

Republic of Iraq
Ministry of Higher Education
and Scientific Research
University of Babylon
College of Engineering
Department of Civil Engineering



Evaluation and Improvement Roadway Freight vehicle Transportation in Hilla City

A Thesis

**Submitted to the Department of Civil Engineering / College of
Engineering / University of Babylon in Partial Fulfillment of the
Requirements for the Degree of Master of Science in Engineering /
Civil Engineering / Transportation**

By

Huda Abdulameer Abbas Mohammad

(B.Sc. in Civil Engineering, 2007)

Supervised by

Prof. Dr. Ali Abdul Ameer Alwash

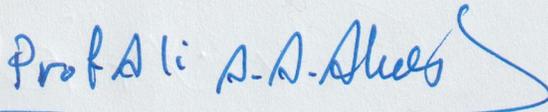
Assist. Prof. Mr. Hayder Abbas Obaid

(2022 A.D)

(1444 A.H)

CERTIFICATE

We certify that the preparation of this dissertation titled " **Evaluation and Improvement Roadway Freight vehicle Transportation in Hilla City**" is prepared by **Huda Abdulameer Abbas Mohammad Al- Tai** under our supervision at the Department of Civil Engineering in the University of Babylon in partial fulfillment of the requirements for the degree of Master of Science in Transportation.

Signature: 

Name: Prof. Ali Abdul Ameer Alwash, Ph.D.

Date: / / 2022

Signature: 

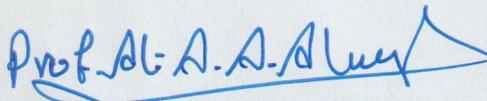
Name: Assist. Prof. Hayder Abbas Obaid, M.Sc.

Date: / / 2022

EXAMINING COMMITTEE CERTIFICATE

We certify as an Examining Committee that we have read this thesis entitled " **Evaluation and Improvement Roadway Freight vehicle Transportation in Hilla City** ", and examined the student (**Huda Abdulameer Abbas Mohammad**) in its content and what related to it, and found it meets the standard of thesis for the degree of Master of Science in Civil Engineering (Transportation).

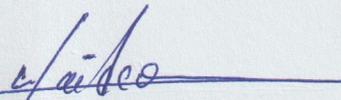
Signature:



Name: **Prof. Dr. Ali Abdul Ameer Alwash**
(Member and Supervisor)

Date: / / 2022

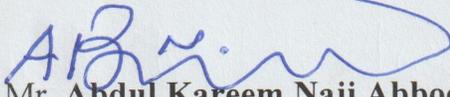
Signature:



Name: **Assist. Prof. Mr. Hayder Abbas Obaid**
(Member and Supervisor)

Date: / / 2022

Signature:



Name: **Prof. Mr. Abdul Kareem Naji Abbood**
(Member)

Date: / / 2022

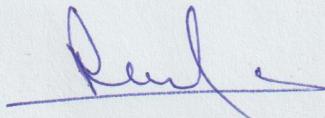
Signature:



Name: **Assist. Prof. Dr. Sahar S. Neham**
(Member)

Date: / / 2022

Signature:



Name: **Prof. Dr. Abdul Ridha Ibrahim Ahmed**
(Chairman)

Date: / / 2022

Approval of the Civil Engineering Department

Signature:

Name: **Prof. Dr. Thair Jabbar Mizhir**
(The Head of the Civil Engineering Department)

Date: / / 2022

Approval of the College of Engineering

Signature:

Name: **Prof. Dr. Hatam Hadi Obeid**
(The Dean of the College of Engineering)

Date: / / 2022

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

﴿قَالُوا سُبْحَانَكَ اللَّهُمَّ إِنَّا كُنَّا ظَالِمِينَ﴾

الْعَلِيِّ الْعَظِيمِ

صَلَّى اللَّهُ عَلَيْهِ وَسَلَّمَ

Acknowledgments

“In the Name of Allah, the Most Gracious, the Most Merciful”

At first, I thank **Allah** who gave me the willingness and strength to complete this research.

I would like to express sincere appreciation and deepest gratitude to my supervisor **Prof. Ali Abdul Ameer Alwash, Ph.D** and **Asst. Prof. Hayder Abbas Obaid, M.Sc.** for their advice, guidance, and encouragement throughout this work.

A special thanks and gratitude to **My Family** for their care, patience, and encouragement throughout the research period.



Huda Abdulameer Abbas Mohammad Al- Tai

16 / 11 / 2022

DEDICATION

To

My

Beloved

Country

(Iraq)

To

My

Dears

(Family)

Huda Abdulameer Abbas

Abstract

Transporting goods is very important to cities economy. At the same time, there are negative consequences resulting from freight truck flow in an urban area ,one of the most important is traffic congestion.

Hilla city suffers from traffic congestion in various locations of its road network, which has resulted in slowing speeds, increased delays, and a poor level of service. These problems are expected to increase in the future relatively with the rate of population growth and the rise in the traffic volume of passenger and freight vehicles.

This research aims to analysis and evaluates the freight road network and trucks flow in the study area represented by Hilla city using collected data and ArcGIS techniques, to identify the most important challenges facing freight truck movements and the problems that are reflected in the transportation network, find appropriate solutions those improve traffic flow in the city.

