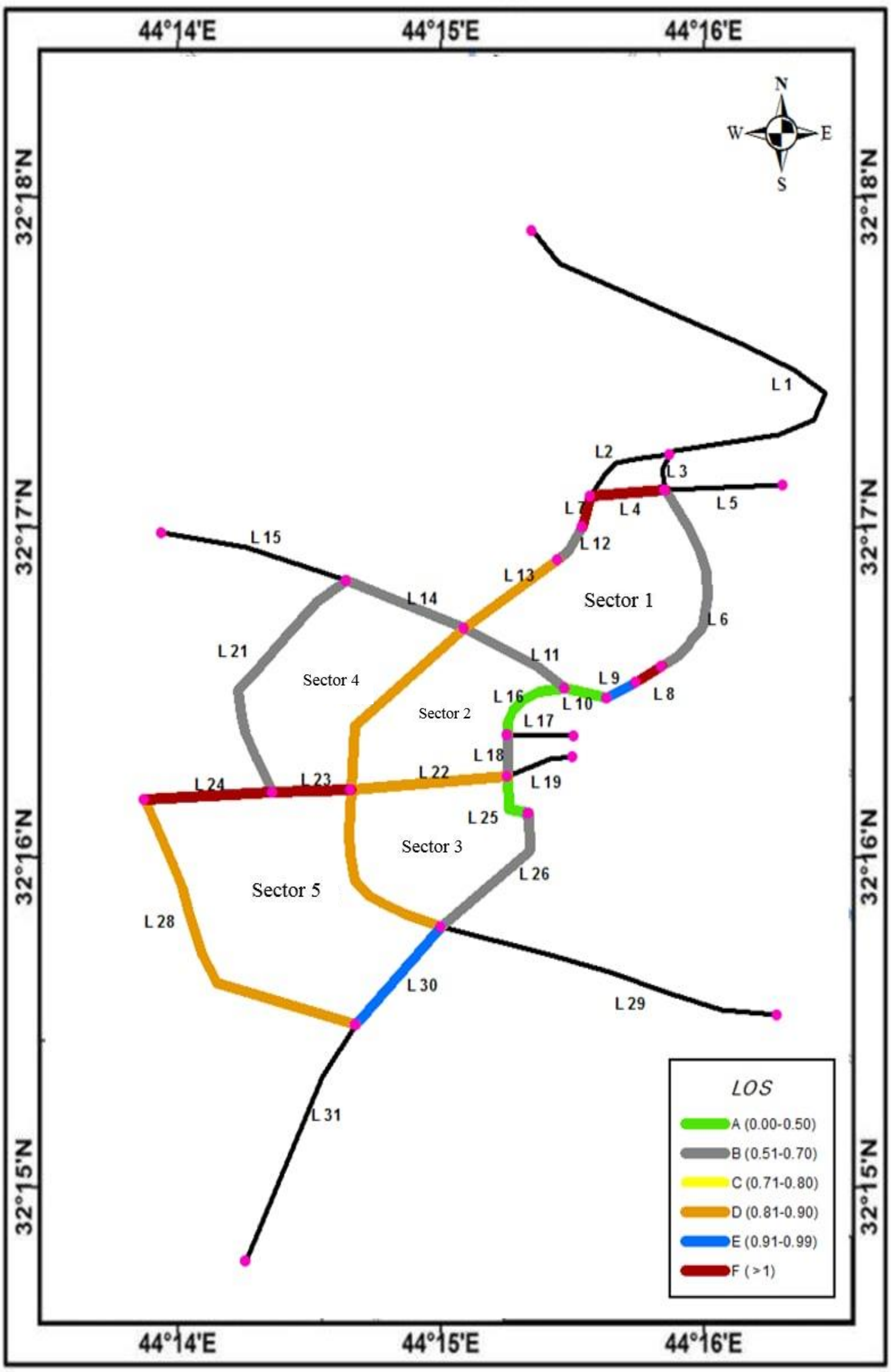

Figure (4 – 2) Level of Service for Base Year (2020).

4.4 Traffic Assignment for Random Destination

A random destination, represented by the higher education center of colleges, was chosen to find the shortest paths from the centers of the study area sectors to the higher education center of colleges in sector 5. Higher education centers of colleges are a major attraction center for trips within the Babylon Governorate because it attracts different types of trips such as (educational trips, work trips, etc.).

Higher education centers of colleges are located west of Hilla city, which is represented by link 31 in sector 5, and it is the largest complex in terms of area and number of workers.

Therefore, traffic assignment will be made for the traffic volumes that use the user equilibrium model / incremental algorithm. Incremental algorithm starting by taking 10% of traffic volume to assign on the arterial network available in the study area, Figures (4–4, 5, 6 and 7) show the assigned shortest paths from the study area sectors to higher education center of colleges, and the rest are in Appendix C.

Table (4.3) shows the shortest assigned paths from the centers of the four sectors to higher education centers of colleges، max travel time, V/C, an average of services level.

Table (4.3) The Assigned Shortest Paths From All Sectors to the Random Destination.

Centroid ID	Paths	Description	T_{MAX} (min)	V/C	Ave. LOS
1 – 5	Path 1	L 6, L 8, L 9, L 10, L 16, L 18, L 25, L26 , L 30 , L 31	22.478	0.799	C
	Path 2	L 4, L 7, L 12, L 13, L 20, L 27, L 30 , L31	27.456	0.94	E

Centroid ID	Paths	Description	T_{MAX} (min)	V/C	Ave. LOS
2 – 5	Path 1	L 18, L 25, L 26, L 30, L 31	25.254	0.97	E
	Path 2	L 16, L 11, L 20, L 27, L 30, L 31	20.145	0.761	C
3 – 5	Path 1	L 26, L 30, L 31	17.624	0.93	E
	Path 2	L 25, L 22, L27, L 30, L 31	15.345	0.792	C
4 – 5	Path 1	L 14, L20, L 27, L 30, L 31	17.674	0.83	D
	Path 2	L 21, L 23, L 27, L 30 , L31	22.768	0.924	E

*Ave. =average

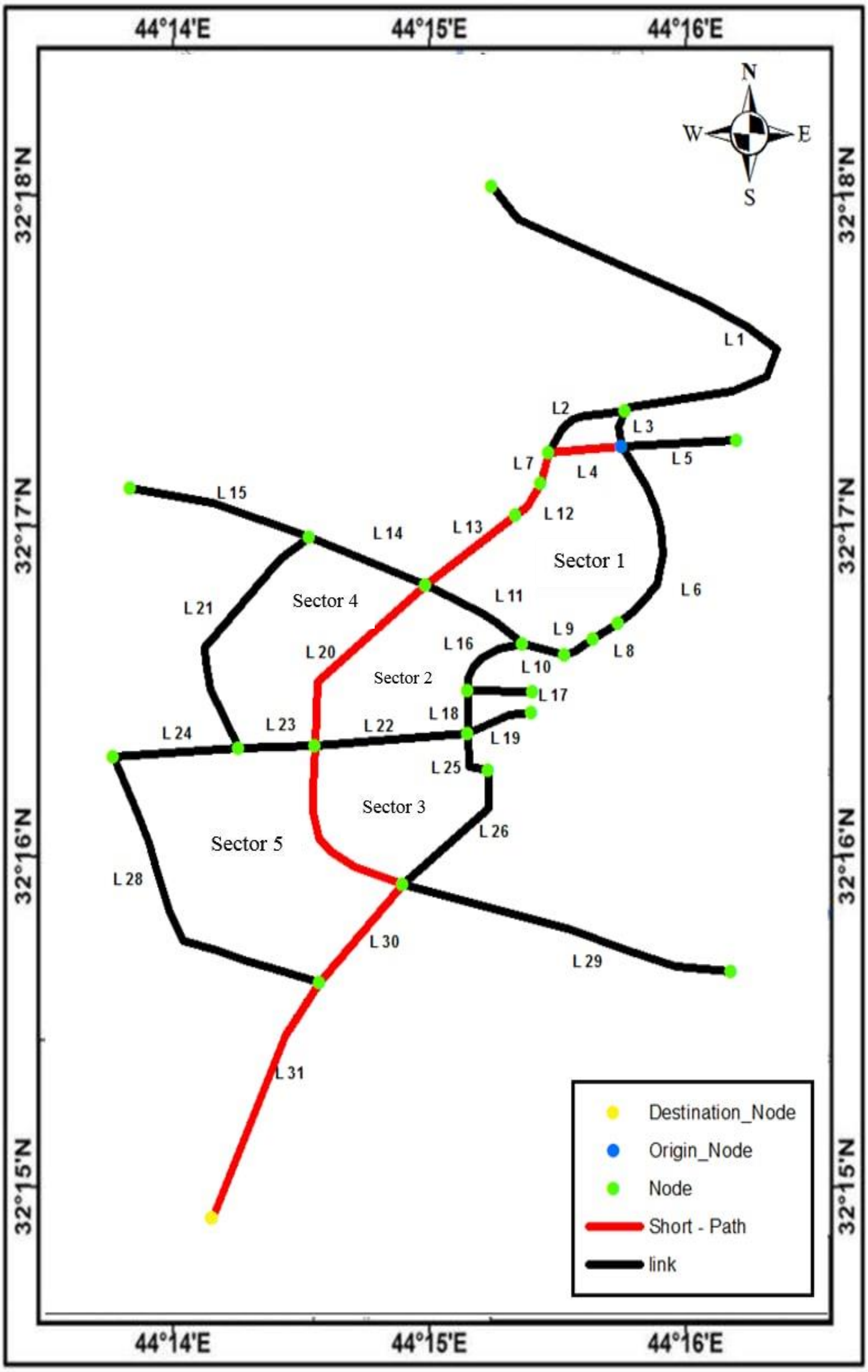

Figure (4 – 4) The Assigned Shortest Path from Sector 1 to the Random Destination**.**

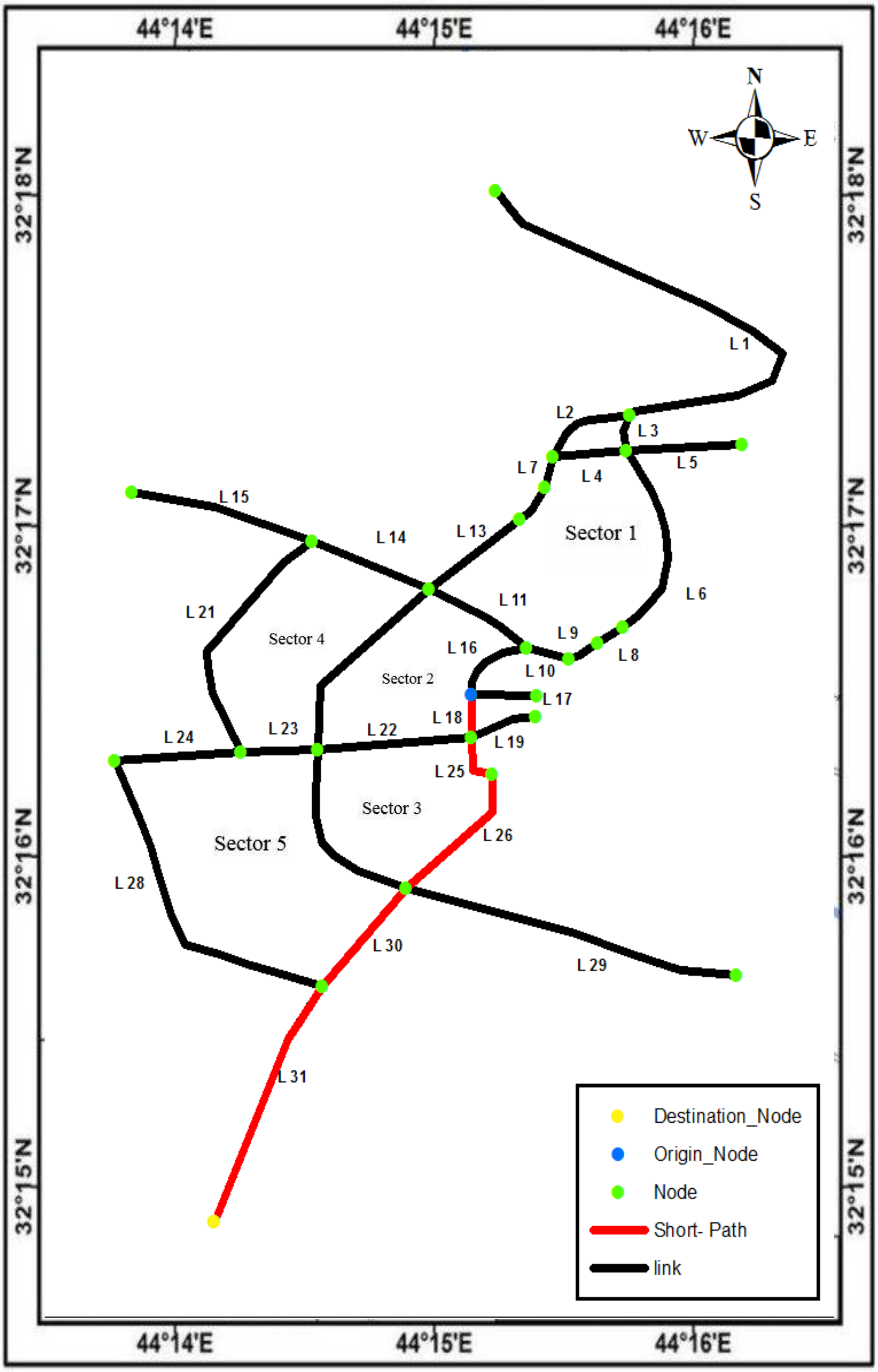

Figure (4 – 5) The Assigned Shortest Path from Sector 2 to the Random Destination.

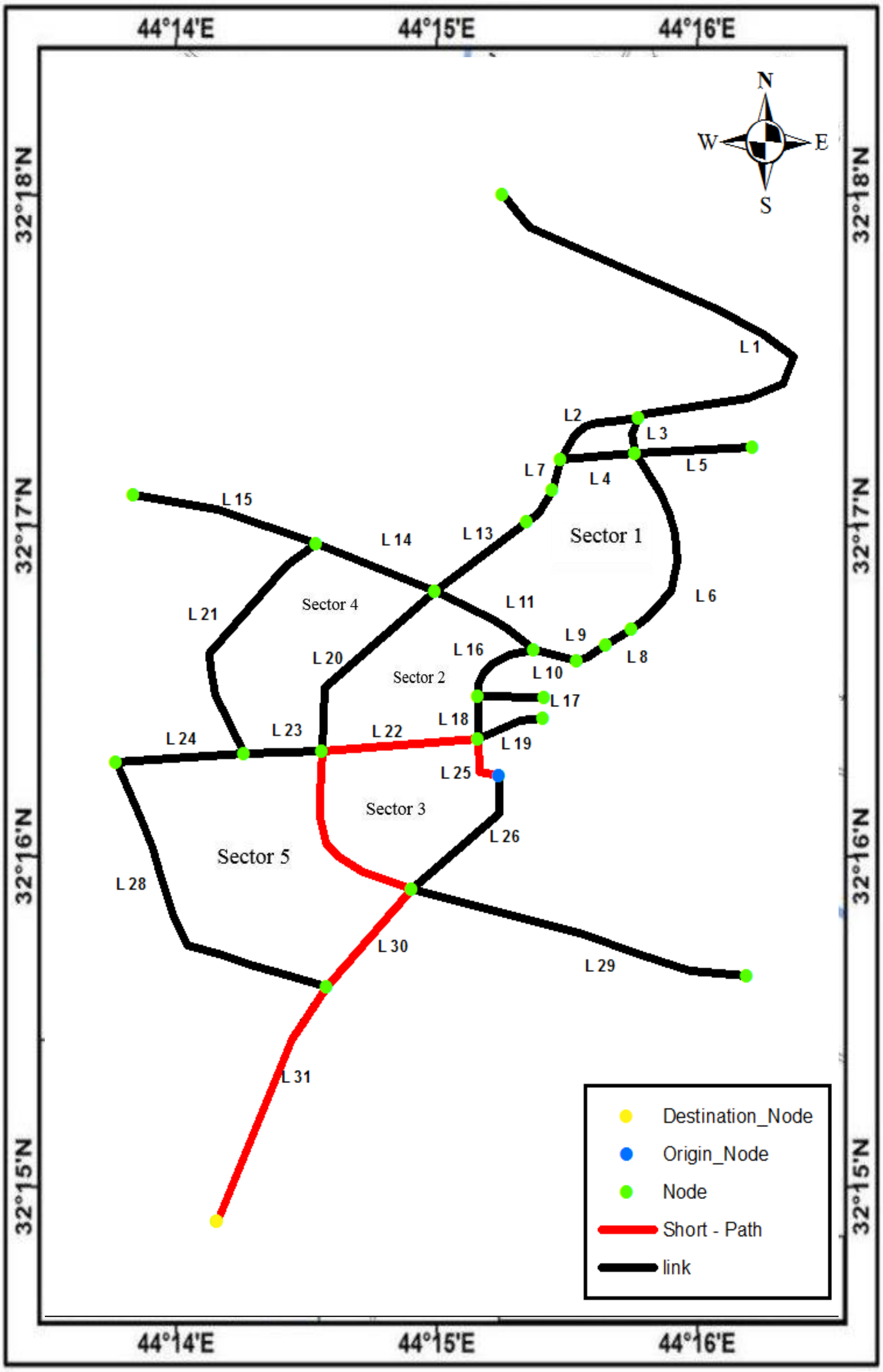

Figure (4 – 6) The Assigned Shortest Path from Sector 3 to the Random Destination.

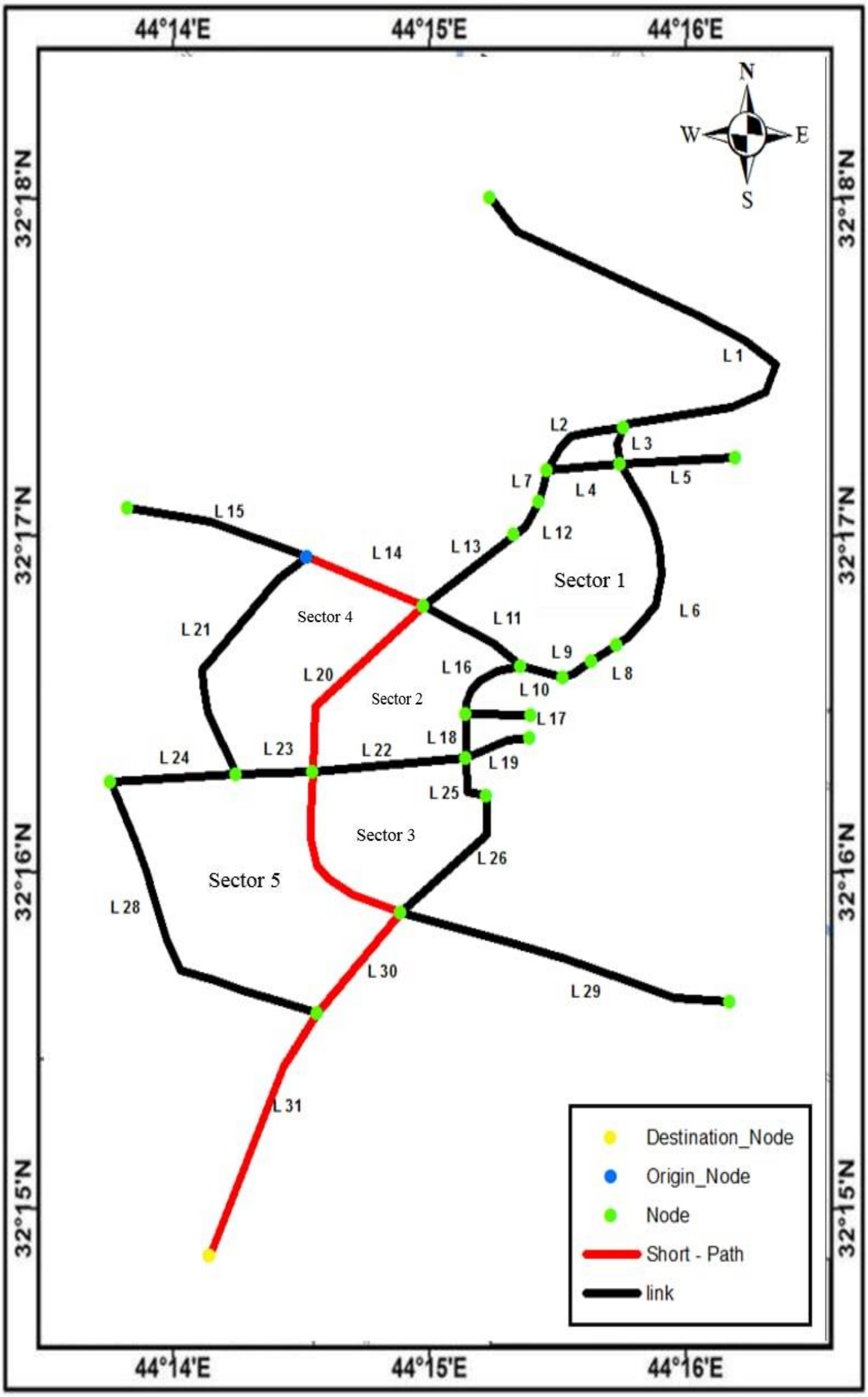

Figure (4 – 7) The Assigned Shortest Path from Sector 4 to the Random Destination.