Freight data was collected based on the questionnaire from freight truck drivers, interviews with checkpoints employees at five city entrances, field surveys to calculate traffic volume at each entrance and main effective roads in Hilla city (12 sections of major arterial roads), in addition to the collected data from the relevant governmental institutions.

A fully accurate digital map has been created for Hilla freight road network. Analysis of freight truck movement has been performed using ArcGIS 10.4 network analysis techniques. The current network analysis results show that the largest traffic for trucks passes through the main arterial roads in Hilla city.

Three maps were prepared using Trans CAD 4.5 program to show the difference in the operating level for road freight network, depending on the results of (V/C ratio), the first map for the study year 2022, based on current network data. The second map is for the study year, with the proposed developments by the implementation of new roads connecting the city's entrances with the current

road network that lead to reduce the percentage of freight vehicles passing through it to 50%, while the third map is for the target year 2030, based on current network capacity taking into account the growth rate of vehicles in Hilla city and increase in traffic volume (2.5%).

The overall evaluation indicates that the level of service for the current network in the study year 2022 is (D), while the target year 2030 is (F). Adoption of the proposed network developments improves the level of service for the modified network in the study year to (C).

Network analysis for a modified network by ArcGIS software shows that the suggested roads will reduce the total (travel time and distance) for the same origin and destination points of freight trucks by 9%, and 30% compared with the current distance and time respectively.

Recommendations have been done to regulate freight flows, and minimize the negative consequences of goods transportation in Hilla. Once included the night delivery option for goods to their destinations located inside the city from (10 PM to 7 AM). As well as a proposal to construct a freight consolidation center in the northern and southern parts of the city to reduce the number of freight trucks inside the city, particularly during peak periods.

List of Content

| Item | Content | Page |
|-------------|--|-------------|
| | Acknowledgments | I |
| | Abstract | II |
| | List of Content | IV |
| | Notation | VII |
| | Abbreviation | VII |
| | List of Tables | VIII |
| | List of Figures | X |
| 1 | Chapter 1 Introduction | 1 |
| 1.1 | General | 1 |
| 1.2 | The problem with the research statement | 3 |
| 1.3 | Research objectives | 5 |
| 1.4 | Research structure | 6 |
| 2 | Chapter 2 Literature Review | 7 |
| 2.1 | Introduction | 7 |
| 2.2 | Urban freight transport | 9 |
| 2.3 | The significance of urban freight transport and its efficiency | 11 |
| 2.4 | Impact of trucks on traffic flow | 13 |
| 2.5 | Selection of the truck's routes | 15 |
| 2.6 | The impact of efficient usage of infrastructure on freight flow | 16 |
| 2.7 | Urban road network expansion | 18 |
| 2.8 | Freight consolidation center FCC | 21 |
| 2.9 | Using inner-city night delivery | 24 |
| 2.10 | Definition and applications of Arc GIS | 25 |
| 2.10.1 | Importance of using ArcGIS in freight and urban planning | 27 |
| 2.10.2 | The use of ArcGIS to analysis the characteristics of the road network. | 28 |
| 2.10.3 | Network analysis tools in Arc GIS | 31 |
| 2.11 | Summary | 32 |
| 3 | Chapter 3 Experimental Investigation | 33 |
| 3.1 | General | 34 |
| 3.2 | Study area | 35 |
| 3.3 | Freight traffic data in Hilla city. | 38 |
| 3.3.1 | Main entrances of Hilla city (origin of freight vehicles) | 38 |
| 3.3.2 | The main road network in Hilla city | 40 |
| 3.3.3 | Trucks classification | 41 |

| | | |
|----------|--|-----------|
| 3.3.4 | Freight data collection | 42 |
| 3.3.4.1 | Vehicle traffic count survey | 43 |
| 3.3.4.2 | Sample size calculation | 50 |
| 3.3.4.3 | Roadside interview survey (Questionnaire) | 51 |
| 3.3.4.4 | Analysis of the results of the questionnaire | 51 |
| 3.4 | Preparing data to analysis Hilla road network by (ArcGIS) program | 53 |
| 3.4.1 | ArcGIS implementation in analysis of road network | 53 |
| 3.4.2 | Study area network | 54 |
| 3.4.3 | Preparing the layers of the road network. | 55 |
| 3.4.4 | Preparing the database of attribute table for Hilla road network. | 57 |
| 3.4.5 | Database of nodes shapefile | 61 |
| 3.4.6 | Applying the network topology to the layers of the road network | 63 |
| 3.5 | Analysis of the Hilla road network using statistical methods and the ArcGIS program. | 64 |
| 3.5.1 | Connectivity | 64 |
| 3.5.2 | Coverage | 66 |
| 4 | Chapter 4 Analysis Results and Discussions | 67 |
| 4.1 | Arc GIS network analysis | 67 |
| 4.2 | ArcGIS stages for freight travel analysis | 67 |
| 4.3 | Best routes | 68 |
| 4.3.1 | (External – Internal) trip: | 68 |
| 4.3.1.1 | Best route from Nile entrance towards the destination points in the city center | 69 |
| 4.3.1.2 | Best route from AL- Athar entrance towards the destination points in the city center | 72 |
| 4.3.1.3 | Best route from Karbala entrance towards the destination points in the city center | 74 |
| 4.3.1.4 | Best route from Najaf entrance towards the destination points in the city center | 77 |
| 4.3.1.5 | Best route from Al-Diwaniyah entrance towards the destination points in the city center. | 78 |
| 4.3.2 | (External – External) trip: | 80 |
| 4.3.2.1 | Best route from Nile entrance to another exit of Hilla city | 80 |
| 4.3.2.2 | Best route from Athar entrance to another exit of Hilla city | 81 |
| 4.3.2.3 | Best Rout from Karbala entrance to another exit of Hilla city | 83 |
| 4.3.2.4 | Best route from Najaf entrance to another exit of Hilla city | 84 |
| 4.3.2.5 | Best route from Diwaniya entrance to another exit of Hilla city | 85 |
| 4.4 | Generating a cost matrix for (origin and destination) | 87 |
| 4.5 | Summary of network analysis | 88 |