4.5 Matrix of Future Flow (O-D)

To evaluate the roadway network of Al-Hilla city and measure its ability to accommodate the annual increase in traffic volumes, future traffic volumes will be estimated based on the annual growth rate of vehicles (3%) according to the Al-Hilla City Traffic Directorate (2020). The future matrix (O-D) for target years (2025, 2030, 2035) is obtained by multiplying every current matrix (O-D) by the growth rate for the base year; the following equation can be used (Al-jazzar, 2012):

$$\text{Future (O-D)} = \text{Current (O-D)} *(1+ 3\%)^{n} \qquad (4.1)$$

n: number of years.

4.5.1 Case 1

For (2025) year, the future matrix (O-D) for 2025 is obtained by multiplying every current matrix (O-D) by the annual growth rate of vehicles (3%) as shown in Table (4.4) by the following equation:

$$\text{Future (O-D)} = \text{Current (O-D)} *(1+ 3\%)^{5} \qquad (4.2)$$

Table (4.4) Future (Origin-Destination) Matrix for the 2025 Year.

Sector ID	1	2	3	4	5
1	0	35588	20163	3266	8103
2	21175	0	37582	7076	13784
3	11975	377836	0	5757	18147
4	12036	42473	34346	0	17863

5	15609	40743	54999	9345	0

The future traffic assignment for the 2025 year will be made by using the user equilibrium assignment /incremental algorithm to assign future traffic volumes on the network of the study area after the increase in traffic volumes to know its effect on the overall evaluation of the arterial network. The results of the user equilibrium assignment for case one will be mentioned in Appendix D. After the user equilibrium assignment for the target year 2025, the comparison is carried out between the assigned volume and the link capacity. The level of service for the various arterial links in the Hilla City network has been estimated by the criteria depicted in the following Table:

Table (4.5) Relationship Between Level of Service and Volume/Capacity Proportion for Case 1.

LOS	V/C Ratio	Links ID	Operating condition
A	0.00-0.50	None	Free flow conditions
B	0.51-0.70	L 10, L 12, L 14, L16, L 18, L 25	Reasonably unimpeded operations
C	0.71-0.80	None	Generally stable operations
D	0.81-0.90	L 9, L 13, L 20, L21, L22, L23, L27	Approaching unstable conditions
E	0.91-0.99	L 6, L26, L28, L30	Significant delays and low average speeds
F	≥ 1	L 4, L7, L8, L11, L24,	Severe congestion and delays

Level of service for case 1 as shown in Figure (4 – 8). The light green color represents the range of v/c (0.00 – 0.50)) level of service (A), the gray color represents the range of v/c (0.51 – 0.70)) level of service (B), where the percentage of links in this level is (27%), the yellow color represents the range of v/c (0.71-0.80) level of service (C), the orange color represents the range of v/c (0.81-0.99) level of service (D), where the percentage of links in this level is (31%), representing the majority of arterial links in the study area. The blue color represents the range of v/c (0.91-0.99) level of service (E), where the percentage of links in this level is (18%). The dark red color represents the range of v/c of (> = 1) level of service (F), where the percentage of links in this level is (22%), as shown in Figure (4 – 9). The overall evaluation of case 1 is LOS (D).

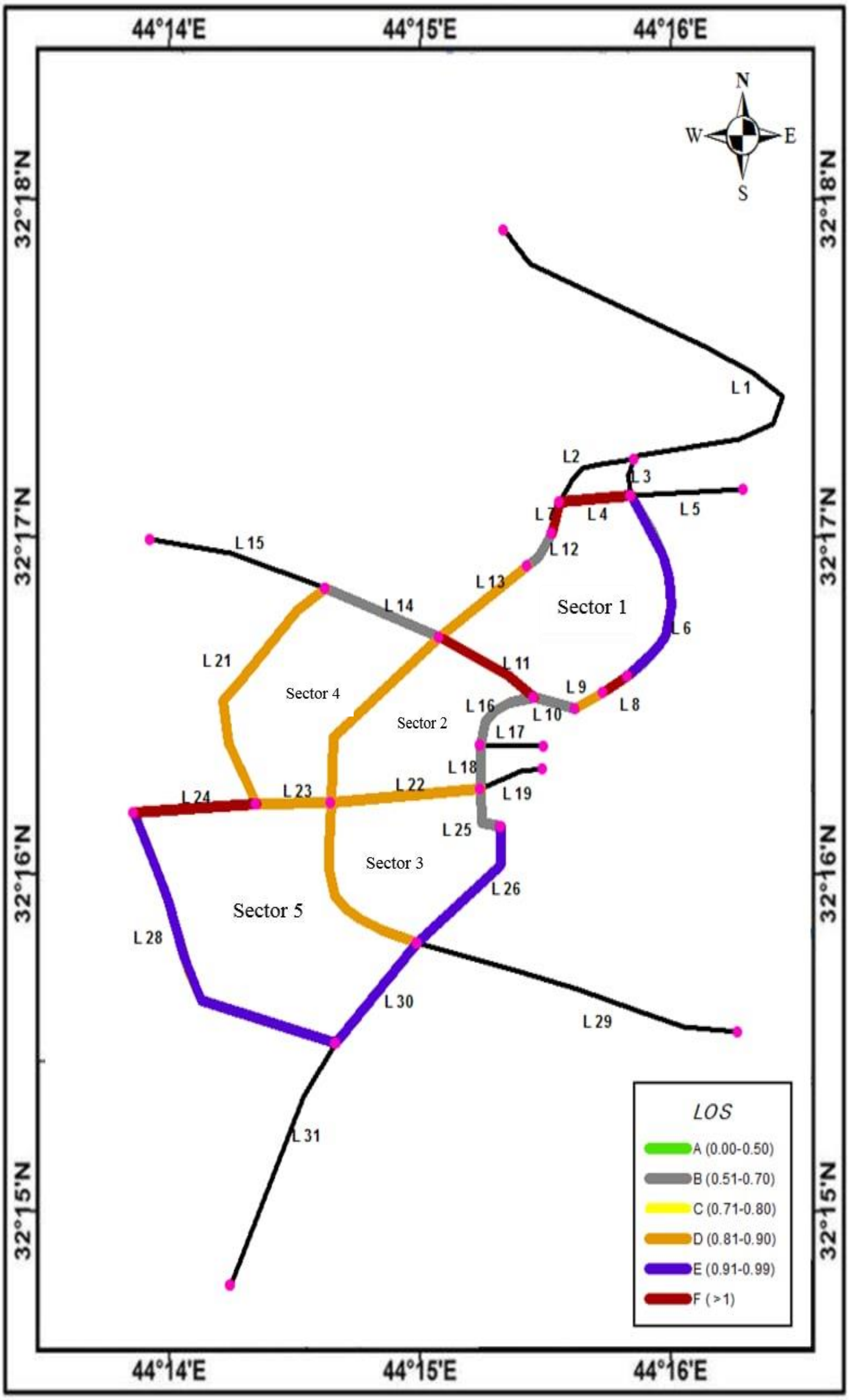

Figure (4 – 8) Level of Service for Case 1.

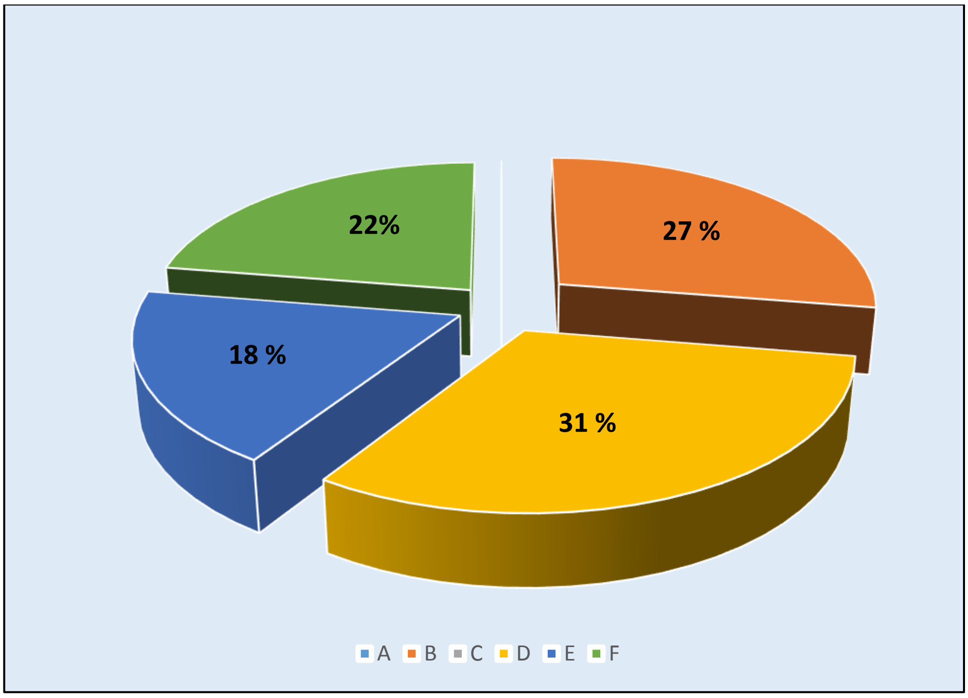

Figure (4 – 9) Percentages of Service Levels for Case 1.

4.5.2 Case 2

For (2030) year, the future matrix (O-D) for 2030 will be obtained by multiplying every current matrix (O-D) by the annual growth rate of vehicles (3%) as shown in Table (4.6) by the following equation:

$$\text{Future (O-D)} = \text{Current (O-D)} *(1+ 3\%)^{10} \quad (4.3)$$

Table (4.6) Future (Origin-Destination) Matrix for the 2030 Year.

Sector ID	1	2	3	4	5
1	0	40229	22793	3692	9159
2	23937	0	42484	7999	15582
3	13537	427119	0	6508	20514
4	13606	48013	38826	0	20193
5	17645	52839	62173	10564	0

The future traffic assignment for the 2030 year will be made by using the user equilibrium assignment /incremental algorithm to assign future traffic volumes on the network of the study area after the increase in traffic volumes to know its effect on the overall evaluation of the arterial network. The results of the user equilibrium assignment for case 2 will be mentioned in Appendix E. After the user equilibrium assignment for the target year 2030, the comparison is carried out between the assigned volume and the link capacity. The level of service for the various arterial links in the Hilla City network has been estimated by the criteria depicted in the following Table:

Table (4.7) Relationship Between Level of Service and Volume/Capacity Proportion for Case 2.

LOS	V/C Ratio	Links ID	Operational condition
A	0.00-0.50	None	Free flow conditions
B	0.51-0.70	None	Reasonably unimpeded operations
C	0.71-0.80	L 10, L12, L14, L16, L18, L25,	Generally stable operations
D	0.81-0.90	None	Approaching unstable conditions
E	0.91-0.99	L 9, L13, L20, L21, L22, L23, L27, L28, L30, L26	Significant delays and low average speeds
F	≥ 1	L 4, L 6, L7, L 8, L11, L24,	Severe congestion and delays

Level of service for case 2 as shown in Figure (4 – 10). The light green color represents the range of v/c (0.00 – 0.50)) level of service (A), the gray color represents the range of v/c (0.51 – 0.70)) level of service (B), the yellow color represents the range of v/c (0.71-0.80) level of service (C), where the percentage of links in this level is (27%), the orange color represents the range of v/c (0.81-0.99) level of service (D), the blue color represents the range of v/c (0.91-0.99) level of service (E), where the percentage of links in this level is (45%), which represents the majority of arterial links in the study area. The dark red color represents the range of v/c of (> = 1) level of service (F), where the percentage of links in this level is (28%), as shown in Figure (4 – 11). The overall evaluation of case 2 is LOS (E).

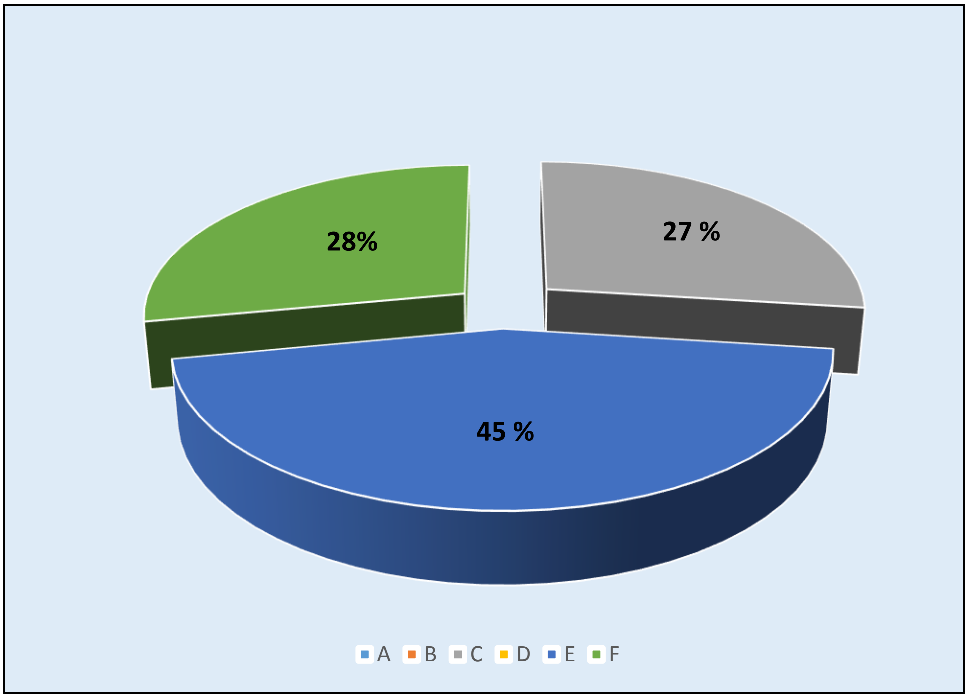

Figure (4 – 11) Percentages of Service Levels for Case 2.

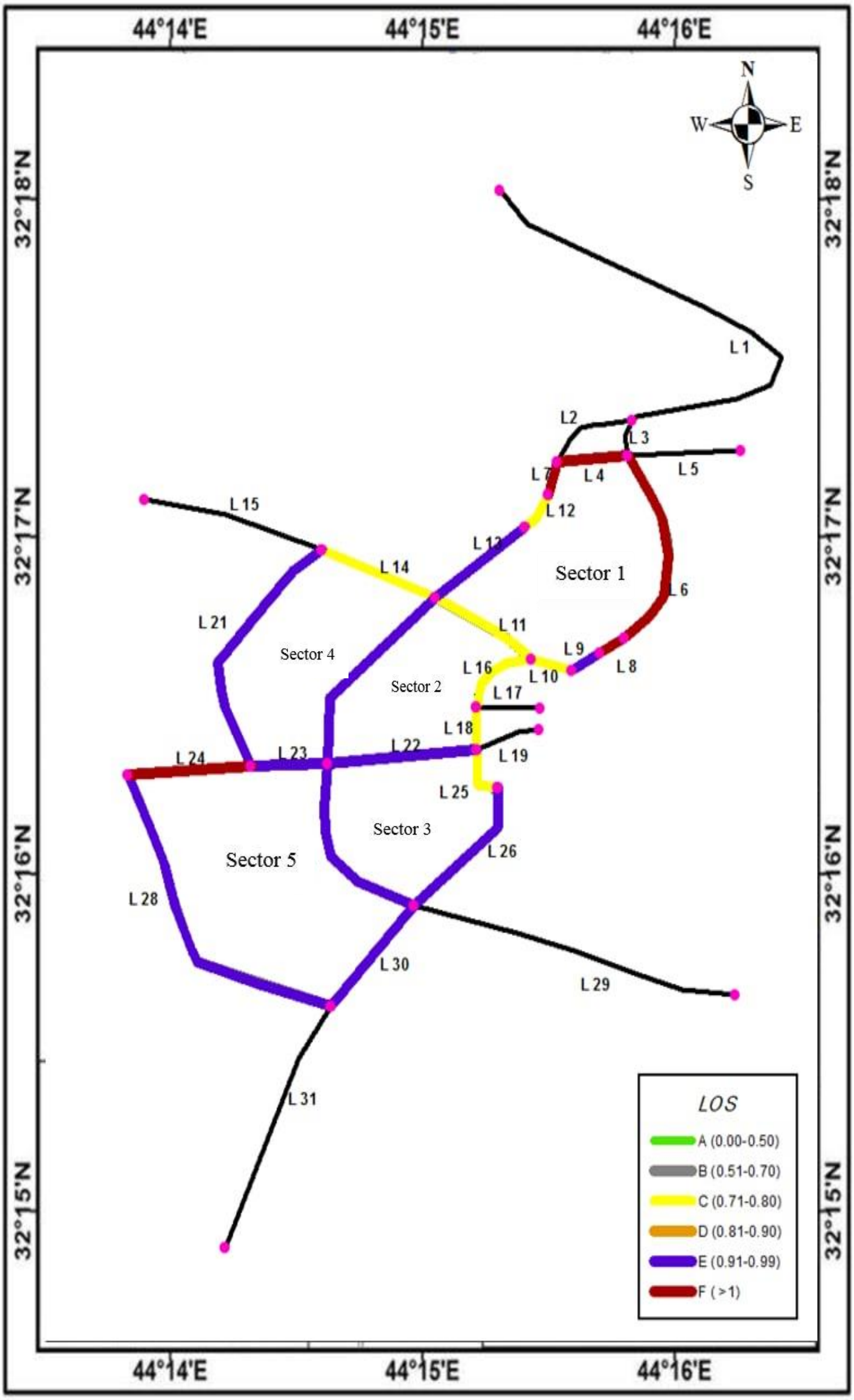

Figure (4 – 10) Level of Service for Case 2.

4.5.3. Case 3

For (2035) year, the future matrix (O-D) for 2035 will be obtained by multiplying every current matrix (O-D) by the annual growth rate of vehicles (3%) as shown in Table (4.8) by the following equation:

$$\text{Future (O-D)} = \text{Current (O-D)} * (1 + 3\%)^{15} \qquad (4.4)$$

Table (4.8) Future (Origin-Destination) Matrix for the 2035 year.

Sector ID	1	2	3	4	5
1	0	46419	26299	4260	10569
2	27619	0	49020	9229	17979
3	15619	49282	0	7509	23670
4	15699	55399	44799	0	23299
5	20359	60969	71739	12189	0

The future traffic assignment for the 2035 year will be made by using the user equilibrium assignment /incremental algorithm to assign future traffic volumes on the network of the study area after the increase in traffic volumes to know its effect on the overall evaluation of the arterial network. The results of the user equilibrium assignment for case 3 will be mentioned in Appendix F. After the user equilibrium assignment for the target year 2035, the comparison is carried out between the assigned volume and the link capacity. The level of service for the various arterial links in the Al-Hilla City network has been estimated by the criteria depicted in the following Table:

Table (4.9) Relationship Between Level of Service and Volume/Capacity Proportion for Case 3.