| | | |
|----------|--|------------|
| 4.6 | Traffic volume and capacity for main effective roads in Hilla | 89 |
| 4.6.1 | Traffic volume | 89 |
| 4.6.2 | Road Capacity | 89 |
| 4.6.3 | Level of service | 91 |
| 4.6.4 | Evaluate the future level of service for the current road network at the target year 2030 | 94 |
| 4.7 | The suggestion of new roads as a solution for decreasing the freight traffics volume for (External – External) trip. | 96 |
| 4.7.1 | Characteristics of suggested roads | 96 |
| 4.7.2 | Effect of implementation suggested roads on the current Hilla road network | 97 |
| 4.7.3 | Effect of implementation of the suggested roads on drivers of freight vehicles | 98 |
| 4.7.4 | Effect of implementation suggested roads on freight network analysis | 98 |
| 4.7.5 | The best route analysis for (External – External) trip after adding suggested roads to the network | 99 |
| 4.7.6 | Summary of network analysis | 107 |
| 4.7.7 | Effect of implementation of the suggested roads on LOS. for the main road in Hilla city. | 108 |
| 4.8 | Suggested scenarios to reduce the impact of (External – Internal) trips on Hilla road network. | 112 |
| 4.8.1 | First scenario: Inner-city night delivery | 112 |
| 4.8.1.1 | Benefits of inner-city night delivery | 113 |
| 4.8.2 | Second scenario: Freight consolidation centers (FCC) | 114 |
| 4.8.2.1 | Objectives of freight consolidation centers | 115 |
| 4.8.2.2 | Operation of freight consolidation centers | 115 |
| 4.8.2.3 | Preferred Site Location of FCC in Hilla city | 116 |
| 4.8.2.4 | Analysis of available location for FCC | 118 |
| 5 | Chapter 5 Conclusions and Recommendations | 120 |
| 5.1 | General | 120 |
| 5.2 | Conclusions | 120 |
| 5.3 | Recommendations | 121 |
| 5.4 | Recommendations for future studies | 122 |
| | References | 123 |
| A | Appendix Roadside Interview Survey Questionnaire Form | A-1 |
| B | Appendix B Network Attributes for Hilla Freight Roads Network | B-1 |

Notations

| Symbol | Notation |
|----------------------------|-------------------------------|
| d | Error proportion |
| e | Number of links |
| L | Total Length of roads in (Km) |
| n | sample size |
| N | Confidence level |
| p | probability |
| Po | Population of city |
| v | Number of nodes |
| Z | Width of section. |
| β | Beta index |
| α | Alpha Index |
| γ | Gamma index |

Abbreviations

| | |
|-----------------|---------------------------------|
| A | Area. |
| C | Capacity. |
| Ex. | External trip. |
| FCC | Freight Consolidation Centers. |
| FHWA | Federal Highway Administration. |
| GIS | Geographic Information Systems. |
| GVWR | Gross Vehicle Weight Rating. |
| hr. | Hour. |
| Km | kilometer. |
| ln | Lane. |
| LOS | Level of service. |
| min | Minute. |
| No. | Number. |
| O-D | Origin – Destination. |
| PCU | Personal Car Unit. |
| s | Second. |
| UTM | Universal Transverse Mercator. |
| Veh | Vehicle. |
| VIUS | Vehicle Inventory Use Service. |
| vph | Vehicle pre-Hour. |
| WGS 1984 | World Geodetic System 1984. |

List of Tables

| Table | Title | Page |
|------------|--|------|
| Table 2.1 | Classification of important urban freight initiatives (Nguyen H. and Jose T., 2010) | 13 |
| Table 2.2 | Reaching and loading cargo vehicles in urban areas approaches (Garth T. et al., 2007) | 18 |
| Table 3.1 | Coordinates of Hilla city entrances. | 39 |
| Table 3.2 | Traffic vol. of freight vehicles in the morning period | 44 |
| Table 3.3 | Traffic Volume of freight vehicles in the evening period | 47 |
| Table 3.4 | Calculated sample size for freight vehicles at peak hour | 51 |
| Table 3.5 | Analyze the results of the Questionnaire | 52 |
| Table 3.6 | Part of nodes and intersections attributes | 61 |
| Table 3.7 | Connectivity result for Hilla road network | 65 |
| Table 4.1 | Route properties of Nile Entrance. | 74 |
| Table 4.2 | Route properties of Athar entrance. | 73 |
| Table 4.3 | Route properties of Karbala entrance. | 75 |
| Table 4.4 | Route properties of Najaf entrance. | 77 |
| Table 4.5 | Route properties of Diwaniyah entrance. | 79 |
| Table 4.6 | Properties of Nile entrance- Ex. destination points routes | 81 |
| Table 4.7 | Properties of Athar entrance- Ex. destination points routes | 82 |
| Table 4.8 | Properties of Karbala entrance- Ex. destination points routes | 84 |
| Table 4.9 | Properties of Najaf entrance- Ex. destination points routes | 84 |
| Table 4.10 | Properties of Diwaniyah entrance- Ex. destination points routes | 86 |
| Table 4.11 | Lines attribute table of the O-D matrix | 88 |
| Table 4.12 | The Reduction Due to Parking and Encroachment | 90 |
| Table 4.13 | Reduction in capacity due to land use | 90 |
| Table 4.14 | HCM Criteria for roadway links Based on Volume-to-Capacity Ratios | 91 |
| Table 4.15 | The accounts of traffic volume, capacity, and level of service for main road in Hilla city | 92 |
| Table 4.16 | Characteristics of suggested roads | 97 |
| Table 4.17 | Properties of Nile entrance- Ex. destination points routes for modified network | 100 |
| Table 4.18 | properties of Athar entrance -Ex. destination point route for modified network | 102 |
| Table 4.19 | Properties of Najaf entrance- Ex. destination points routes for modified network | 104 |

| | | |
|------------|---|------|
| Table 4.20 | Properties of Karbala entrance- Ex. destination points routes for modified network | 105 |
| Table 4.21 | Properties of Diwaniyah entrance- Ex. destination points routes for modified network | 107 |
| Table 4.22 | The accounts of traffic volume, capacity, and level of service for main road in Hilla city after adding suggested roads | 109 |
| Table 4.23 | The coordinates of the Site Location of FCC in Hilla city (Southside location) | 117 |
| Table 4.24 | The coordinates of the Site Location of FCC in Hilla city (Northside location) | 117 |
| Table B.1 | The attribute table for current Hilla freight roads network | B-2 |
| Table B.2 | Attribute information for the suggested roads | B-14 |

List of Figures

| Figure | Title | Page |
|-------------|--|------|
| Plate 1.1 | Congestion due to heavy Tracks presence. | 4 |
| Plate 2.1 | Air pollution by heavy tracks gases. | 8 |
| Plate 2.2 | Weight and time restriction signs for trucks. | 11 |
| Plate 2.3 | Overloaded trucks. | 16 |
| Figure 2.4 | Line density of road network in Nanjing city. (a) Line density of road network in 2012, (b) Line density of road network in 2016, (Liang D. et al., 2019). | 21 |
| Plate 2.5 | Freight consolidation center FCC. | 22 |
| Figure 2.6 | The concept of layers GIS ESRI layers image (Sutton T. et al., 2019). | 26 |
| Figure 3.1 | Diagram methodology. | 34 |
| Figure 3.2 | Geographic location of Hilla city (According to Hilla Municipality Directorate). | 36 |
| Figure 3.3 | Hilla master plan (According to Municipality Directorate of Hilla). | 37 |
| Figure 3.4 | Hilla main entrances. | 37 |
| Figure 3.5 | Main entrances of Hilla city by ArcGIS 10.4 software | 40 |
| Figure 3.6 | Truck classification according to the Vehicle Inventory Use Service (VIUS) and (FHWA). | 42 |
| Figure 3.7 | Comparison of traffic volume of entrances by days in the morning period. | 45 |
| Figure 3.8 | Percentage of traffic volume at each entrance from total volume for freight vehicles in the morning period. | 45 |
| Figure 3.9 | Comparison of total traffic volume of entrances by days in the morning period. | 46 |
| Figure 3.10 | Comparison of traffic volume of entrances by days in the evening Period. | 48 |
| Figure 3.11 | Percentage of traffic volume at each entrance from total volume for freight vehicles in the evening period. | 48 |
| Figure 3.12 | Comparison of total traffic volume of entrances by days in the evening period. | 49 |
| Figure 3.13 | Modeling for finding the fastest route to evaluate the network in many factors by using GIS | 54 |
| Plate 3.14 | Hilla satellite image | 55 |
| Plate 3.15 | Building the main layers (Feature data set) of freight road network using Arc catalog program | 56 |
| Plate 3.16 | Building the sub-layers (Feature Class) of freight road network using ArcGIS 10.4 Program | 57 |