LOS	V/C Ratio	Links ID	Operational condition
A	0.00-0.50	None	Free flow conditions
B	0.51-0.70	None	Reasonably unimpeded operations
C	0.71-0.80	None	Generally stable operations
D	0.81-0.90	L10, L12, L14	Approaching unstable conditions
E	0.91-0.99	L16, L18, L25, L27, L28	Significant delays and low average speeds
F	≥ 1	L 4, L6, L7, L8, L9, L11, L13, L20, L21, L22, L23, L24, L30	Severe congestion and delays

Level of service for case 3 as shown in Figure (4 – 12). The light green color represents the range of v/c (0.00 – 0.50)) level of service (A), the green color represents the range of v/c (0.51 – 0.70)) level of service (B), the gray color represents the range of v/c (0.71-0.80) level of service (C). The orange color represents the range of v/c (0.81-0.99) level of service (D), where the percentage of links in this level is (14%), the blue color represents the range of v/c (0.91-0.99) level of service (E), where the percentage of links in this level is (23%). The dark red color represents the range of v/c of (> = 1) level of service (F), where the percentage of links in this level is (59 %), which represents the majority of arterial links in the study area as shown in figure (4 – 13). The overall evaluation of case 3 is LOS (F).

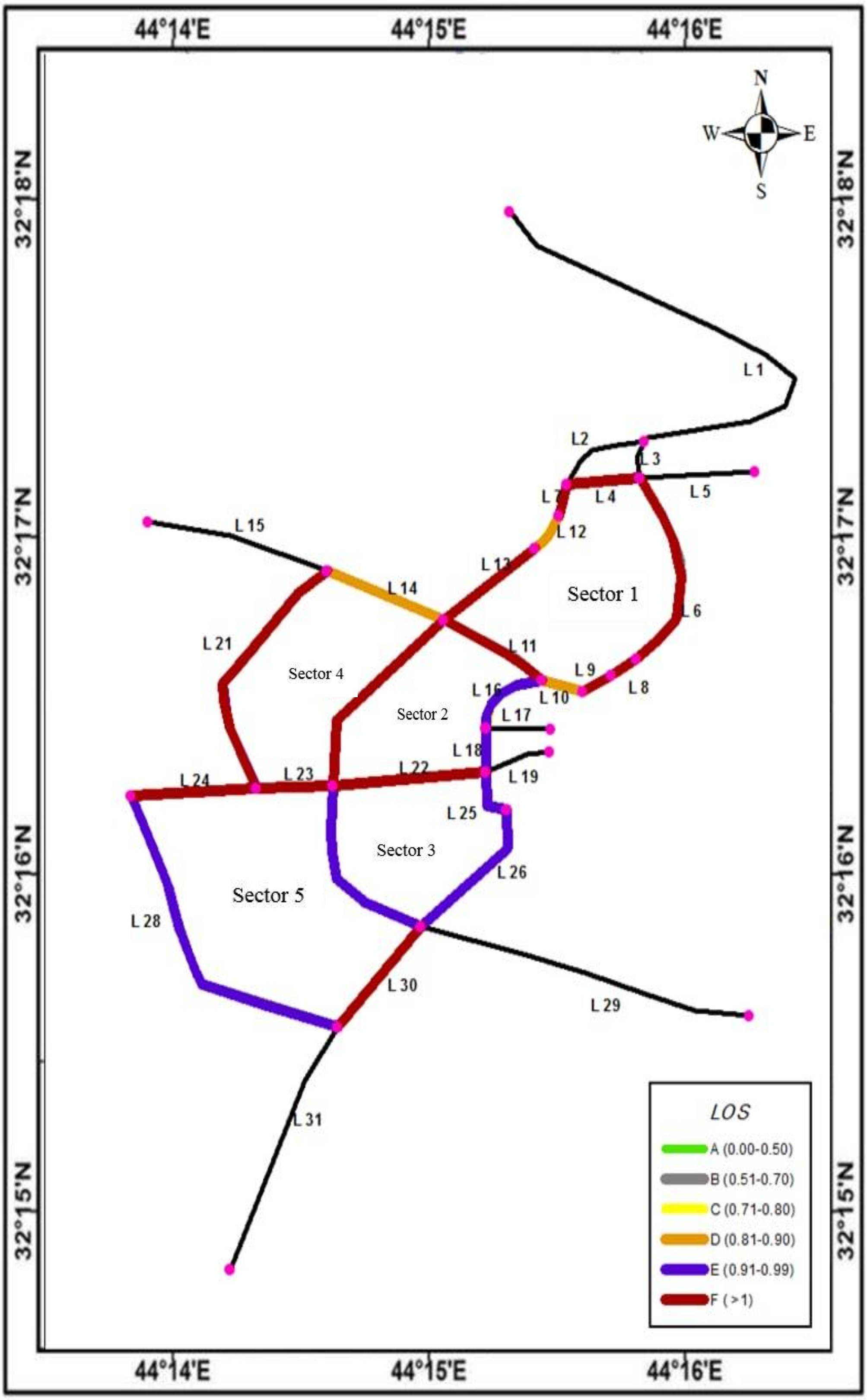

Figure (4 – 12) Level of Service for Case 3.

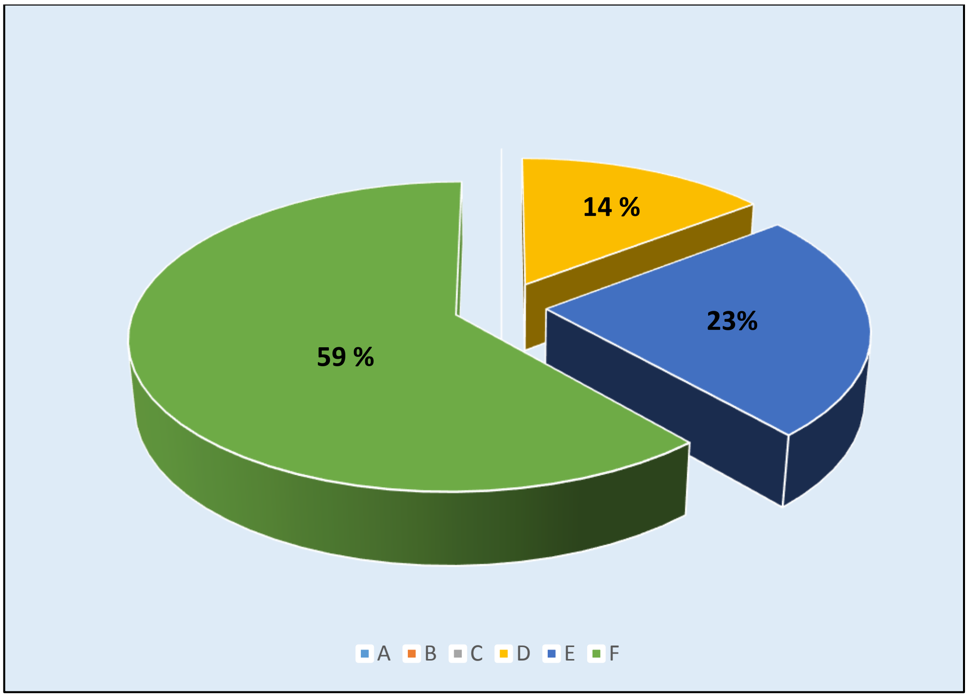

Figure (4 – 13) Percentages of Service Levels for Case 3.

4.6 Results Analysis for Current and Future Cases

The final outputs for the average of Volume/Capacity for current and future scenarios, as shown in Figure (4 – 14) traffic assignment processes were conducted on traffic volumes of the arterial roadway network for the years (2020, 2025, 2030, and 2035) by used the user equilibrium assignment model, which can conclude:

- The average of V/C for both (2020 & 2025) cases represents LOS (D), approaching conditions for the traffic condition in the study area due to high traffic density.
- The average of V/C for the (2030) year case represents LOS (E), representing the operational situation at or near the capacity level.
- The average V/C for the (2035) year case represents LOS (F), representing many stops, delays, low convenience and comfort levels, and increased accident exposure.

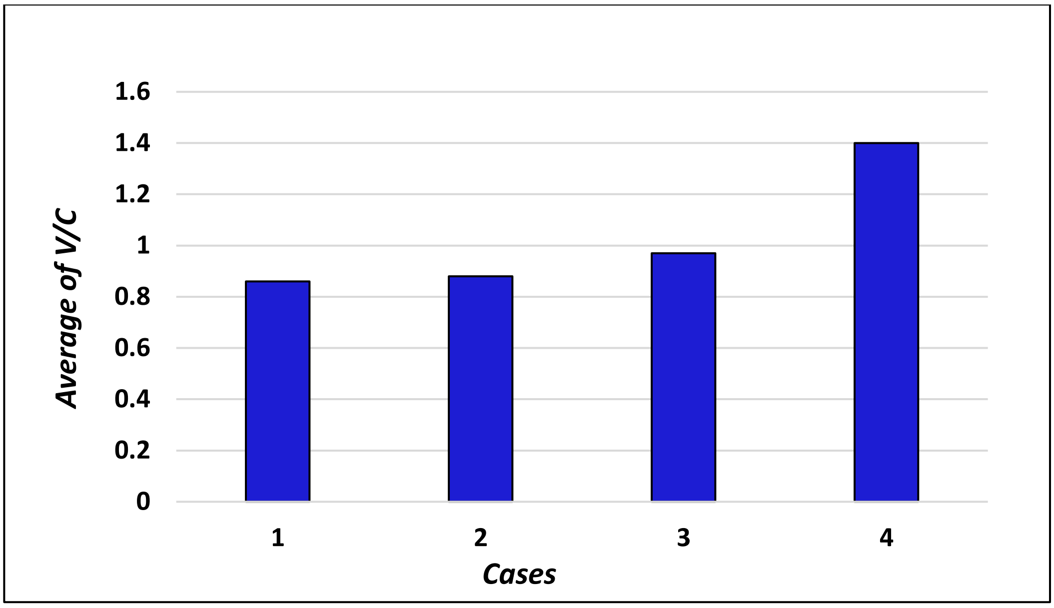

Figure (4 – 14) The Results of Volume/Capacity for Current and Future Cases.

4.7 Result Analysis for Random Destination

The user equilibrium assignment was used to assign traffic volumes on the arterials network, also find the shortest paths between the centers of the four sectors and random point, Figure (4 – 15) shown the final outputs for the average of V/C for the shortest paths, can conclude:

- The average of V/C for path (2) represents LOS (D), approaching conditions for the traffic condition in the study area due to high traffic density.
- The average of V/C for paths (1, 4, 7, and 8) represents LOS (E), representing the operational condition at or near the capacity level.
- The average of V/C for paths (3, 5, and 6) represents LOS (F), which represents many stops, delays, low convenience and comfort levels, and increased accident exposure.

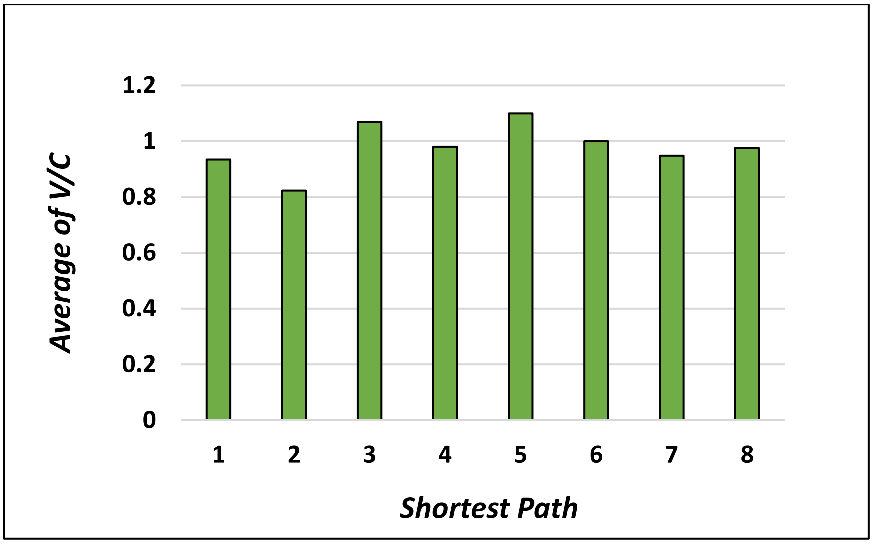

Figure (4 – 15) The Average of Volume/Capacity for Shortest Path.

4.8 Suggested Improvements for Roadway Network

Several suggestions can be implemented at several different stages of time (long term and short term) that help to improve roadway network performance in the study area and raise the level of service, including:

4.8.1 Suggestion New Arterial Roadways (Long Term)

There are several new arterials suggested (major & minor) by the directorate of Hilla municipality for the target year (2030) illustrated in Figure (4 – 16). According to the Directorate of Hilla Municipality, it is proposed to implement suggested roadways to be adopted within the evaluation model to redistribute traffic flows in the future roadway network and find their impact on the comprehensive evaluation of the case study.

Major arterials are have a free flow speed of (80 km/hr) and a lane capacity1600 (PCU/ hr), minor arterials have a free flow speed of having (60 km/hr) and a lane capacity of 1200 (PCU/ hr)(Plan, 2007).

In case 1, major arterials roadway (ring roadways) will be implemented. In case 2, the major & minor arterial roadways will be implemented to determine the impact of both cases on the overall evaluation of the study area network.

4.8.1.1. Case 1

The traffic assignment will be made using the user equilibrium assignment /incremental algorithm to assign traffic volumes on the study area network after adding major suggested arterials (ring roadways) to know their effect on the overall evaluation of the roadway network. The results of the user equilibrium assignment for major suggested arterials will be mentioned in Appendix G.

After applying the user equilibrium assignment for suggested ring roadways in the Hilla roadway network, a comparison is made between the assigned volume and the link capacity. LOS for the various arterials links in the Hilla network has been estimated by the criteria depicted in the following Table (4.10):

Table (4.10) Relationship Between Level of Service and Volume/Capacity Proportion for Case 1.

LOS	V/C Ratio	Links ID	Operational condition
A	0.00-0.50	L 4, L 23, L 24, L 1	Free flow conditions
B	0.51-0.70	L 14, L 18, L15, R1	Reasonably unimpeded operations
C	0.71-0.80	L 22, L7, L2, L13, L20, L27, L11, R3	Generally stable operations
D	0.81-0.90	L 6, L 21, L 28, L 30	Approaching unstable conditions
E	0.91-0.99	L 26, L25, L8, L9	Significant delays and low average speeds

F	≥ 1	L 12 , L 10	Severe congestion and delays

The level of service for case (1) is shown in Figure (4 – 17). The light green color represents the ranging of v/c (0-0.50) service's level (A), where the percentage of links in this level is (17%), the gray color represents the v/c ranging from (0.71-0.8) service's level (B), where the percentage of links in this level is (17%). The yellow color represents the ranging of v/c (0.81-0.99) service's level (C) where the percentage of links in this level is (38%), which represents the majority of arterial links in the study area, the orange color represents the ranging of v/c (0.81-0.99) service's level (D), where the percentage of links in this level is (17%). The blue color represents the v/c ranging from (0.91-0.99) service's level (E), where the percentage of links in this level is (17%), the dark red color represents the v/c ranging of (> = 1) service's level (F), where the percentage of links in this level is (17%) as shown in Figure (4 – 18). The overall evaluation for case (1) is LOS (C).

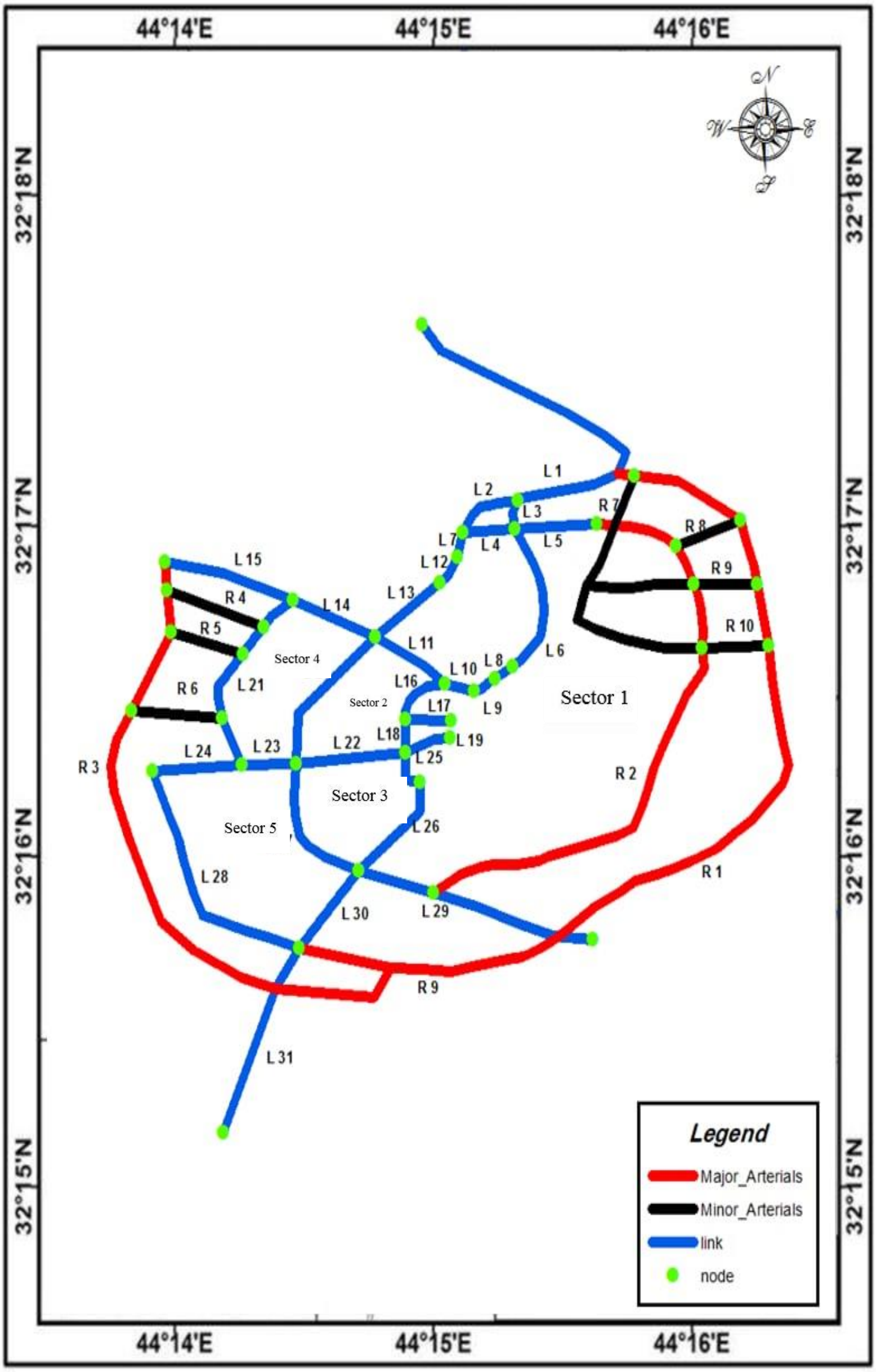

Figure (4–16) The New Suggested Arterial Roadways in Hilla City.

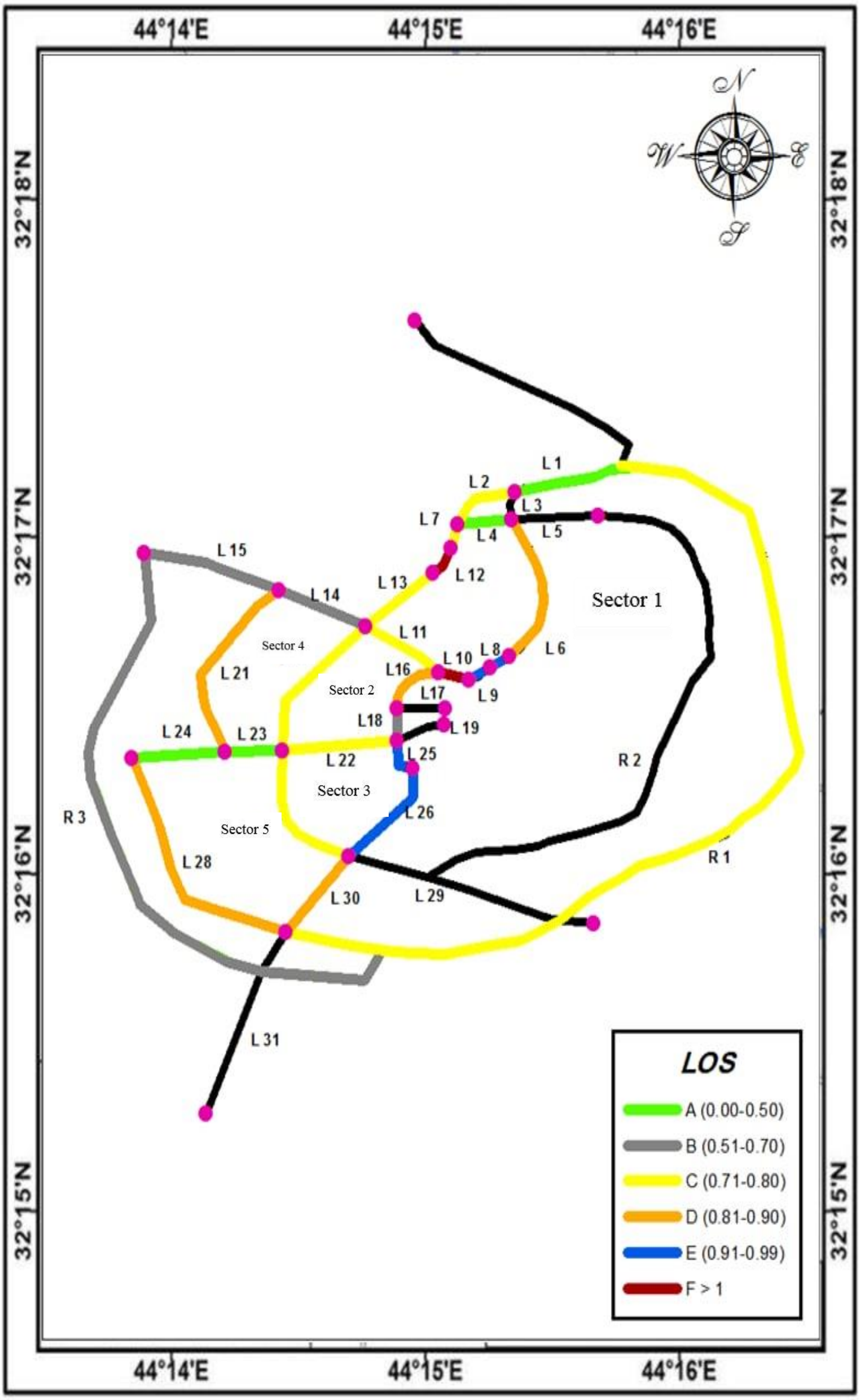

Figure (4–17) Level of Service for Case (1).

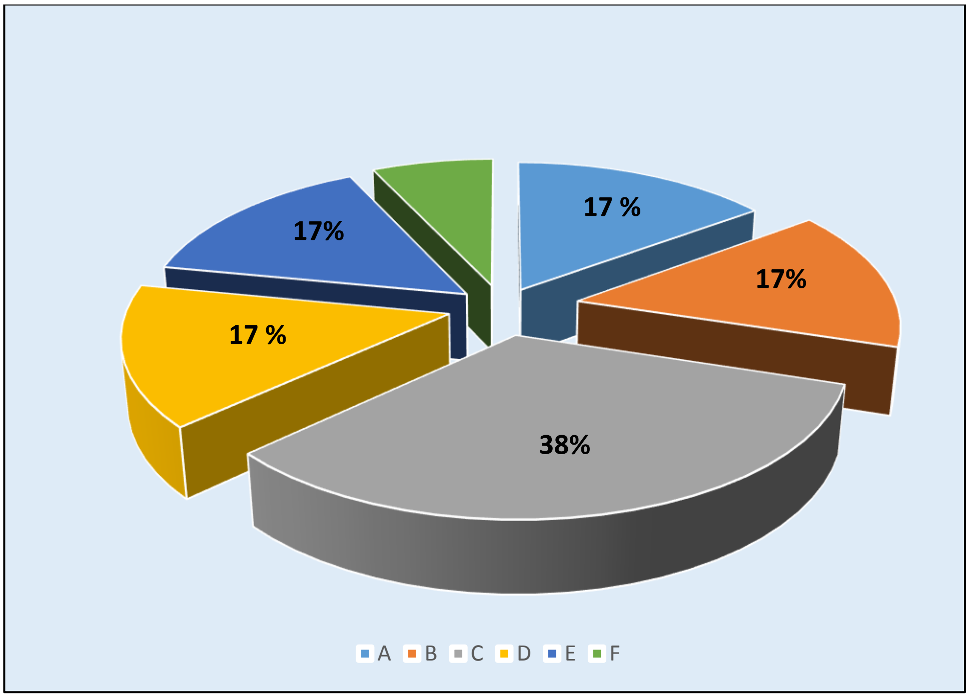

Figure (4 – 18) Percentages of Service Levels for Case (1).

4.8.1.2. Case 2

After adding suggested (major & minor) arterials roads, the traffic assignment will be made using the user equilibrium assignment /incremental method to assign traffic volumes in the study area network to determine the impact on the overall assessment of the roadway network. The results of the user equilibrium assignment for suggested (major & minor) arterials roadways (2030) will be mentioned in Appendix H. After applying the user equilibrium assignment for case (2) on the Hilla roadway network. A comparison is made between the assigned volume and the link capacity, the level of service for the various arterials links in Hilla network has been estimated by the criteria depicted in the following Table:

Table (4 .11) Relationship Between Level of Service and Volume/Capacity Proportion for Case (2).

LOS	V/C Ratio	Links ID	Operational condition
A	0.00-0.50	L 1, L 4, L 23, L 24, L18, R3	Free flow conditions
B	0.51-0.70	R 4, R 5, R 6, L 22, L 14, L 15, L 7, L 13, L 20, L28	Reasonably unimpeded operations
C	0.71-0.80	R 1, L 21, L 2, L16 , L 27	Generally stable operations
D	0.81-0.90	L 30,L26, L25, L11	Approaching unstable conditions
E	0.91-0.99	L 10, L 8, L6	Significant delays and low average speeds
F	≥ 1	L12, L 9	Severe congestion and delays

The level of service for case (2) is shown in Figure (4 – 19). The light green color represents the ranging of v/c (0-0.50) service's level (A), where the percentage of links in this level is (20%), the gray color represents the v/c ranging from (0.71-0.8) service’s level (B), where the percentage of links in this level is (33%), which represents the majority of arterial links in the study area. The yellow color represents the ranging of v/c (0.81-0.99) service's level (C) where the percentage of links in this level is (17%), the orange color represents the ranging of v/c (0.81-0.99) service’s level (D), where the percentage of links in this level is (13%), the red color represents the v/c ranging from (0.91-0.99) service’s level (E), where the percentage of links in this level is (10%). The dark red color represents the v/c ranging of (> = 1) service's level (F), where the percentage of links in this level is (7

%), as shown in Figure (4 – 20). The overall evaluation for case (2) is LOS (B).

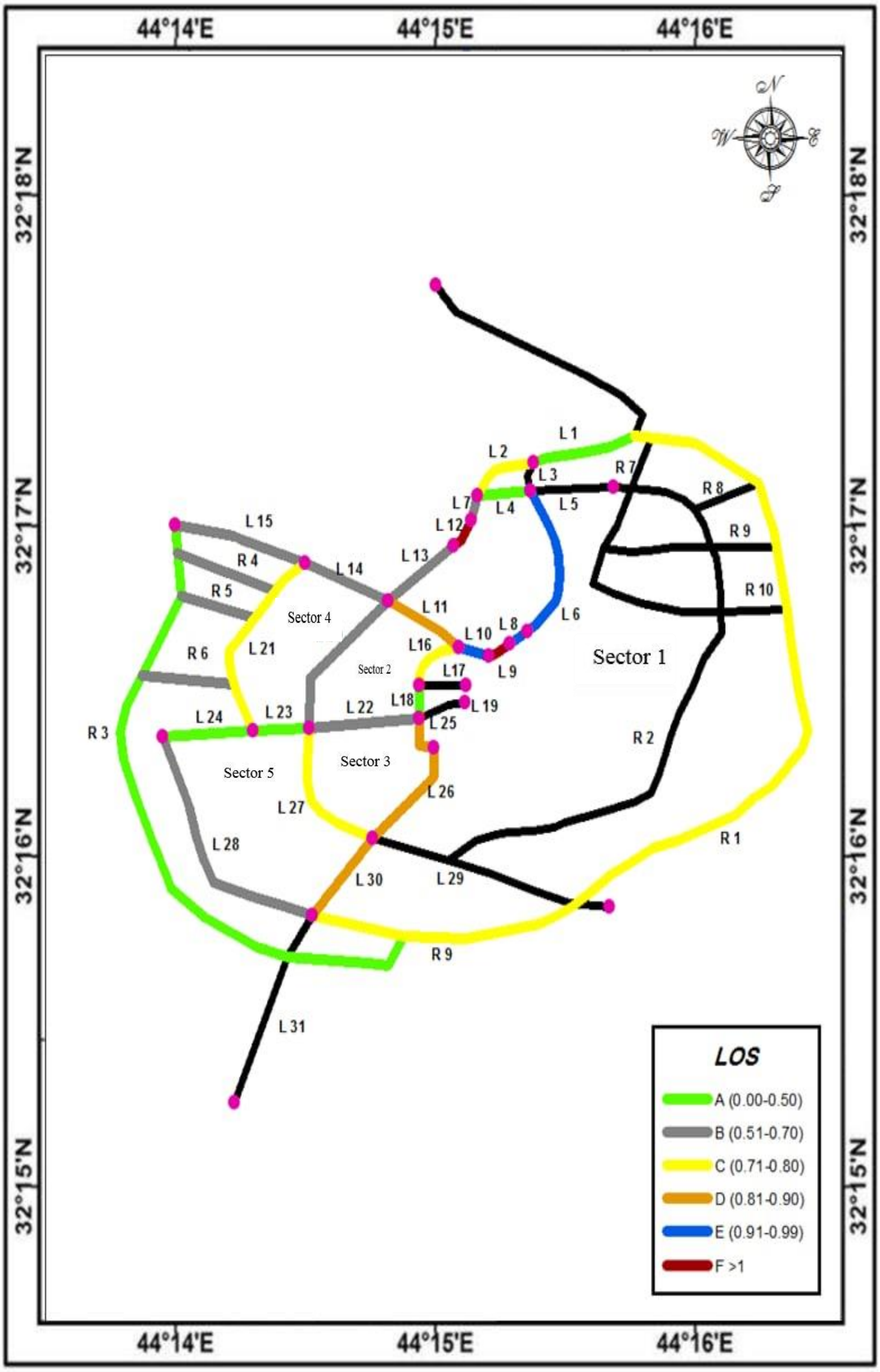

Figure (4 – 19) Level of Service for Case (2).

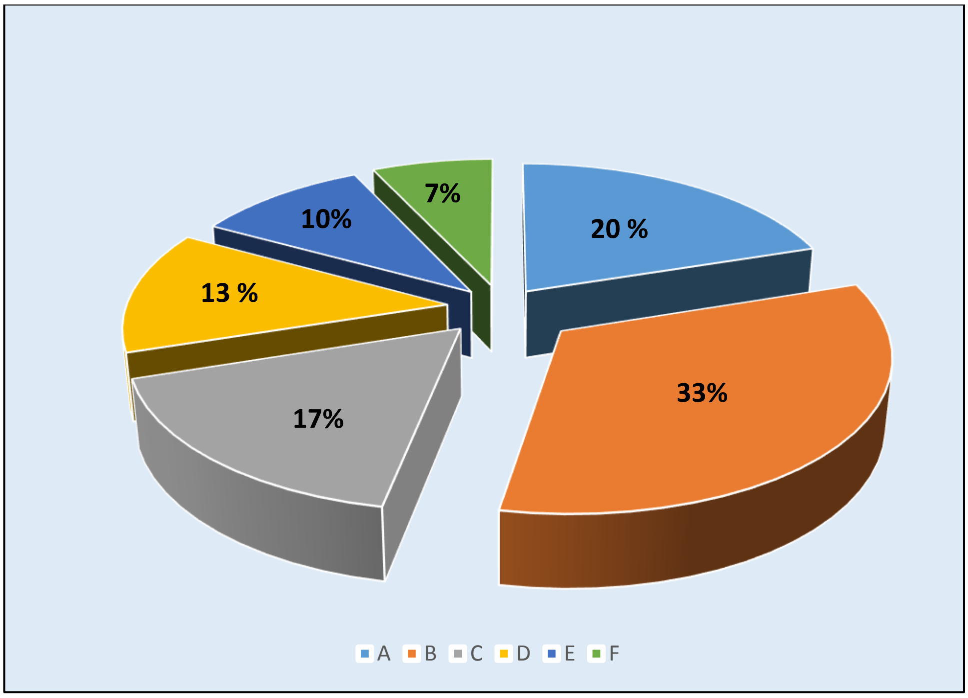

Figure (4 – 20) Percentages of Service Levels for Case (2).

4.8.1.3 Results Analysis for the New Suggested Arterials

The final outputs for the average of V/C for the new suggested arterials scenarios as shown in Figure (4 – 21), traffic assignment processes were conducted on traffic volumes for the target year 2030 by using user equilibrium assignment, with and without the suggested improvements can conclude:

- The average of V/C for case (1), represents LOS (E) for the target year 2030 without the new suggested arterials, representing the operational condition at or near the capacity level.
- The average of V/C for case 2, which represents LOS (C) for 2030 with the addition of major suggested arterials (ring roadways), represents the range of stable flow, stable condition, movements somewhat restricted due to higher volumes, the level of convenience and comfort declines noticeably at this level.

- The average of V/C for case 3, which represents LOS (B) for the year 2030 with both (major & minor) suggested arterials, represents the stable flow range, which provided convenience and comfort for users.
- The priority in the implementation is (R1, R3) of major suggested arterials and (R4, R5, R6) of minor suggested arterials because it has an important impact on improving the study area network level.

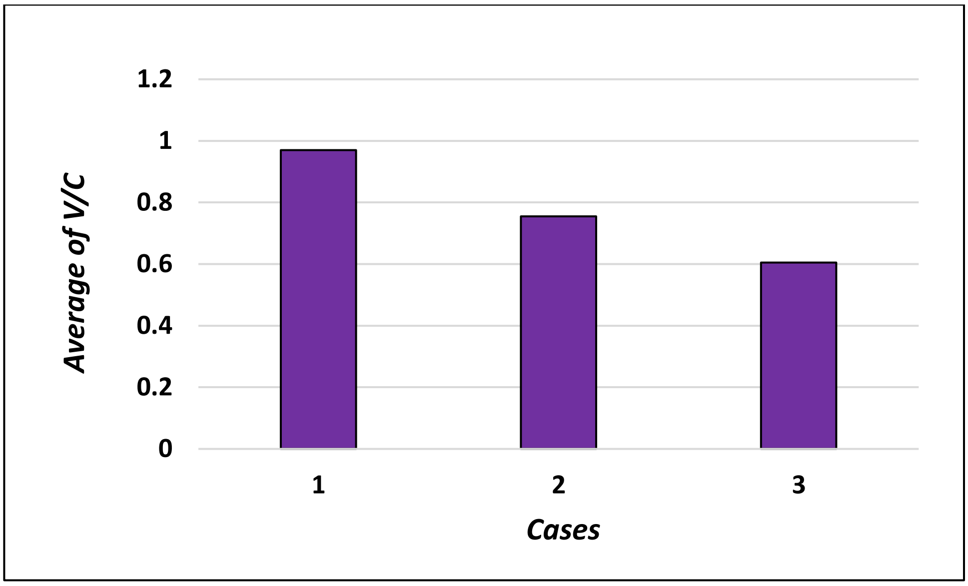

Figure (4 – 21) The Results of Volume/Capacity for the New Suggestion Arterials.

4.8.2 Addition of New Lanes (Short Term)

For finding solutions for the problems of Al-Hilla city roadway network which suffers it from in the base year 2020, some short-term solutions can be implemented within an estimated period of 3 years (Garber & Hoel, 2009), these solutions work to quickly raise the level of service for the arterial roadway network during this short period.

One of these solutions is creating new lanes by reducing the median islands' width for the existing arterial network in the study area. The width of the median islands of major & minor arterials roadways was measured using a tape measure, where the width of median islands for the major roadways is (6 m) and for the minor roadways is (5 m).

The median islands width is reduced in two cases of the major & minor arterial roadways, so that the width of the median islands becomes (1 m), to find the effect of increasing the roadways width & capacity on the overall evaluation of the roadway network in the study area.

4.8.2.1. Case 1

The width of the median islands is reduced on both sides for assigned major & minor roadways in the base year; the width of the median islands will become (1 m) for every of the assigned major & minor arterial roadways, as shown in Table (4.12), which represents enough space for to cross-pedestrians and stop.

Table (4 .12) Attributes for Al-Hilla Roadway Network for Case 1.

Link ID	Capacity (pcph)	Width of Roadway (m)	Width of Median Islands (m)	New Width of Median Islands (m)	New width of Roadway (m)	New Capacity (pcph)
L4	4200	60	5	1	64	5600
L6	7000	60	6	1	65	8667
L7	4200	60	5	1	64	5600
L8	4200	60	5	1	64	5600
L10	4200	30	5	1	34	5600
L11	4200	60	5	1	64	5600
L13	7000	60	5	1	64	8667
L14	7000	60	6	1	65	8667

Link ID	Capacity (pcph)	Width of Roadway (m)	Width of Median Islands (m)	New Width of Median Islands (m)	New width of Roadway (m)	New Capacity (pcph)
L16	7000	60	6	1	65	8667
L18	7000	60	6	1	65	8667
L20	7000	60	6	1	65	8667
L21	7000	60	6	1	65	8667
L22	4200	30	5	1	34	5600
L23	4200	30	5	1	34	5600
L24	4200	60	6	1	65	5600
L25	7000	40	6	1	45	8667
L26	7000	30	5	1	34	8667
L27	7000	60	6	1	65	8667
L28	7000	60	6	1	65	8667

The traffic assignment will be made by using the user equilibrium assignment /incremental to estimate the improvement will occur to the roadway network. Results of the user equilibrium assignment for case (1) will be mentioned in Appendix L. After applying the user equilibrium assignment for case (1), a comparison is made between the assigned volume, and the link capacity, the level of service for the various arterials links in the Al-Hilla network has been estimated by the criteria depicted in the following Table:

Table (4.13) Relationship Between LOS and V/C Proportion for Case 1.

LOS	V/C Ratio	Links ID	Operational condition
A	0.00-0.50	L 16, L18, L 20, L25	Free flow conditions
B	0.51-0.70	L 6, L 10, L 11, L 13, L 14, L 21, L 22, L28, L 26	Reasonably unimpeded operations
C	0.71-0.80	L 4, L7, L 8, L 23, L27, L 30	Generally stable operations
D	0.81-0.90	L 9	Approaching unstable conditions
E	0.91-0.99	L 24	Significant delays and low average speeds
F	≥ 1	None	Severe congestion and delays

The level of service for case (1) is shown in Figure (4 – 22). The light green color represents the range of v/c (0-0.50) level of service (A), where the percentage of links in this level is (18%), the gray color represents the range of v/c (0.71-0.8) level of service (B), where the percentage of links in this level is (41%), which represents the majority of arterial links in the study. The yellow color represents the range of v/c (0.81-0.99) level of service (C), where the percentage of links in this level is (27%), the orange color represents the range of v/c (0.81-0.99) level of service (D), where the percentage of links in this level is (5%). The blue color represents the v/c range from (0.91-0.99) level of service (E), where the percentage of links in this level is (5%), the dark red color represents the range of v/c (> = 1) level of service (F), as shown in Figure (4 – 23). The overall evaluation of case 1 is LOS (B).