| | | |
|-------------|--|----|
| Figure 3.17 | Line layer (Feature Class) of freight road network using Arc catalog program | 59 |
| Figure 3.18 | Details A and B in Figure 3.17 | 60 |
| Figure 3.19 | Part of the data set of links attributes | 60 |
| Figure 3.20 | Layer of nodes of Hilla city fright road network | 62 |
| Figure 3.21 | Topology error window in ARC GIS program. | 63 |
| Figure 4.1 | Network analysis process | 68 |
| Figure 4.2 | Best route from Nile entrance to suggested destination points. | 70 |
| Figure 4.3 | Direction of Nile entrance toward 80 street best route. | 71 |
| Figure 4.4 | Best route from Athar entrance to suggested destination points. | 72 |
| Figure 4.5 | Direction of Athar entrance toward 80 street best route. | 73 |
| Figure 4.6 | Best route from Karbala entrance to suggested destination points. | 74 |
| Figure 4.7 | Direction of Karbala entrance toward Babel food store's best route. | 75 |
| Figure 4.8 | Best route from Najaf entrance to suggested destination points. | 76 |
| Figure 4.9 | Direction of Najaf entrance toward Jebal best route. | 77 |
| Figure 4.10 | Best route from Al Diwaniyah entrance to suggested destination points. | 78 |
| Figure 4.11 | Direction of Diwaniyah entrance towards Wardiyah food store. | 79 |
| Figure 4.12 | Best route from Nile entrance to exterior destination points. | 81 |
| Figure 4.13 | Best route from Athar entrance to exterior destination points. | 82 |
| Figure 4.14 | Best route from Karbala entrance to exterior destination points. | 83 |
| Figure 4.15 | Best route from Najaf entrance to exterior destination points. | 85 |
| Figure 4.16 | Best route from Diwaniyah entrance to exterior destination points. | 86 |
| Figure 4.17 | The resulting routes for least-cost paths along with the network from multiple origins to multiple destinations (O-D matrix) | 87 |
| Figure 4.18 | The level of service for main roads in city based on current network in study year by Trans CAD 4.5 program | 93 |

| | | |
|-------------|---|-----|
| Figure 4.19 | The main roads level of service in Hilla based on current network in target year 2030 using Trans CAD 4.5. | 95 |
| Figure 4.20 | Hilla city modified freight road network. | 99 |
| Figure 4.21 | Best route from Nile entrance to exterior destination points for the modified road network. | 101 |
| Figure 4.22 | Best route from Athar entrance to exterior destination points for the modified road network. | 102 |
| Figure 4.23 | Best route from Najaf entrance to exterior destination points for the modified road network. | 103 |
| Figure 4.24 | Best route from Karbala entrance to exterior destination points for the modified road network. | 105 |
| Figure 4.25 | Best route from Diwaniyah entrance to exterior destination points for the modified road network. | 108 |
| Figure 4.26 | The level of service for main roads in city based on modified network in study year using Trans CAD 4.5 program | 110 |
| Figure 4.27 | V/C Comparison between study year 2022 (current and modified network) and target year 2030 | 111 |
| Figure 4.28 | Concept of freight consolidation centers (FCC) | 114 |
| Figure 4.29 | Consolidation Center Basic Operations | 116 |
| Figure 4.30 | Northern and southern consolidation center locations | 117 |
| Figure A.1 | Interview survey questionnaire form. | A-1 |

Chapter 1

Introduction

1.1 General

Freight transport is one of the most important and lively aspects of the transport sector, and it's being the main supportive element for the trade sector. But, the lack of efficiency in transporting goods in addition to the complexities and increased costs associated with transporting and delivering goods cause a major challenge to improve this important sector.

Trillions of dollars of goods are consumed annually worldwide and the largest proportion of them are transported via road networks. Therefore, the process of freight transport in urban areas is now at a crossroads due to the negative effects that freight transportation causes on urban life such as traffic congestion, greenhouse gas emissions, air pollution, noise pollution, traffic accidents, and associated safety concerns, and reduced green spaces as a result of urbanization.

In recent years, researchers have paid a lot of attention to studies on traffic on road networks and its influence on cities throughout the world, but the greatest interest has been focused on public transport and private car movement, while relatively little consideration has been paid to road freight transport. However, urban freight transport is important for many reasons, the most important ones are **(Browne M. et al.,2011)**:

- It is critical to the continuation of our current way of life.
- Its impact on supporting and retaining industrial and commerce activity.
- The contribution of an efficient freight sector makes to the competitiveness of industry in the region is concerned.
- The impact of freight transportation and logistical expenses on the price of goods available for consumption in that market.

- The entire cost of freight transportation and logistics is huge, and it has a direct impact on the economy's efficiency.
- The influence of urban goods transportation on the environment (in terms of energy use and environmental consequences such as pollution, noise, and so forth.)

Road network is an important part of modern supply networks. It connects production, distribution, and consumption due to the flexibility and capability to deliver door-to-door services as well as its ability to connect all supply network operators at the local, national, regional, and global levels. Road transportation is the primary mode of transportation in many areas of the world, and it is especially important in developing and impoverished countries that lack alternative internal modes of transit such as railways or water transportation. In this situation, road transport is frequently the main available mode of access for land-locked developing nations to regional and global markets (**Boylaud O. et al.,2001**).

The road network and infrastructure of Hilla city in general were designed in the nineties in proportion to the population growth, commercial and economic situation, and the number of vehicles at that time.