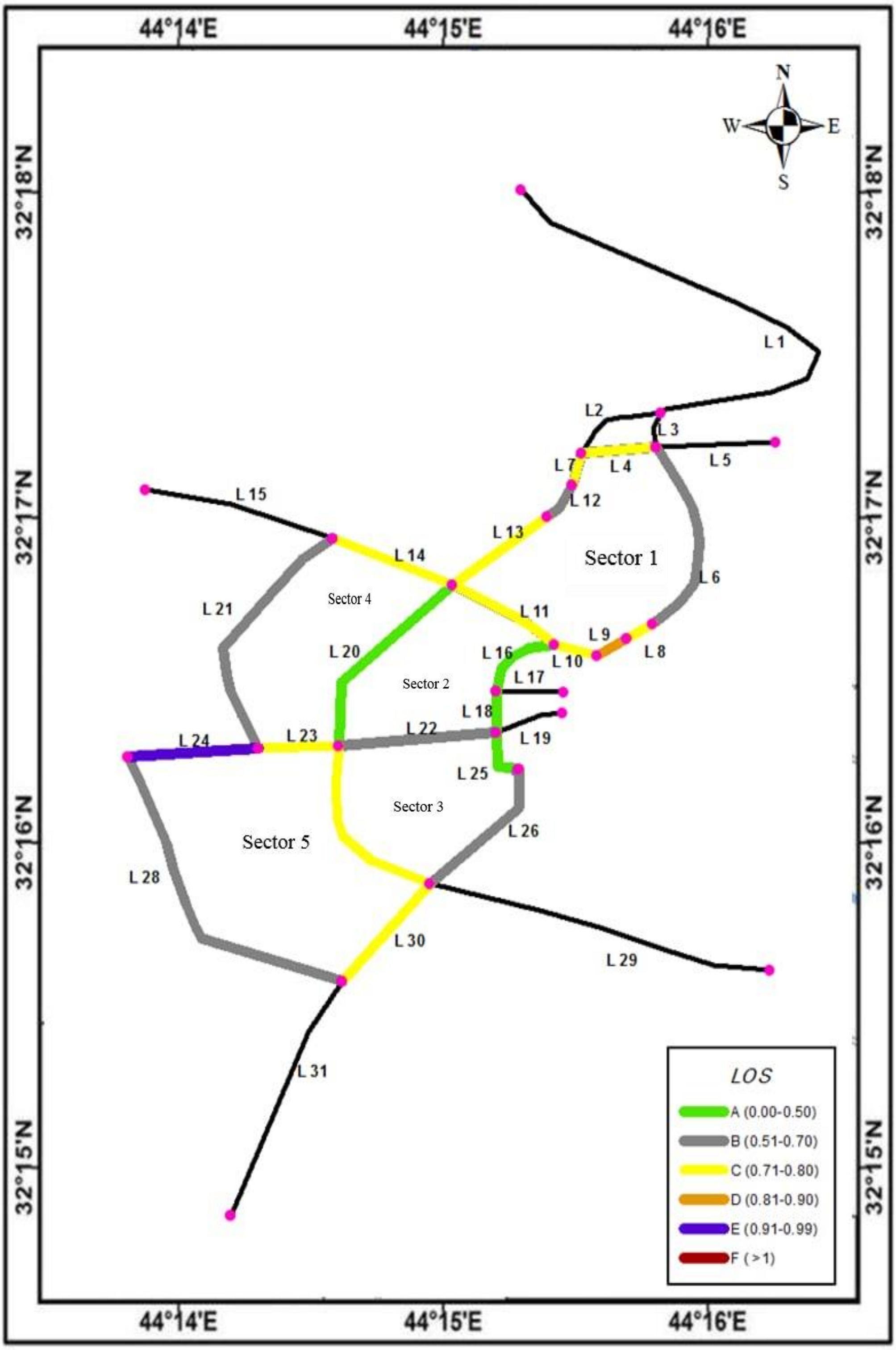

Figure (4 – 22) Level of Service for Case (1).

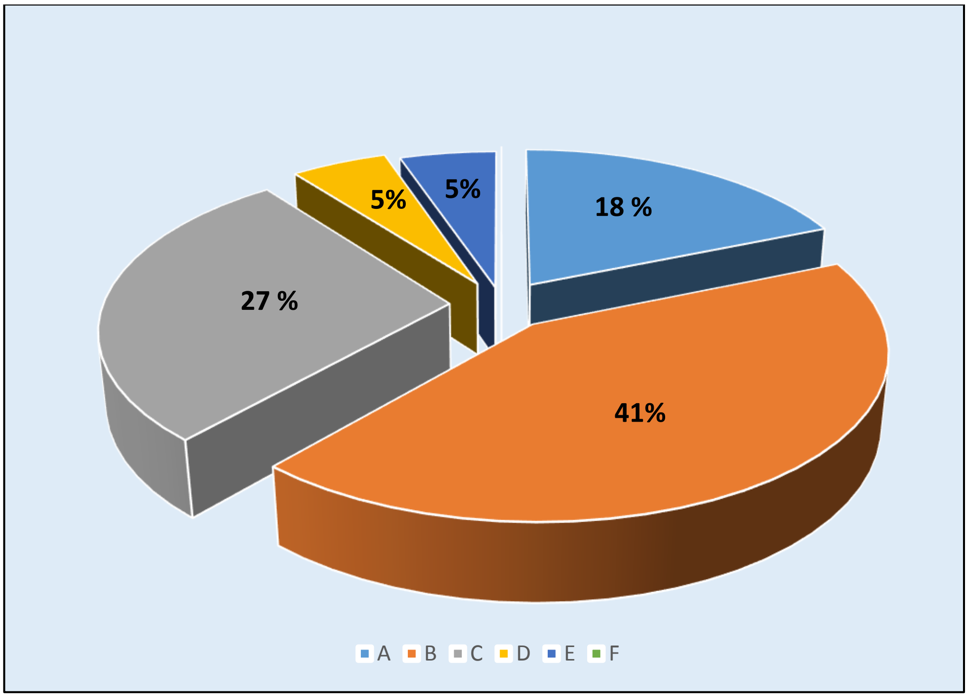

Figure (4 – 23) Percentages of Service Levels for Case (1).

4.8.2.2. Case 2

Traffic assignment will be made by using the user equilibrium assignment / incremental algorithm to assign traffic volumes on the shortest path between the centers of the study area sectors for the (2020) year before and after reducing the width of the median islands of these paths to find the optimum paths between (origin nodes) and (destination nodes). Table (4. 14) shows the shortest paths between the centers of the of the study area sectors, travel times, delays, LOS, before and after the improvements made in the 2020 year. Travel time, delay, and LOS are used for the overall evaluation of traffic conditions. Delay is the time lost to travel because of traffic frictions and traffic control devices. In the following equation, a formula is used to calculate the delay is (Manual, 2010):

$$d = \frac{3600}{Cmx} + 900\,T\left[\frac{Vm}{Cmx} - 1\sqrt{\left(\frac{Vm}{Cmx} - 1\right)^2 + \frac{(\frac{3600}{Cmx}) + (\frac{Vm}{Cmx})}{450\,T}}\right] + 5 * \min(x, 1) \qquad (4.5)$$

Whereas:

d = average delay controlling (sec/veh);

Vx= the movement flow rate in the x-direction (veh/h);

Cmx = the movement capacity in the x-direction (veh/h);

T = time of analysis, h (T=0.25 for time=fifteen minutes).

Table (4.14) Comparison of 2020 Before and After Improvements.

Before Improvement						After Improvement		
Centroid ID	Paths	Link ID	Max Travel Time (min)	Max Delay (sec/veh)	LOS	Max Travel Time (min)	Max Delay (sec/veh)	LOS
1 – 2	Path 1	L 6	3.187	43.76	B	3.008	34.32	B
		L 8	0.459	66.147	F	0.341	45.731	C
		L 9	0.134	47.873	D	0.134	47.873	E
		L 10	0.780	52.845	B	0.645	30.844	A
		L 16	1.89	37.81	A	1.470	32.263	A
	Path 2	L 4	2.45	49.165	F	1.068	40.609	C
		L 7	1.324	50.430	F	1.024	41.079	C
		L 12	0.125	46.223	B	0.125	46.223	B
		L 13	3.621	53.190	D	2.673	44.523	B
		L 11	2.127	30.05	B	1.765	23.203	B
	Path 3	L 4	2.45	49.165	F	1.068	40.609	C
		L 7	1.324	50.430	F	1.024	41.079	C
		L 12	0.125	46.223	B	0.125	46.223	B
		L 20	6.182	30.249	D	3.296	22.689	A
		L 22	2.366	50.40	D	1.123	39.772	A
		L 18	1.019	40.548	B	0.852	30.458	A

Before Improvement						After Improvement		
Centroid ID	Paths	Link ID	Max Travel Time (min)	Max Delay (sec/veh)	LOS	Max Travel Time (min)	Max Delay (sec/veh)	LOS
1 – 3	Path 1	L 4	2.45	49.165	F	1.068	40.609	C
		L 7	1.324	50.430	F	1.024	41.079	C
		L 12	0.125	46.223	B	0.125	46.223	B
		L 13	3.621	53.190	D	2.673	44.523	B
		L 11	2.127	30.05	B	1.765	23.203	B
		L 16	1.89	37.81	A	1.470	32.263	A
		L 18	1.019	40.548	B	0.852	30.458	A
		L 25	1.007	30.409	A	0.651	25.262	A
	Path 2	L 6	3.187	43.76	B	3.008	34.32	B
		L 8	0.459	66.147	F	0.341	45.731	C
		L 9	0.134	47.873	D	0.134	47.873	E
		L 10	0.780	52.845	B	0.645	30.844	A
		L 16	1.89	37.81	A	1.470	32.263	A
		L 18	1.019	40.548	B	0.852	30.458	A
		L 22	2.366	50.40	D	1.123	39.772	A
	Path 3	L 25	1.007	30.409	A	0.651	25.262	A
		L 4	2.45	49.165	F	1.068	40.609	C
		L 7	1.324	50.430	F	1.024	41.079	C
		L 12	0.125	46.223	B	0.125	46.223	B
		L 13	2.624	50.205	D	1.780	44.535	B
		L 20	6.182	30.249	D	3.296	22.689	A
		L 27	7.557	50.134	D	3.095	48.034	C

Before Improvement						After Improvement		
Centroid ID	Paths	Link ID	Max Travel Time (min)	Max Delay (sec/veh)	LOS	Max Travel Time (min)	Max Delay (sec/veh)	LOS
1 – 4	Path 1	L 4	2.45	49.165	F	1.068	40.609	C
		L 7	1.324	50.430	F	1.024	41.079	C
		L 12	0.125	46.223	B	0.125	46.223	B
		L 13	2.624	50.205	D	1.780	44.535	B
		L 14	2.110	40.188	B	1.040	30.789	B
1 - 5	Path 1	L 4	2.45	49.165	F	1.068	40.609	C
		L 7	1.324	50.430	F	1.024	41.079	C
		L 12	0.125	46.223	B	0.125	46.223	B
		L 13	3.621	53.190	D	2.673	44.523	B
		L 14	2.110	40.188	B	1.040	30.789	B
		L 21	5.345	33.117	C	4.509	29.56	B
		L 23	1.002	60.10	F	1.472	49.172	C
		L 27	7.557	50.134	D	3.095	48.034	C
		L 30	4.634	40.056	E	2.560	24.536	C
	Path 2	L 6	3.187	43.76	B	3.008	34.32	B
		L 8	0.459	66.147	F	0.341	45.731	C
		L 9	0.134	47.873	D	0.134	47.873	E
		L 10	0.780	52.845	B	0.645	30.844	A
		L 16	1.89	37.81	A	1.470	32.263	A
		L 18	1.019	40.548	B	0.852	30.458	A
		L 22	2.366	50.40	D	1.123	39.772	A
		L 27	7.557	50.134	D	3.095	48.034	C

Before Improvement						After Improvement		
Centroid ID	Paths	Link ID	Max Travel Time (min)	Max Delay (sec/veh)	LOS	Max Travel Time (min)	Max Delay (sec/veh)	LOS
		L 30	4.634	40.056	E	2.560	24.536	C
2 – 3	Path 1	L 18	1.019	40.548	B	0.852	30.458	A
		L 22	2.366	50.40	D	1.123	39.772	A
		L 27	7.557	50.134	D	3.095	48.034	C
		L 26	2.770	50.879	E	1.579	40.339	B
	Path 2	L 16	1.89	37.81	A	1.470	32.263	A
		L 11	2.127	30.05	B	1.765	23.203	B
		L 20	6.182	30.249	D	3.296	22.689	A
		L 22	2.366	50.40	D	1.123	39.772	A
		L 25	1.007	30.409	A	0.651	25.262	A
2 - 4	Path 1	L 16	1.89	37.81	A	1.470	32.263	A
		L 11	2.127	30.05	B	1.765	23.203	B
		L 14	2.110	40.188	B	1.040	30.789	B
	Path 2	L 18	1.019	40.548	B	0.852	30.458	A
		L 22	2.366	50.40	D	1.123	39.772	A
		L 20	6.182	30.249	D	3.296	22.689	A
		L 14	2.110	40.188	B	1.040	30.789	B
2 – 5	Path 1	L 18	1.019	40.548	B	0.852	30.458	A
		L 25	1.007	30.409	A	0.651	25.262	A
		L 26	2.770	50.879	E	1.579	40.339	B
		L 30	4.634	40.056	E	2.560	24.536	C
	Path 2	L 18	1.019	40.548	B	0.852	30.458	A

Before Improvement						After Improvement		
Centroid ID	Paths	Link ID	Max Travel Time (min)	Max Delay (sec/veh)	LOS	Max Travel Time (min)	Max Delay (sec/veh)	LOS
		L 22	2.366	50.40	D	1.123	39.772	A
		L 23	1.002	60.10	F	1.472	49.172	C
		L 24	3.182	31.115	E	1.540	24.358	B
		L 28	11.599	57.450	D	8.748	48.213	C
	Path 3	L 16	1.89	37.81	A	1.470	32.263	A
		L 11	2.127	30.05	B	1.765	23.203	B
		L 20	6.182	30.249	D	3.296	22.689	A
		L 27	7.557	50.134	D	3.095	48.034	C
		L 30	4.634	40.056	E	2.560	24.536	C
3 – 4	Path 1	L 14	2.110	40.188	B	1.040	30.789	B
		L 20	6.182	30.249	D	3.296	22.689	A
		L 27	7.557	50.134	D	3.095	48.034	C
		L 26	2.770	50.879	E	1.579	40.339	B
	Path 2	L 21	5.345	33.117	C	4.509	29.56	B
		L 23	1.002	60.10	F	1.472	49.172	C
		L 22	2.366	50.40	D	1.123	39.772	A
		L 25	1.007	30.409	A	0.651	25.262	A
3 – 5	Path 1	L 25	1.007	30.409	A	0.651	25.262	A
		L 22	2.366	50.40	D	1.123	39.772	A
		L 27	7.557	50.134	D	3.095	48.034	C
		L 30	4.634	40.056	E	2.560	24.536	C
4 -5	Path 1	L 14	2.110	40.188	B	1.040	30.789	B

Before Improvement						After Improvement		
Centroid ID	Paths	Link ID	Max Travel Time (min)	Max Delay (sec/veh)	LOS	Max Travel Time (min)	Max Delay (sec/veh)	LOS
		L 20	6.182	30.249	D	3.296	22.689	A
		L 27	7.557	50.134	D	3.095	48.034	C
		L 30	4.634	40.056	E	2.560	24.536	C
	Path 2	L 21	5.345	33.117	C	4.509	29.56	B
		L 23	1.002	60.10	F	1.472	49.172	C
		L 27	7.557	50.134	D	3.095	48.034	C
		L 30	4.634	40.056	E	2.560	24.536	C

The optimum paths were extracted between the centers of the study area sectors after improvements, as shown in the following table:

Table (4.15) The Optimum Paths Between Study Area Sectors after Improvements.

Centroid ID	Optimum Path ID	Description path	Total max of travel time (min)	Total max of delay (sec/veh)	Ave. of level of service
1 – 2	Path 1	L 6, L 8, L 9, L 10 L 16	5.598	191.031	A
1 – 3	Path 2	L 6, L 8, L 9, L 10 L 16, L 18, L 22	7.573	207.261	B

1 – 4	Path 1	L 4, L 7, L 12, L 13, L 14	5.037	203.235	B
1 – 5	Path 2	L 6, L 8, L 9, L 10, L 16, L 18, L 22, L 27, L 30	13.226	333.831	C
2 – 3	Path 2	L 16, L 11, L 20, L 22, L 25	8.305	143.189	A
2 – 4	Path 1	L 16, L 11, L 14	4.275	86.255	A
2 – 5	Path 1	L 18, L 25, L 26, L 30	5.642	120.595	B
3 – 4	Path 2	L 21, L 23, L 22, L 25	7.614	143.766	B
3 – 5	Path 1	L 25, L 22, L 27, L 30	7.489	137.604	C
4 – 5	Path 1	L 14, L 20, L 27, L 30	9.991	126.048	C

4.8.3. The Results Analysis for Addition of New lanes

The final outputs of V/C average for scenarios as shown in Figure (4 – 24), traffic assignment processes was conducted on traffic volumes for the base year 2020 with and without the suggested improvements that work to achieving optimization state for the short term:

- The average of V/C for case (1), represents LOS (D) for the base year (2020) without suggested improvements (which represent unstable approaching conditions for the traffic condition in the study area due to high traffic density).

- The average of V/C for case (2), represents LOS (B) (the range of stable flow) for the base year (2020) with suggested improvement, where the width of median islands for assigned roadways has been reduced from (6 and 5 m) for major & minor roadways to (1m).

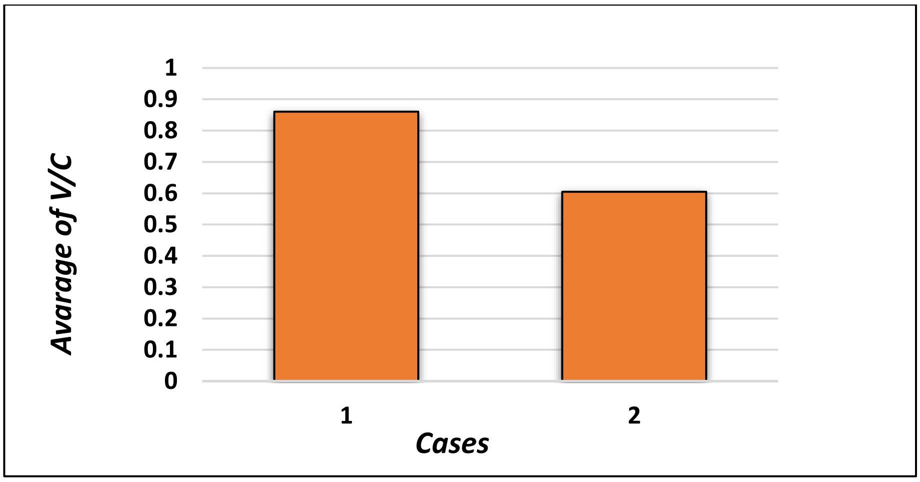

Figure (4 – 24) The Results of V/C for Addition of New Lanes.

- In case 3, the user equilibrium assignment model was used to find the optimum paths between the centers of the study area sectors for the base year (2020) before and after the improvements, to find the impact of these improvements on average of V/C, travel times and delays as shown in Figures (4 – 25, 26, 27).

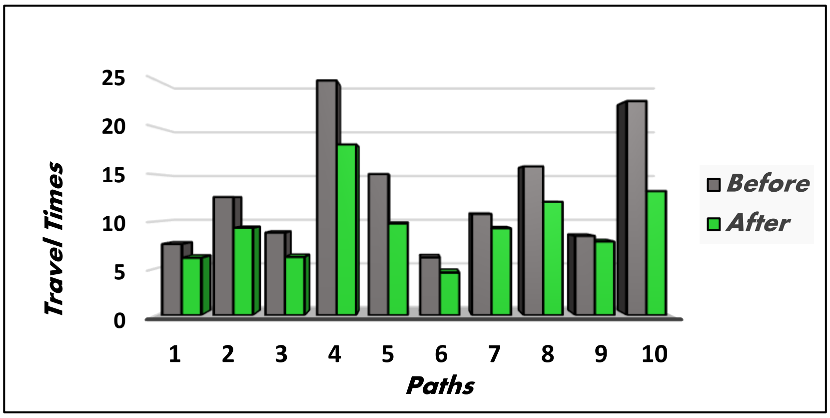

Figure (4 – 25) Travel Times Before and After Improvements.