Although the master plan of Hilla city was updated in 2009 to expand and develop all the infrastructure and transportation networks in the city, this design did not improve the reality of the city for several reasons, including the non-implementation of most proposed plans to expand the city as well as the significant increase in population growth and not absorbing this increase in the prepared design, as the study which prepared in 2006 to modernize of Hilla city master plan estimated the population growth in the city (542630) people for the year 2030 (**Hilla Municipality Directorate, 2022**), while the population census amounted(645016) people in 2022 (**Babylon Statistics Directorate,2022**).

This large and unexpected increase in population growth has been positively reflected in the growth of private vehicle ownership and the increase

in demand for transporting products and cargo, particularly after 2003 due to the commercial and economic boom and the rise in per capita income. At the same time, the impact was negative on the transportation network, since large amounts of products and commodities are moved annually via the city's road network, resulting in a high rate of accidents and traffic congestion in multiple locations.

As a result, this research will highlight the freight transportation network in Hilla city to analyze the movement of freight vehicles across the road network, places of loading and unloading, and the most important destinations for freight vehicles in the city, as well as the impact of transporting goods on traffic congestion and the level of service for the main roads in Hilla city to identify the problems and discover appropriate solutions to increase road users' comfort by using the ArcGIS10.4 and Trans CAD 4.5 software.

The ArcGIS 10.4 and Trans CAD 4.5 software are considered the most important and most widely used programs in transportation projects due to their ability to enter, store, edit and analyze a huge amount of information based on the data collected from field surveys which included a survey of calculating the traffic volume of vehicles at city entrances as well as main effective roads, in addition to a questionnaire with drivers of freight vehicles to collect information about the vehicle and the trips at the city's entrances, as will be explained later.

1.2 The problem with the Research Statement

Hilla is one of the most densely populated cities in Iraq, located in an important geographical location in the central region of the country, linking Baghdad and the southern provinces. The increase in economic activity and population with the rapid transformation of land use has led to an irregular increase in trips, causing traffic congestion in various locations of the city's road network as it is the main means of transporting passengers and freight in the city.



Plate 1.1 Congestion due heavy tracks presence.

Thus, the most essential freight shipping problems in Hilla city can be stated as follows:

- Neglecting the periodic maintenance of the road network has led to a decrease in road capacity disproportionately with the large traffic volume of freight trucks and passenger vehicles, and thus led to a decrease in the level of network service.
- Freight transportation lacks many of the factors necessary for the success of this mode of transportation, such as climbing lanes and time limits for their entry into cities, which advances their movement.
- The general lack of data, as well as the lack of a comprehensive strategy for planning and managing transportation difficulties, especially freight transporting.
- Unavailable of river and air transport with the great neglect of railways in Hilla city, which constitutes an excessive load on the city's road network and causes its inefficiency.

- The road network in Hilla city is under additional load due to (external - external) trips, especially freight trips by trucks due to its important location in central Iraq, which makes it an important transit route.

1.3 Research objectives

This research aims to analysis and evaluate the land system for roadway freight transportation, represented by the main road network in Hilla city, to identify the most significant challenges facing shipping goods in the city and find appropriate solutions. Therefore, the main objectives of this research can be summarized as follows:

- Preparing a database for the movement of trucks entering and exiting the city based on-field surveys which include: Counting the volume of traffic surveys and roadside interview surveys (Questionnaire).
- Preparing geodatabase of the road freight network in Hilla city using Arc GIS 10.4 software.
- Analyzing the characteristic of the Hilla road network by using the Arc GIS10.4 software.
- Perform network analysis and select the best routes for freight trips in Hilla city for both current and modified networks using the network analysis tool of ArcGIS 10.4 software
- Calculate the level of service for main roads in Hilla city for the current road network then it's recalculated after modifying them by adding new suggested roads to the network and representing all results using Trans CAD 4.5 software.
- Suggesting solutions to address the challenges facing the freight transport process in Hilla city for both **(External – Internal)** trips and **(External – External)** trips.

1.4 Research structure

The presented research is divided into five chapters as follows:

Chapter One provides an introduction that includes a brief idea of the research, a definition of the problem, the purpose of this research, and the research's structure.

Chapter two includes a review of the available literature for past studies and investigations linked to the subject of the research.

Chapter Three describes the methodology and data collection as well as the composition of the city's traffic.

Chapter four presents the results of the freight transportation network analysis in Hilla City, as well as their discussion and a detailed explanation of the proposed solutions.

Chapter five: This chapter contains the conclusions of the research, recommendations, and recommendations for future studies.

Chapter 2

Literatures Review

2.1 Introduction

This chapter is a review of the process of analyzing freight transportation by highlighting previous research and studies that were conducted on this subject from different countries and regions around the world, with the goal of identifying the most important problems and proposing appropriate solutions.

Increased demand for goods in cities as a result of population growth, as well as economic growth (such as economic growth via internet shopping), are all factors that increase the load on transportation networks. Generally, Iraq cities and in Hilla city (study area) especially, there is an increase in the volume of traffic with a deficiency in the development of the transportation network, and the carrying capacity of the city's roads is not proportionate with the large traffic volume of vehicles (Freight vehicles and passengers' cars), which led to increasing the problems of the transportation system in the study area. As a result, more attention to the transportation sector and the expansion of road networks based on accurate studies are required to accommodate this increase.