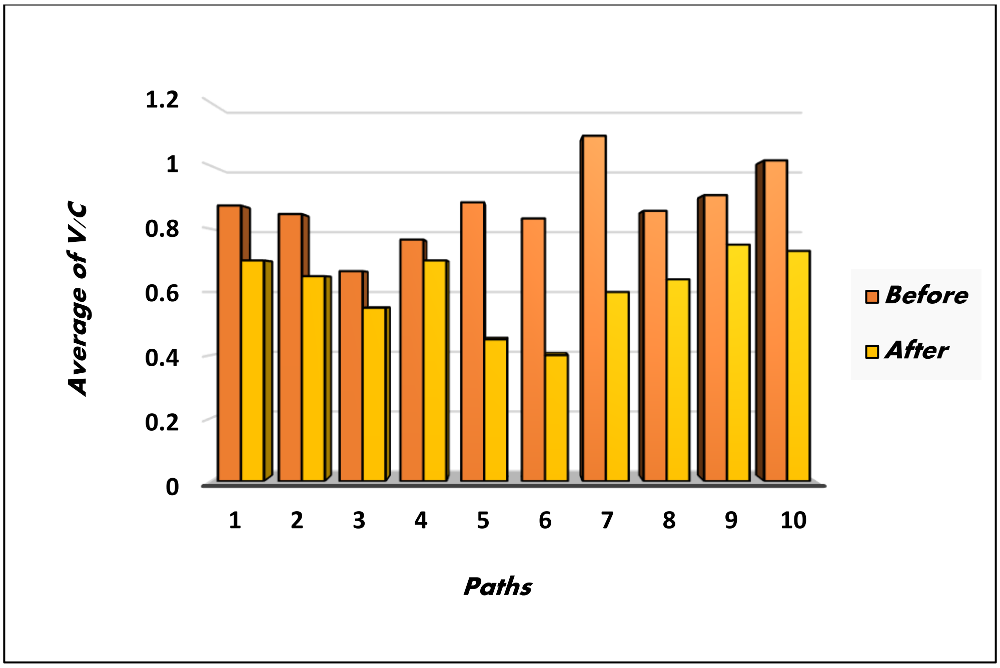

Figure (4 – 26) Averages of V/C Before and After Improvements.

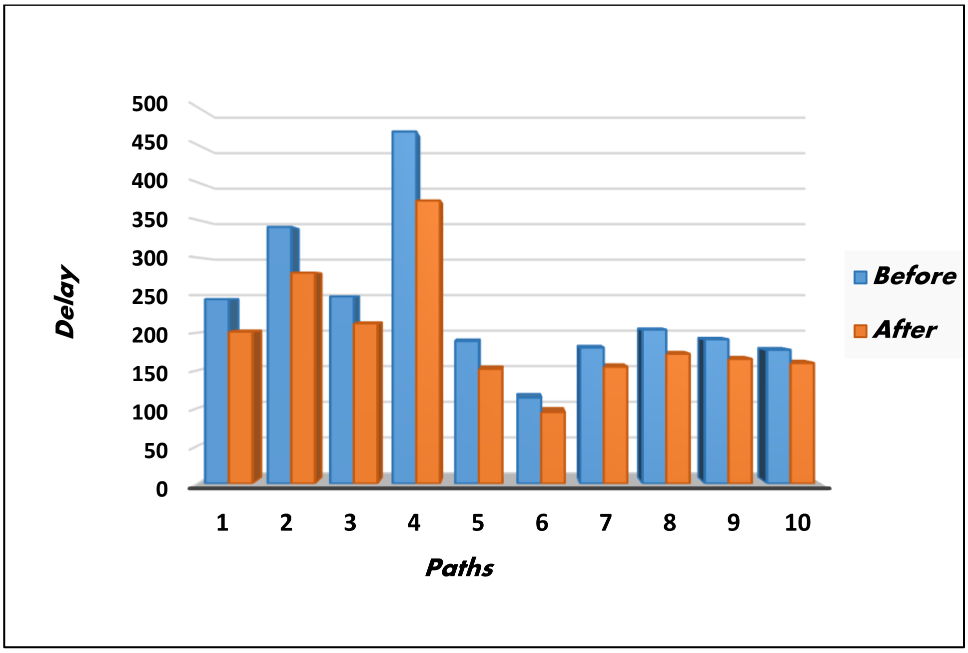

Figure (4 – 27) Delays Before and After Improvements.

Chapter Five

Conclusions and Recommendations

Chapter Five

Conclusions and Recommendations

5.1 Introduction

In this chapter, the conclusions have been summarized within the limits of collected data for Hilla arterials network, recommendations, and recommendations for future works are given:

5.2 Conclusions

- According to the {$\boldsymbol{\beta}$(Beta), $\boldsymbol{\alpha}$(Alpha), $\boldsymbol{\gamma}$(Gamma) and ε(Eta)} indices of which is considered the network slightly complex, correlation considered low because it is less than one although the network is considered well developed.
- The overall evaluation for the base year (2020) represent that the overall evaluation is LOS (D), and the overall evaluation for the target years (2025, 2030, and 2035) LOS are between (D – F) respectively.
- The suggested long-term improvements are represented by suggesting new arterial roadways, the overall evaluation for the suggested roadways is (C, B) respectively.
- The suggested short-term improvements are represented in new lanes by reducing the width of median islands on both sides of the assigned (major & minor) arterial roadways from (6 and 5 m) to (1m), where the overall evaluation for new lanes is (B).
- The overall evaluation of the optimum paths before the improvements, LOS are between (B – F), and the overall evaluation for the optimum paths after making the improvements, LOS are between (A – C) respectively.

5.3 Recommendations

The study recommended the following:

- It is recommended to build a database for the roadway network of Hilla City through the GIS program for planning and traffic management, to know the reality of the network.
- Increase the capacity of the links that suffer from congestion and work to expand those links by reducing the width of the median islands.
- It is proposed to added new roads to the current arterials network of Hilla city.
- Hilla City needs to activate modern public transportation systems based on coordination with the general directorates of traffic in Hilla City to reduce traffic congestion, travel times, and costs and improve the level of service in the city.

5.4 Recommendations for Future Works

- Suggestion to preparing similar studies for congested sectors in Hilla City, like the CBD sector (sector 2) by using the work methodology used in this thesis.
- Using another software in the traffic assignment process, such as VISSIM Software.
- It is conducting studies that improve the reality of the study area network by using techniques other than those used in the proposals (suggestion new arterials, addition of new lanes).

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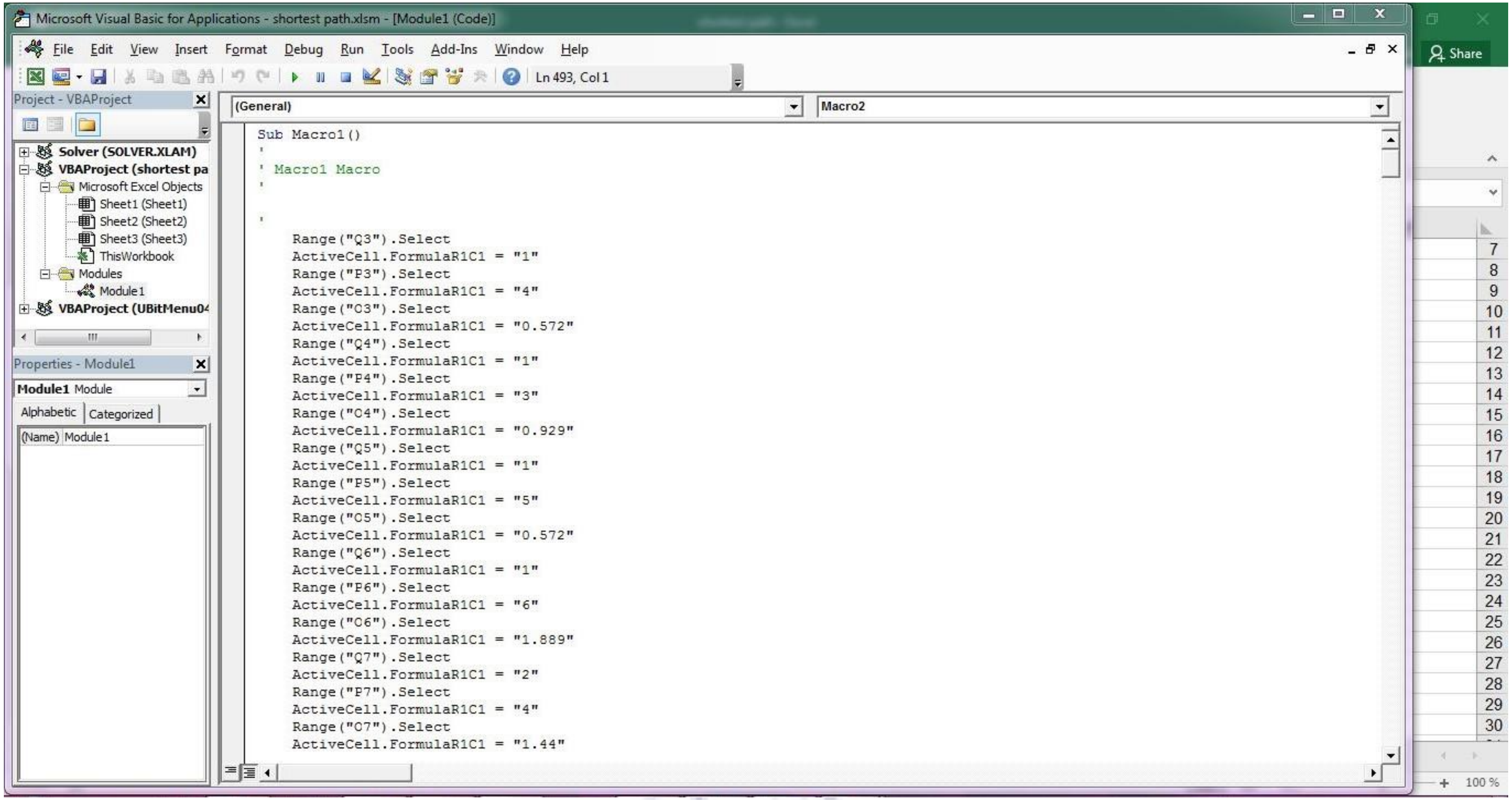
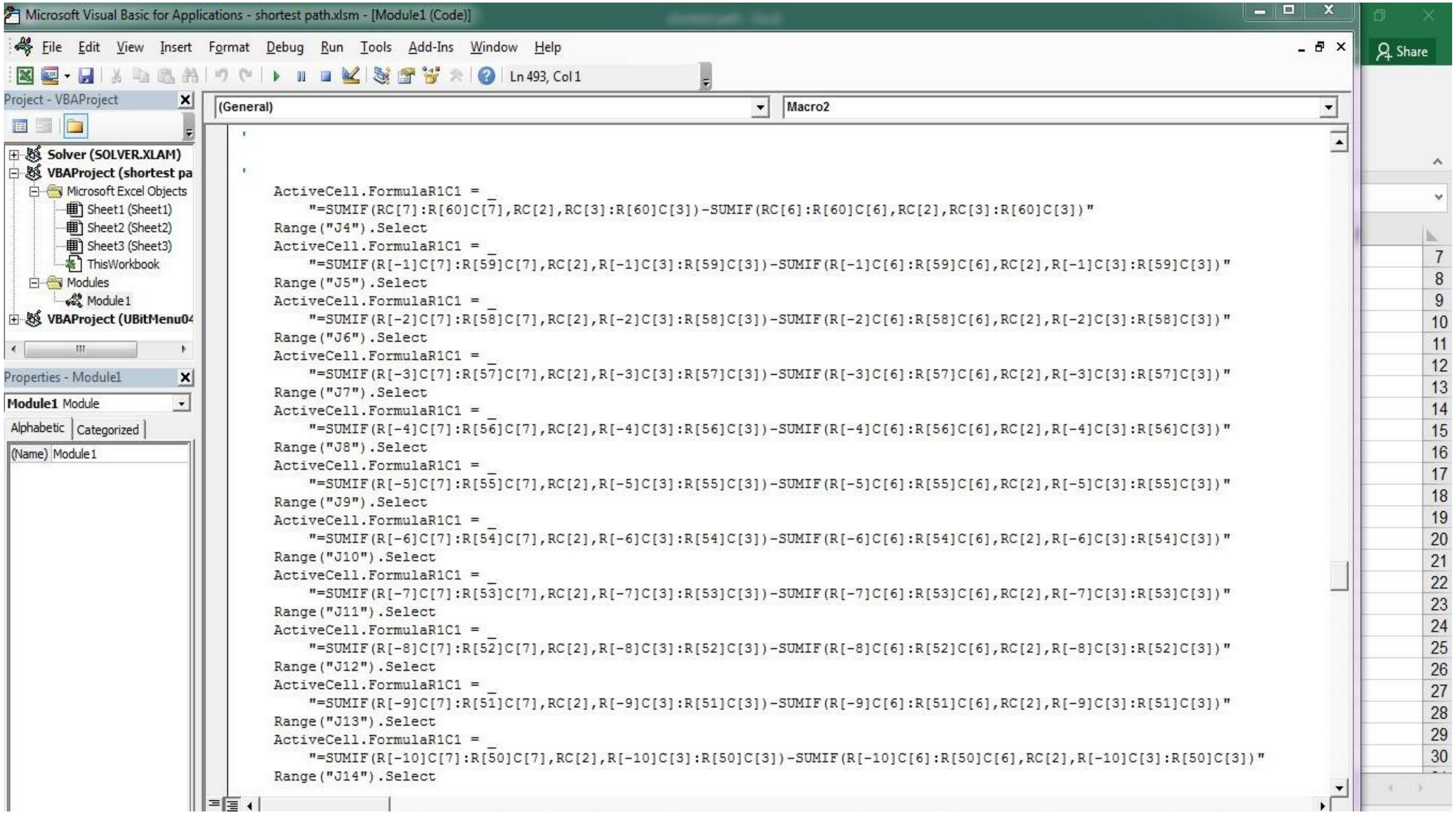
Appendix A

The Codes of Visual Basic & Microsoft Excel Solver

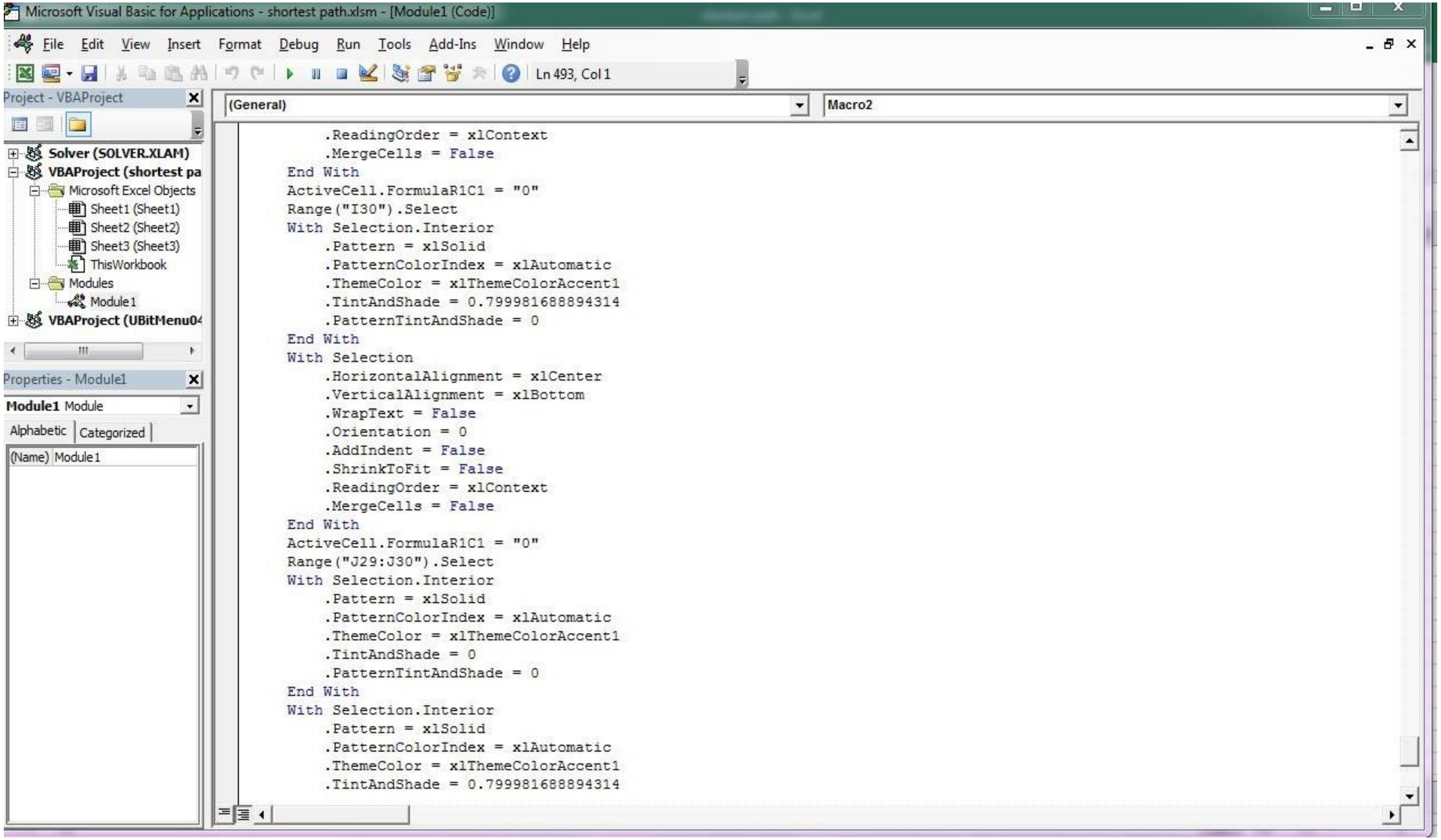
Appendix



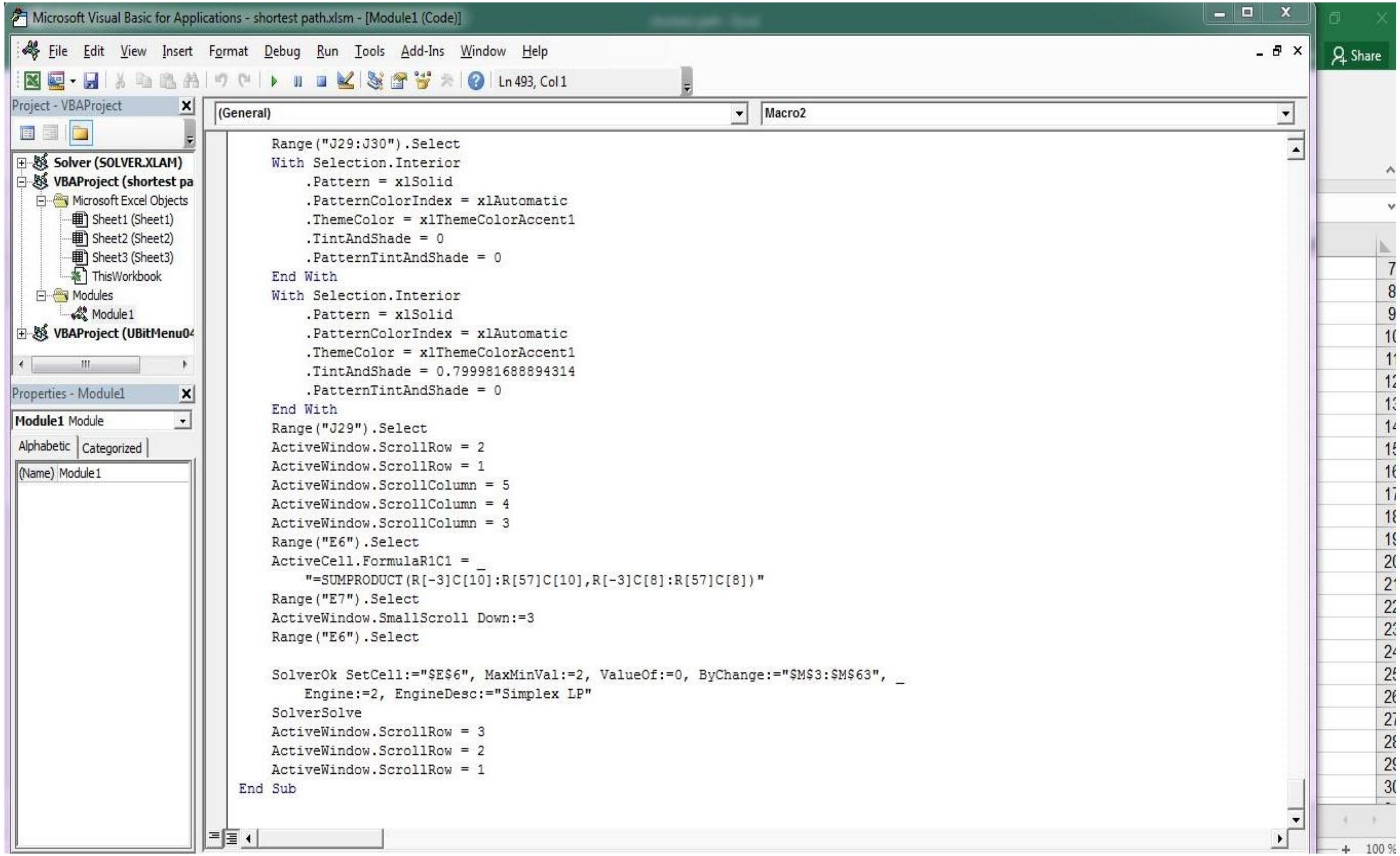
(A-1) The Code of Microsoft Excel Solver.