Despite the vital role of freight transportation in urban areas by preserving them and developing their economies. Freight transportation within urban areas is also known for its unsustainable effects, as it is responsible for many environmental, economic, and social impacts that may have a significant impact on the ability to live in urban areas, as described below (**Banister D.,2000**):

➤ **Environmental Impacts.**

- The transportation of goods contributes to climate pollution by producing air polluting gases such as carbon dioxide, carbon monoxide,

and nitrogen oxides, as well as volatile organic compounds and others, especially for the heavy trucks that miss the scheduled maintenance, as shown in Plate 2.1.

- Waste items such as tires, oil, and other things.



Plate 2.1 Air pollution by heavy tracks gases.

➤ **Social Impacts.**

- The physical effects of pollutant emissions on the overall health of the community, such as disease risk.
- Traffic accidents cause injuries and deaths.
- Increase in loudness, visual intrusion, and vibration.
- A decrease in the quality of life is a result of reduced green spaces and open areas due to the expansion of infrastructure and transport networks in urban areas.

➤ **Economic Impacts**

- Inefficiency and waste of resources.
- Congestion and a reduction in city accessibility.

There are many sponsors in the urban freight transport system: receivers, retailers, manufacturers, distributors, and shippers. To achieve high urban freight performance, cities must have reliable forecasting and analysis tools that can be provided an overview of all aspects of transportation operations **(Holguín V. et al., 2014)**.

In the common method of analysis, the basic steps are to identify the goods that are being transported and delivered, where they originate, and the type of transport services and vehicles that are most frequently used for them. This helps in estimating and modeling freight demand and then simulating and forecasting results **(Kazubowski D. et al., 2018)**.

2.2 Urban freight transport

Cities are densely populated areas in addition to being centers of production and consumption. Most transportation of goods and people begin and ends in cities, often passing through many cities on longer journeys. The movement of large quantities of goods through transportation networks that connect large land uses such as industrial and manufacturing facilities, warehouses, and commercial areas, in turn, supports and interacts with urban activities. Typically, these flows are organized at major crossing points in cities such as distribution centers and truck depots as well as railways, ports, and airports **(Rodrigue J. et al.,2020)**.

Freight movements are complex. There is an increase in freight traffic in many countries, which may have a substantial, direct, and broader influence on urban life. Increasing volumes reflect a rise in the magnitude and complexity of freight's influence on cities **(Van Duin J. et al., 2007)**.

Although Urban Freight Transport (UFT) is critical to the economic development of cities as well as to ensure the quality of life of the residents, at the same time it is a challenge for these areas, due to several reasons, the most important of which is the lack of proper planning for the movement of freight

flows. The basic strategy is the development of local development plans related to the development of roads and infrastructure to face the challenges that coincide with the movement of freight vehicles within urban areas (**Watkiss P. et al., 2003**).

(**Akgün E. et al., 2019**) outline the most important issues and problems facing urban freight delivery that must be taken into consideration to improve urban freight operations: security, street lighting, signage, lack of unloading and loading space, noise, and vehicle delivery restrictions at night. Therefore, analyzing urban freight logistics problems is a complex matter that requires a capital of data and information, the development of models, and assessment plans.

Regarding to the regulation of access and the operations of unloading and loading goods, studies have shown that the most common restrictions those approved by public authorities and proven to have a positive impact on regulating the movement of freight vehicles within urban areas are based on limiting the arrival of goods vehicles to specific streets within the city during certain periods of the day, as well as determining the type of vehicles allowed to enter either a particular road or a particular area. These types of restrictions are depended on several factors like including transportation infrastructure, customers behavior, weight and size of vehicles. (**Allen j. et al., 2007**).

Plate 2.2 show some type of these restrection.



Plate 2.2 Weight and time restriction signs for trucks.

2.3 The significance of urban freight transport and its efficiency

Effective freight transportation is essential to a successful and efficient system of urban transportation networks, which are essential to serving the requirements of both businesses and city residents. Thus, providing efficient freight transportation is a key aspect of urban development, which is critical to maintaining cities' economy and live ability, (Anderson et al., 2005).

As urban traffic congestion worsens, the ability to reach efficient operations in freight forwarding in metropolitan area is questionable. Despite the successes achieved by the industry in terms of improving vehicle productivity, traffic congestion imposes significant restrictions that impede additional improvements (Browne M. et al., 2011).

(Marcotullio P.J., 2009) Summarize the problems and obstacles facing workers in the freight forwarding sector within urban areas, which impede transportation and delivery operations and reduce the efficiency of urban freight as shown below:

- Issues with traffic flow and congestion caused by high traffic volumes, accidents, the inadequate infrastructure of roads, narrow street geometries, and bad driving behavior.
- Transportation challenges include the neglect of freight transportation requirements in city and traffic layout, as well as other key issues such as limited or no access to vehicles based on time and/or vehicle type, and truck routes.
- Problems with parking of the vehicles, unloading, and loading of products, insufficient area for unloading goods, heavy fines, and commodities handling.
- Customer and receiver-related complaints include long lines for deliveries and collections, trouble recognizing the receiver, collection and delivery timeframes desired by customers and receivers.