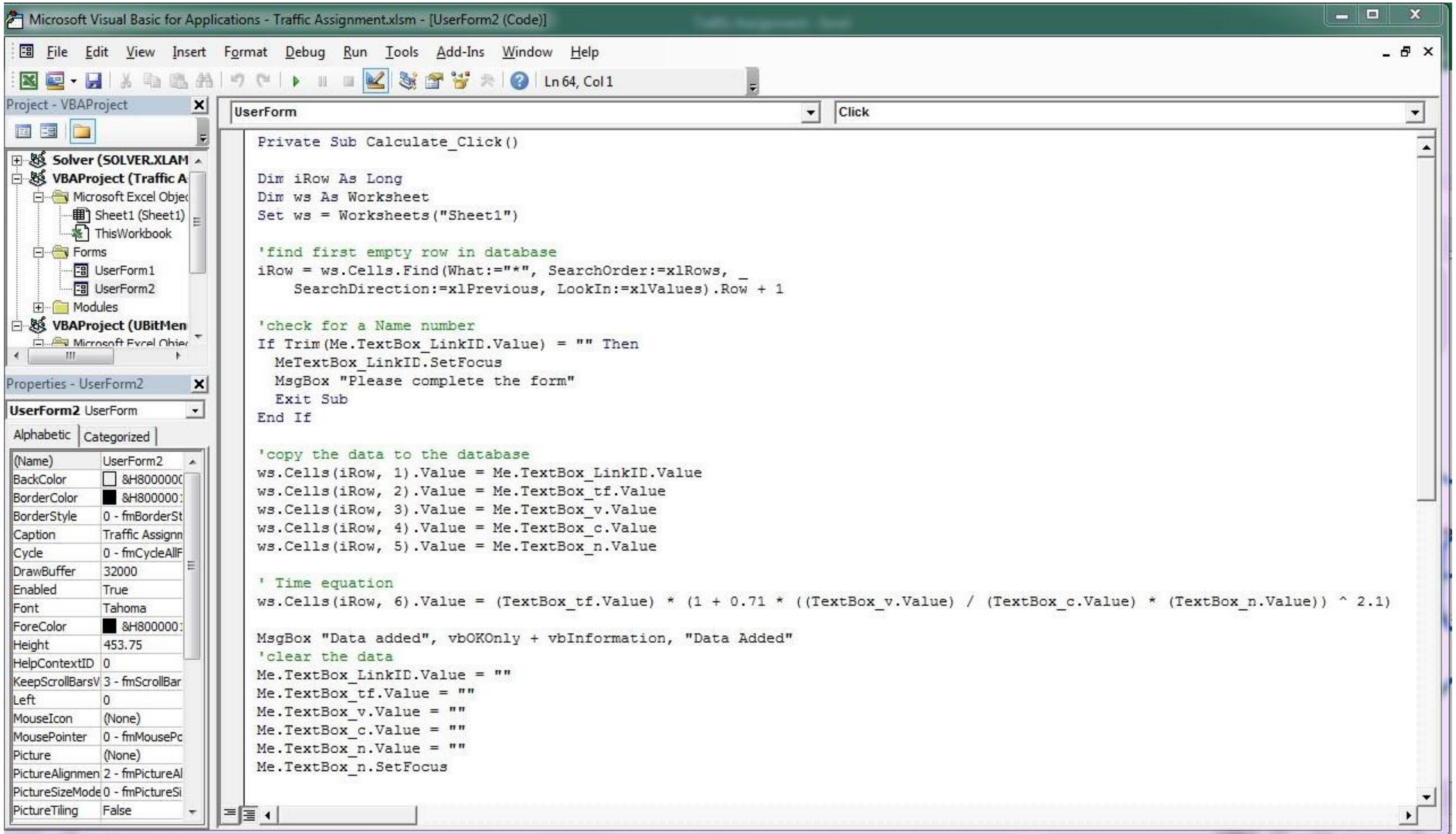
(A-2) The Code of Microsoft Excel Solver.



(A-3) The Code of Microsoft Excel Solver.



(A-4) The Code of Microsoft Excel Solver.



(A-5) The Code of Visual Basic.

Appendix B

User Equilibrium Assignment Model Results for Base Year (2020).

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Appendix B

Table (B-1) User Equilibrium Assignment Model Results for Base Year (2020).

Link ID	Between Nodes	V_{AB}	V_{BA}	V_{TOTAL}	T_{AB}	T_{BA}	T_{MAX}
L4	28 – 19	3000	1200	4200	1.407	0.666	1.407
L6	21 – 22	2300	2260	4560	3.543	3.892	3.892
L7	19 – 18	3000	1200	4210	1.334	0.622	1.334
L8	22 – 23	4332	1472	4332	0.910	0.215	0.910
L9	23 – 24	1764	1766	3530	0.188	0.188	0.188
L10	24 – 1	1200	1968	3168	0.590	0.840	0.840
L11	1 – 2	3268	1668	3268	2.090	2.148	2.148
L12	5 – 18	2520	1020	2520	0.127	0.100	0.127
L13	5 – 2	3852	2200	6052	3.829	2.018	3.829

Link ID	Between Nodes	V_{AB}	V_{BA}	V_{TOTAL}	T_{AB}	T_{BA}	T_{MAX}
L14	2 – 3	2280	2369	4569	2.028	2.115	2.115
L16	1 – 6	2069	1200	3269	1.910	1.275	1.910
L18	6 – 9	2300	2032	4333	1.321	1.157	1.321
L20	10 – 2	3600	2520	6120	7.292	4.785	7.292
L21	3 – 16	3500	1522	5022	10.109	4.412	10.109
L22	10 – 9	1890	1566	3456	2.669	2.285	2.669
L23	10 – 16	2697	1503	4200	2.053	1.147	2.053
L24	16 – 11	2300	3094	5394	2.262	3.182	3.182
L25	9 – 17	1170	2100	3270	2.449	3.770	3.770
L26	17 – 12	4372	2360	6732	8.677	4.025	8.677
L27	10 – 12	1868	1200	5780	3.735	3.190	3.735

Link ID	Between Nodes	V_{AB}	V_{BA}	V_{TOTAL}	T_{AB}	T_{BA}	T_{MAX}
L28	11 – 13	2100	3816	5916	5.966	11.599	11.599
L30	12 – 13	3030	2750	5780	3.590	3.215	3.590

Appendix C

The Assigned Shortest Path from Sectors to the Random Destination.

Appendix C

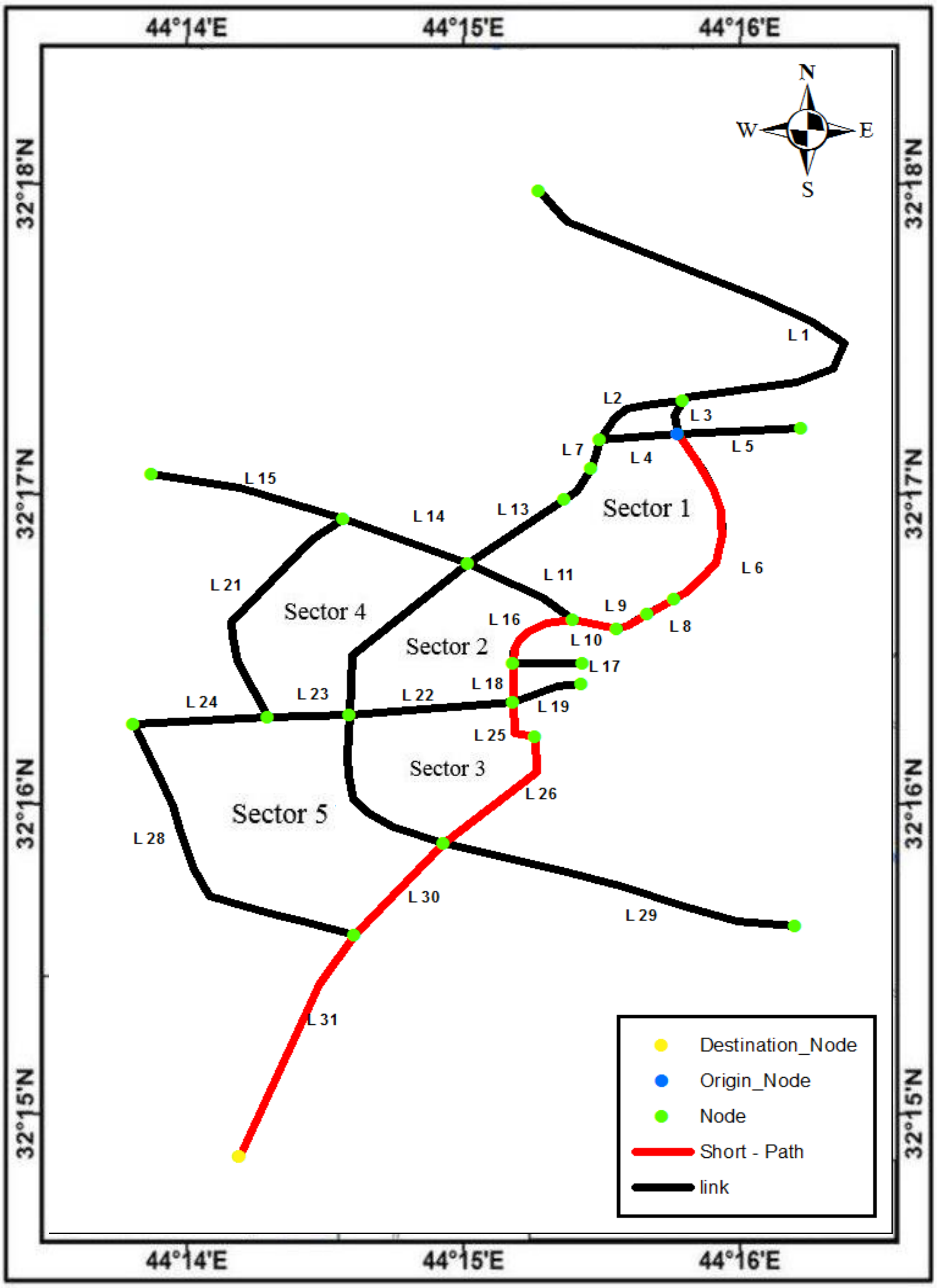

Figure (C – 1) The Assigned Shortest Path from Sector 1 to the Random Destination.

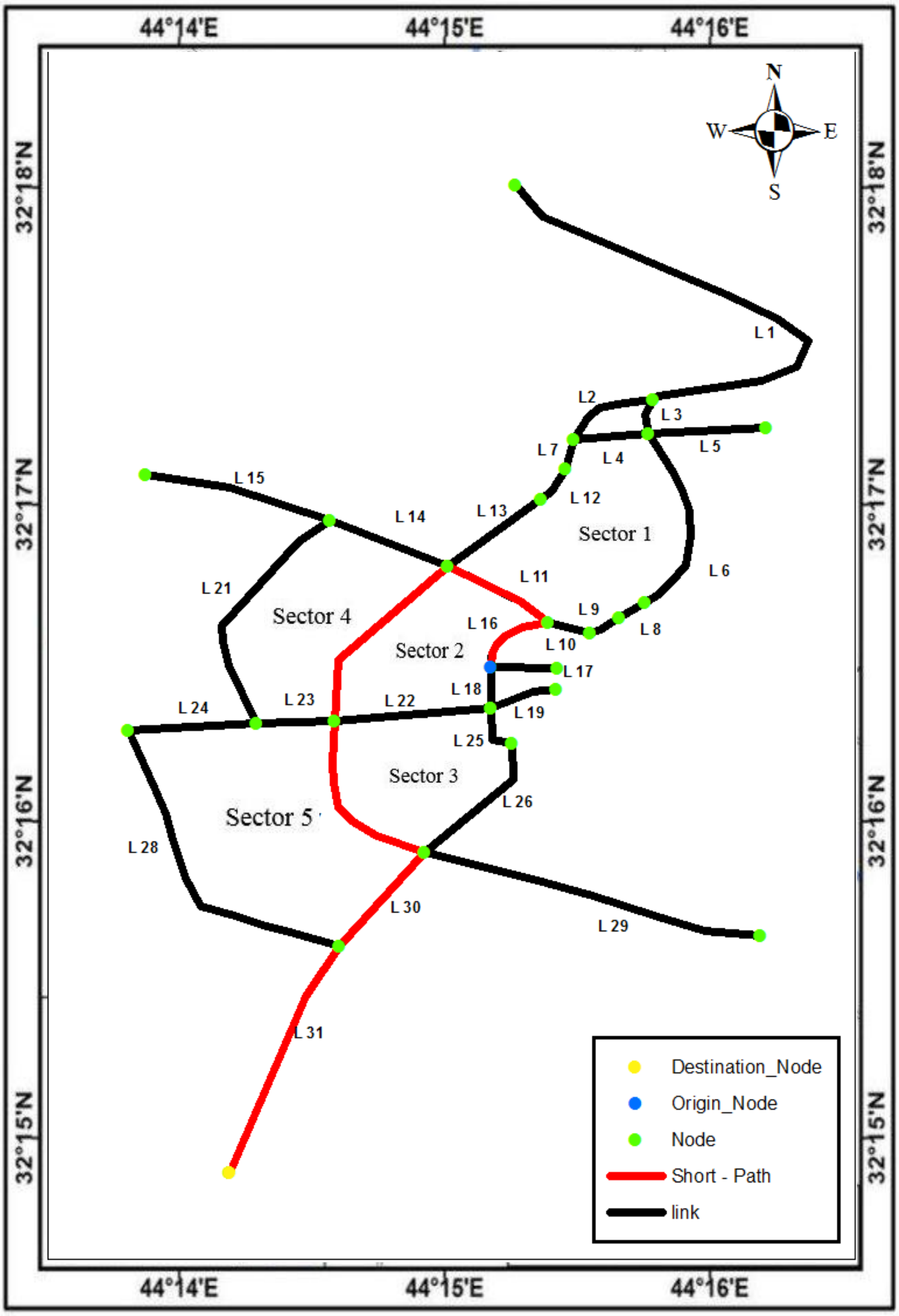

Figure (C – 2) The Assigned Shortest Path from Sector 2 to the Random Destination.

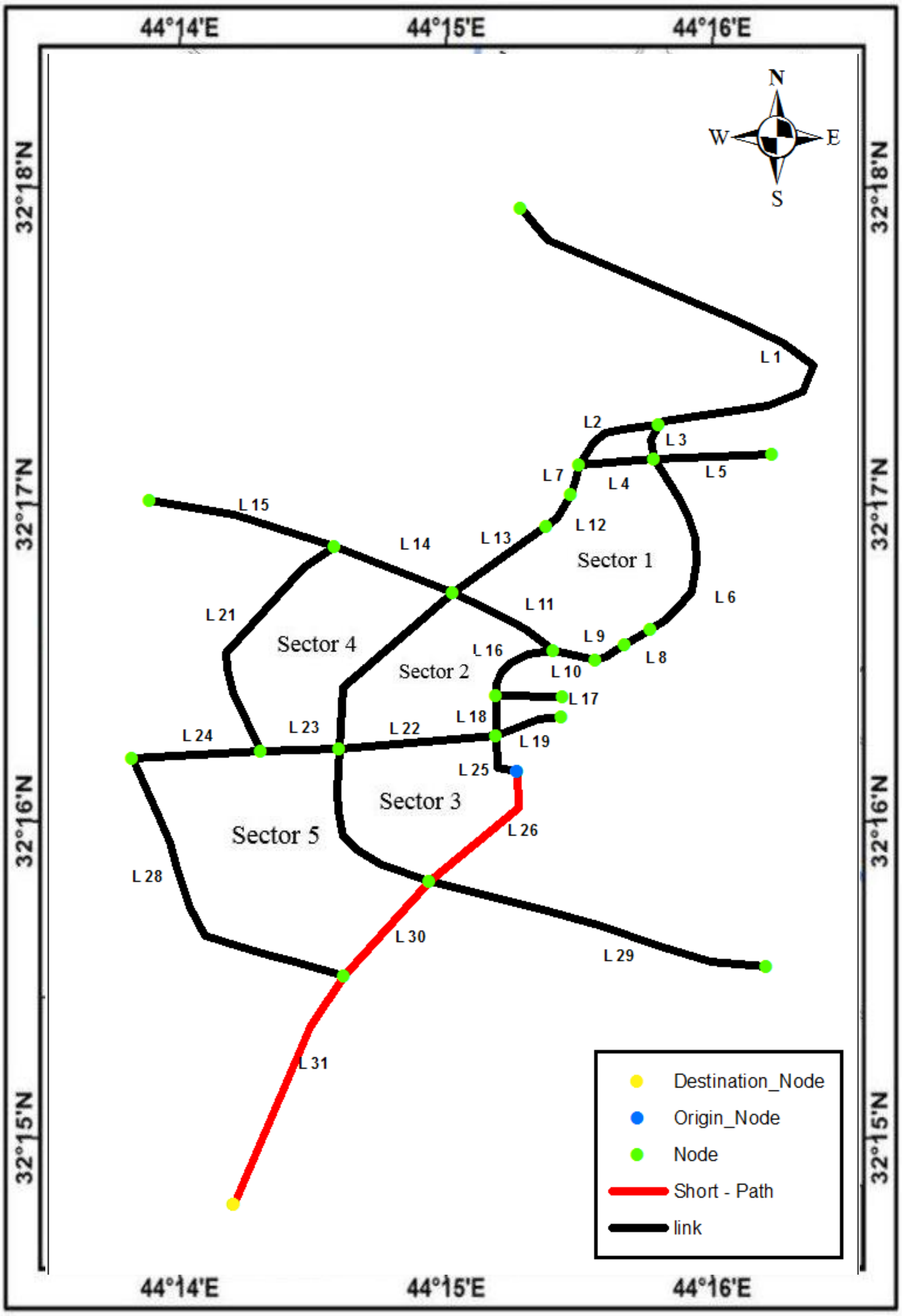

Figure (C – 3) The Assigned Shortest Path from sector 3 to the Random Destination.

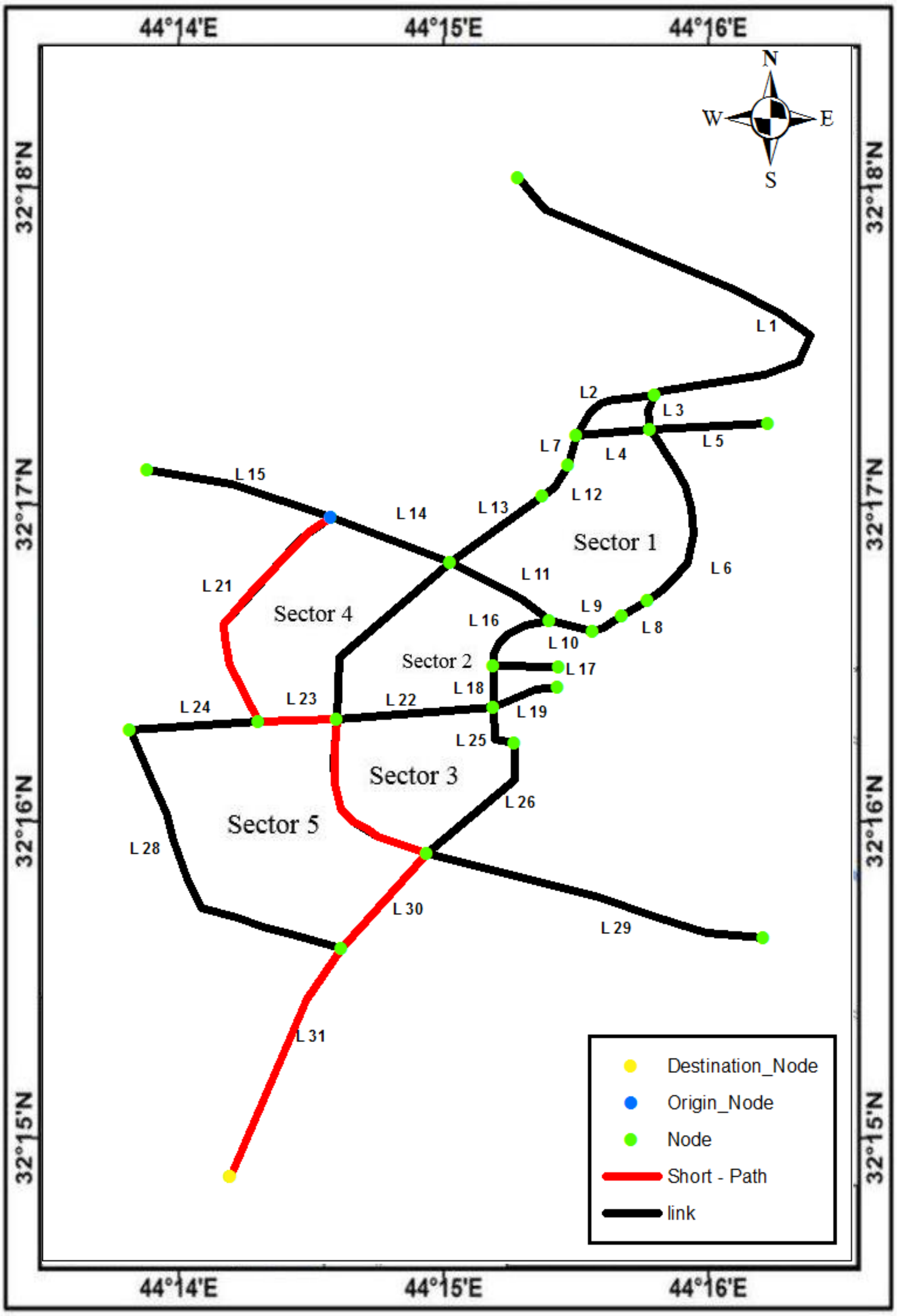

Figure (C – 4) The Assigned Shortest Path from Sector 4 to Random Destination.

Appendix D

User Equilibrium Assignment Model Results for Case 1

Appendix D

Table (D-1) User Equilibrium Assignment Model Results for Case 1.

Link ID	Between Nodes	V_{AB}	V_{BA}	V_{TOTAL}	T_{AB}	T_{BA}	T_{MAX}
L4	28 – 19	2537	2500	5037	1.150	1.131	1.150
L6	21 – 22	3940	2900	6840	8.092	5.148	8.092
L7	19 – 18	2630	2407	5037	1.133	1.025	1.133
L8	22 – 23	3800	3400	7200	0.724	0.601	0.724
L9	23 – 24	1200	2400	3600	0.145	0.257	0.257
L10	24 – 1	1028	2500	3528	0.552	1.094	1.094
L11	1 – 2	2600	3100	5700	3.229	4.025	4.025
L12	5 – 18	2752	1500	2752	0.254	0.127	0.254
L13	5 – 2	3752	2300	6052	3.688	2.097	3.688

Link ID	Between Nodes	V_{AB}	V_{BA}	V_{TOTAL}	T_{AB}	T_{BA}	T_{MAX}
L14	2 – 3	1200	3645	4845	1.262	3.766	3.766
L16	1 – 6	2500	2630	5130	2.364	2.520	2.520
L18	6 – 9	2563	2569	5132	1.504	1.509	1.509
L20	10 – 2	4300	1752	6052	9.444	3.584	9.444
L21	3 – 16	3000	3200	6200	8.202	8.926	8.926
L22	10 – 9	1200	2400	3600	1.946	3.434	3.434
L23	10 – 16	1356	2100	3456	1.074	1.529	1.529
L24	16 – 11	2538	3600	6138	2.466	3.926	3.926
L25	9 – 17	2500	2630	5130	1.536	1.637	1.637
L26	17 – 12	2300	868	3168	4.163	2.195	4.163
L27	10 – 12	3552	2500	6052	6.412	4.251	6.412
L28	11 – 13	3900	2500	6400	11.968	6.960	11.968
L30	12 – 13	3400	3000	6400	4.147	3.548	4.147

Appendix E

User Equilibrium Assignment Model Results for Case 2

Appendix E

Table (E – 1) User Equilibrium Assignment Model Results for Case 2.

Link ID	Between Nodes	V_{AB}	V_{BA}	V_{TOTAL}	T_{AB}	T_{BA}	T_{MAX}
L4	28 – 19	2400	3300	5700	1.083	1.599	1.599
L6	21 – 22	2365	4475	6840	4.012	9.994	9.994
L7	19 – 18	2630	3070	5700	1.133	1.375	1.375
L8	22 – 23	3400	2300	5707	0.601	0.340	0.601
L9	23 – 24	2200	3200	5400	0.233	0.378	0.378
L10	24 – 1	1500	1812	3312	0.672	0.779	0.779
L11	1 – 2	3503	2207	5710	4.780	2.710	4.780
L12	5 – 18	1500	1812	3312	0.127	0.151	0.151
L13	5 – 2	4092	2300	6392	4.183	2.097	4.183
L14	2 – 3	2500	2402	4902	2.249	2.148	2.249
L16	1 – 6	2430	2754	5184	2.284	2.676	2.676
L18	6 – 9	2600	2580	5180	1.532	1.517	1.532

Link ID	Between Nodes	V_{AB}	V_{BA}	V_{TOTAL}	T_{AB}	T_{BA}	T_{MAX}
L20	2 – 10	2892	3500	6392	5.539	7.019	7.019
L21	3 – 16	3540	3900	7440	10.276	11.869	11.869
L22	10 – 9	2800	2600	5400	4.176	3.790	4.176
L23	10 – 16	1500	1812	3312	1.145	1.327	1.327
L24	16 – 11	3240	2836	6076	3.384	2.851	3.384
L25	9 – 17	2684	2500	5184	1.680	1.536	1.680
L26	17 – 12	1600	1424	3024	2.958	2.729	2.958
L27	10 – 12	3600	2792	6392	6.530	4.768	6.530
L28	11 – 13	2600	4840	7440	7.239	16.702	16.702
L30	12 – 13	5068	2380	7448	7.546	2.781	7.546

Appendix F

User Equilibrium Assignment Model Results for Case 3

Appendix F

Table (F – 1) User Equilibrium Assignment Model Results for Scenario 3.

Link ID	Between Nodes	V_{AB}	V_{BA}	V_{TOTAL}	T_{AB}	T_{BA}	T_{MAX}
L4	28 – 19	3600	2195	5795	1.812	0.990	1.812
L6	21 – 22	2500	4340	6840	4.275	9.489	9.489
L7	19 – 18	4563	3837	8400	2.511	1.898	2.511
L8	22 – 23	2300	2980	5280	0.340	0.4888	0.4888
L9	23 – 24	2500	2180	4680	0.270	0.230	0.270
L10	24 – 1	1630	1754	3384	0.714	0.757	0.757
L11	1 – 2	3500	2560	6060	4.774	3.172	4.774
L12	5 – 18	1500	1380	2880	0.127	0.120	0.127
L13	5 – 2	2500	3348	5848	2.267	3.161	3.161

Link ID	Between Nodes	V_{AB}	V_{BA}	V_{TOTAL}	T_{AB}	T_{BA}	T_{MAX}
L14	2 – 3	2815	2600	5415	2.605	2.357	2.605
L16	1 – 6	1854	3600	5454	1.718	3.958	3.958
L18	6 – 9	3800	1658	5458	2.663	0.964	2.663
L20	2 – 10	2623	3225	5848	4.982	2.566	4.982
L21	3 – 16	4500	3900	8400	14.903	11.869	14.903
L22	10 – 9	2380	2300	4680	3.400	3.268	3.400
L23	10 – 16	2100	3564	3564	1.529	3.072	3.072
L24	16 – 11	3200	3600	6800	2.606	3.121	3.121
L25	9 – 17	2000	1528	3528	1.199	0.956	1.199
L26	17 – 12	2600	964	3564	4.827	2.267	4.827
L27	10 – 12	3500	2348	5848	6.286	4.007	6.286
L28	11 – 13	4200	2600	6800	13.358	7.239	13.358
L30	12 – 13	3600	3200	6800	4.477	3.837	4.477

Appendix G

User Equilibrium Assignment Model Results for Case 1.

Appendix G

Table (G-1) User Equilibrium Assignment Model Results for Case 1.

Link ID	Between Nodes	V_{AB}	V_{BA}	V_{TOTAL}	T_{AB}	T_{BA}	T_{MAX}
L1	20 – 26	2000	790	2790	2.387	1.574	2.387
L2	20 – 19	1975	2600	4575	1.480	1.941	1.941
L3	20 – 28	2500	1064	3564	1.176	0.672	1.176
L4	28 – 19	1400	1650	3050	0.715	0.787	0.787
L6	22 – 21	2775	1500	4275	4.860	2.705	4.860
L7	19 – 18	2000	2500	4500	0.856	1.069	1.069
L8	22 – 23	1200	3120	4320	0.187	0.524	0.524
L9	23 – 24	2000	1204	3204	0.211	0.146	0.211
L10	24 – 1	1700	828	2528	0.738	0.515	0.738
L11	1 – 2	1200	3300	4500	1.798	4.387	4.387
L12	5 – 18	928	1600	2528	0.096	0.135	0.135
L13	5 – 2	2604	2700	5304	2.361	2.452	2.452

Link ID	Between Nodes	V_{AB}	V_{BA}	V_{TOTAL}	T_{AB}	T_{BA}	T_{MAX}
L14	2 – 3	1600	2162	3762	1.411	1.823	1.823
L 15	3 – 4	2900	1489	4389	3.740	1.957	3.740
L16	1 – 6	2290	2300	4590	2.131	2.142	2.142
L18	9 – 6	2000	1564	3564	1.139	0.923	1.139
L20	10 – 2	2500	2804	5304	4.747	5.350	5.350
L21	16 – 3	2008	3448	5456	5.360	9.896	9.896
L22	9 – 10	1600	740	2340	2.322	1.658	2.322
L23	16 – 10	1040	760	1800	0.945	0.861	0.945
L24	11 – 16	2000	1050	3050	1.991	1.403	1.991
L25	17 – 9	1600	1150	2790	0.988	0.812	0.988
L26	12 – 17	1064	2500	3564	2.350	4.596	4.596
L28	13 -11	2840	2600	5440	7.956	7.239	7.956
L30	13 – 12	2300	3616	5916	2.696	4.504	4.504
R 1	13 – 26	3895	3689	7584	8.228	7.769	8.228
R 3	27 – 4	3512	3400	6912	0.415	0.402	0.415

Appendix H

User Equilibrium Assignment Model Results for Case 2

Appendix H

Table (H-1) User Equilibrium Assignment Model Results for Case 2.

Link ID	Between Nodes	V_{AB}	V_{BA}	V_{TOTAL}	T_{AB}	T_{BA}	T_{MAX}
L1	26 – 20	2790	1705	2790	3.347	2.117	3.347
L2	19 – 20	1542	3108	4650	1.240	2.420	2.420
L3	28 – 20	1400	2164	3564	0.751	1.019	1.019
L4	19 – 28	1814	1236	3050	0.841	0.674	0.841
L 5	25 – 28	963	2090	3053	1.065	1.625	1.625
L6	21 – 22	1200	3075	4275	2.399	5.575	5.575
L7	18 – 19	2000	2140	4140	0.856	0.911	0.911
L8	22 – 23	1600	2720	4320	0.230	0.427	0.427
L9	23 – 24	1200	2220	3420	0.145	0.235	0.235
L10	24 – 1	1400	1128	2528	0.642	0.573	0.642
L11	1 – 2	2600	1900	4500	3.229	2.369	3.229
L12	5 – 18	1500	2850	4350	0.127	0.267	0.267
L13	5 – 2	2316	1900	4216	2.110	1.804	2.110

Link ID	Between Nodes	V_{AB}	V_{BA}	V_{TOTAL}	T_{AB}	T_{BA}	T_{MAX}
L14	2 – 3	960	2800	3762	1.065	1.673	1.673
L15	3 – 4	1700	2000	3700	2.144	2.458	2.458
L16	1 – 6	2012	1988	4000	1.857	1.835	1.857
L18	9 – 6	750	1896	2646	0.672	1.082	1.082
L20	2 – 10	1400	3100	4500	3.190	6.010	6.010
L21	16 – 3	2100	2550	4650	5.572	6.759	6.759
L22	9 – 10	989	1162	2160	1.795	1.917	1.917
L23	16 – 10	1260	540	1800	1.031	0.815	1.031
L24	11 – 16	1450	1600	3050	1.602	1.694	1.694
L25	17 – 9	1320	1470	2790	0.871	0.931	0.931
L26	12 – 17	1200	2364	3564	2.479	4.297	4.297
L27	12 – 10	2900	3200	6120	4.976	5.597	5.597
L28	13 – 11	1360	3290	4650	4.620	9.490	9.490
R 1	13 – 26	3420	3588	7008	7.211	7.554	7.554
R 3	27 – 4	2300	2980	5280	0.302	0.359	0.359
R 4	29 – 28	1311	1520	2832	0.079	0.083	0.083

Link ID	Between Nodes	V_{AB}	V_{BA}	V_{TOTAL}	T_{AB}	T_{BA}	T_{MAX}
R 5	30 – 29	1234	1838	3072	0.057	0.068	0.068
R 6	31 – 30	1420	1748	3168	0.072	0.080	0.080

Appendix L

User Equilibrium Assignment Model Results for Case 1

Appendix L

Table (L-1) User Equilibrium Assignment Model Results for Case 1.

Link ID	Between Nodes	V_{AB}	V_{BA}	V_{TOTAL}	T_{AB}	T_{BA}	T_{MAX}
L4	28 – 19	3000	1200	4200	1.093	0.620	1.093
L6	21 – 22	2100	2460	4560	2.945	3.36	3.36
L7	19 – 18	3000	1200	4210	1.033	0.578	1.033
L8	22 – 23	2860	1472	4332	0.341	0.186	0.341
L9	23 – 24	1764	1766	3530	0.188	0.188	0.188
L10	24 – 1	1200	1968	3168	0.528	0.665	0.665
L11	1 – 2	1600	1668	3268	1.857	1.895	1.895
L12	5 – 18	1500	1020	2520	0.127	0.100	0.127
L13	5 – 2	3852	2200	6052	2.883	1.726	2.883
L14	2 – 3	2200	2369	4569	1.606	1.709	1.709
L16	1 – 6	2069	1200	3269	1.573	1.168	1.573
L18	6 – 9	2300	2032	4333	1.062	0.957	1.062

Link ID	Between Nodes	V_{AB}	V_{BA}	V_{TOTAL}	T_{AB}	T_{BA}	T_{MAX}
L20	2 – 10	1868	1400	3268	3.301	2.953	3.301
L21	3 – 16	3500	1522	5022	7.614	3.978	7.614
L22	10 – 9	1890	1566	3456	2.136	1.926	2.136
L23	10 – 16	2697	1503	4200	1.472	0.977	1.472
L24	16 – 11	1608	1660	5394	1.518	1.540	1.540
L25	9 – 17	1170	1660	3268	0.749	0.871	0.871
L26	17 – 12	4372	2100	3270	6.659	2.922	6.659
L27	10 – 12	3030	2360	6732	4.165	3.391	4.165
L28	11 – 13	2100	3816	5916	5.153	8.748	8.748
L30	13 – 12	3030	3600	6780	0.914	3.338	3.271

الخـــلاصـــــــة

تعاني شبكة طرق مدينة الحلة من ازدحام مروري متكرر نتيجة زيادة الكثافة السكانية وزيادة ملكية السيارات مع سعة الطرق الثابتة ، وقد أجريت هذه الدراسة لتقييم حجم حركة المرور وتحسين شبكات طرق مدينة الحلة. لتنفيذ نموذج تخصيص حركة المرور ، يجب إنشاء قاعدة بيانات لطرق منطقة الدراسة ، وقد تم تنفيذ ذلك بواسطة برنامجArcMap GIS 10.7 ، وتم جمع غالبية بيانات شبكة الطرق من الميدان ، وتم توفير الباقي من قبل المديريات الحكومية المعنية وتتكون الشبكة الشريانية لمدينة الحلة من 31 وصلة و 26 عقدة. يتم تعيين أحجام المرور في منطقة الدراسة على شبكة الشرايين باستخدام نموذج تخصيص توازن المستخدم باستخدام برنامج مصمم خصيصًا لهذه الدراسة المبرمجة بواسطة لغة Visual Basic و Microsoft Excel Solver ، للعثور على الروابط التي تعاني من الازدحام ، وتقدير أوقات سفر الارتباط لـ تقييم الحالة العامة لمنطقة الدراسة في سنة الأساس (2020) ، والسنوات المستهدفة (2025 ، 2030 ، 2035). تم تنفيذ العديد من التحسينات في الاقتراحات في عدة مراحل زمنية مختلفة (طويلة المدى وقصيرة المدى) ، بما في ذلك (اقتراح شرايين جديدة وإضافة ممرات جديدة). لإظهار الفرق في مستوى الخدمة لشبكة شرايين الحلة ، تم عمل أربع حالات لعام الأساس (2020) والأعوام المقبلة (2025 ، 2030 ، 2035) ، التقييم العام لشبكة الحلة للشرايين (D-F)على التوالي بين تم اختيار وجهة عشوائية تمثل مراكز التعليم العالي للكليات لإيجاد أقصر المسارات في الدراسة ، وأوقات السفر ، V / C، LOS ، التقييمات الكلية لأقصر المسارات المخصصة LOS بين (C - E). حالتان للتحسينات المقترحة على المدى الطويل مع اعتماد طرق الشرايين الرئيسية والثانوية المقترحة ، التقييمات الشاملة للاقتراحات طويلة الأجل هي (C, B) على التوالي. حالتان للتحسينات المقترحة على المدى القصير ، في الحالة 1 ، إضافة ممرات جديدة بتقليل عرض الجزر الوسطى من (6 و 5 م) إلى (1 م). التقييم العام للحالة 1 هو(B). في الحالة الثانية ، قم بتعيين أحجام حركة المرور من مراكز جميع القطاعات لبعضها البعض للعثور على المسارات المثلى. التقييم العام للمسارات المثلى المخصصة قبل التحسين LOS بين (B-F) ، وبعد التحسين LOS بين (A - C) على التوالي.

جمهوريـــة العراق

وزارة التعليم العالي والبحث العلمي

جامعة بابل كلية الهندســة

قسم الهندسة المدنيـة

تحسين الاداء المروري لشبكه طرق مدينة الحلة

رسالة

مقدمة الى قسم الهندسه المدنيه في كليه الهندسه / جامعة بابل

كجزء من متطلبات نيل درجة الماجستير في الهندسة/ الهندسة المدنية/ المواصلات

من قبل

فاطـــمة كـــريم عبيـــس حسان

(بكالوريوس في الهندسه المدينه - 2018)

بأشراف

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