The negative impacts of transporting freight in urban areas are relatively well known and there are great efforts to estimate the additional expenses caused by these effects. The most important issues related to the procedures and policies that must be taken to reduce these impacts to achieve a better efficient and sustainable outcome for the freight forwarding sector in terms of environmental, social, and economic. **(Allen j.et al., 2010).**

(Nguyen, H.O. and Tongzon, J., 2010) Clarified that the investment in transportation infrastructure, as well as innovation in information and communication technology and cargo handling, can help to reduce costs and enhance freight transport efficiency. Within the field of urban freight transport, many initiatives are based on modern and innovative policies in planning and management aimed at reducing the negative effects of urban freight and improving freight efficiency, thus enhancing sustainability in urban areas.

Table 2.1 shows an explanation of the main freight initiatives.

Table 2.1: Classification of important urban freight initiatives (Nguyen, H.O. and Tongzon, J., 2010)

| Category of initiatives and objective | Example |
|--|--|
| Operations | |
| <ul style="list-style-type: none"> • To improve operational efficiency including speed and reliability of deliveries, reduction of costs, convenience and customer service, and operational safety. | <ul style="list-style-type: none"> • Off-peak/night deliveries. • Information and technology tool (real-time traffic information, routing and scheduling, vehicle tracking systems). • consolidation of deliveries. |
| Land use and infrastructure | |
| <ul style="list-style-type: none"> • To reduce demand for freight transport by reorganizing land use patterns in Urban area. | <ul style="list-style-type: none"> • Relocating logistics and industrial activities. • Off-street unloading facilities. • Underground logistics system. |
| Environment | |
| <ul style="list-style-type: none"> • To reduce or minimize the environmental impacts of urban freight transport. | <ul style="list-style-type: none"> • Urban consolidation center. • Use of environmentally-friendly/clean vehicle (electric vehicles, freight trams, cargo bikes). • Low emission zones. |
| Regulations | |
| <ul style="list-style-type: none"> • To influence urban transport behavior and patterns through the implementation of traffic and transport policies. | <ul style="list-style-type: none"> • Access restriction (vehicle weigh size/dimension/time/load factors). • Dedicated facilities for freight traffic. • Road pricing. |
| Technology | |
| <ul style="list-style-type: none"> • To Improve operational performance through equipment and facilities. | <ul style="list-style-type: none"> • Access controls systems. • Information technology for reduced noise operations. |

2.4 Impact of trucks on traffic flow

The majority of commodities consumed today are produced hundreds of kilometers elsewhere. As a result, the demand for freight transportation is increasing dramatically, harming traffic congestion and air pollution levels (Chankaew N. et al., 2018).

Although trucks play an important role in road freight network, they are also a significant contributor to traffic accidents and congestion. Trucks have a considerable impact on roadway capacity and overall efficiency, among other

things, due to their physical (e.g., size) and operational (e.g., acceleration and deceleration) characteristics (**Sarvi M.,2013**).

Trucks can obstruct the progress of fast vehicles due to their slow acceleration and top speed. Furthermore, heavy trucks have been demonstrated to cause blurring of vision to the vehicles behind them, leading to a change in their driving behavior. As a result, studying the impact of trucks is critical for improving traffic operations (**Kong D. and Xiucheng G., 2016**).

(Johannes S.et al., 2000) discuss the influence of trucks on traffic flow which have a lower maximum velocity than ordinary cars. The study discovered that even for the case of 10% trucks in the system, the mean velocity of all vehicles is significantly larger than the maximum velocity of the trucks within this time range. But the influence of trucks is negligible in case of high density of vehicles within current section of road where jams dominate the system.

Ezquerro S. et al., (2018) studied a model used in Santander, Spain, to improve the administration and planning of freight vehicles traveling from outside the city to a specific location in the city center. The model optimizes large freight vehicle planning and management within city centers (lorries used to load and unload large amounts of commodities) by evaluating several feasible routes, which are specified by the space constraints and turning radii appropriate for this type of vehicle. The model's strength is built on bilevel mathematical programming, which allows variables that represent characteristics of the city network to be nested within the issue of cost minimization, allowing for a more accurate reflection of the practical situation. According to the study, better management and planning of large vehicle traffic reduce its social, economic, and environmental impact on cities. It is necessary to select both the types of vehicles and the routes to be used to minimize the costs connected with the movement of these vehicles and their impact on urban traffic.

2.5 Selection of the truck's routes

The selection of certain routes for usage by trucks is a very important strategy. The following are some of the major things to consider while choosing good truck routes (**Satoh I., 2011**):

- Routes should include all significant roads in the region as well as connections between them.
- The roads should connect to key freight sources.
- Traffic lanes should be within the limits of the standard specifications.
- The routes must be selected with adjacent land uses in consideration; residential and commercial land uses, as well as sites with high pedestrian activity, should be avoided to the greatest extent possible.
- Roads used as a part of the network must have good road geometrics with few sharp turns
- All roads on the network should have adequate traffic control.
- All planning authorities with responsibilities for roads in the urban area and the freight transport industry should be involved in the selection of proposed routes.
- Adequate and clear road signs, as well as map distribution, are important to the route's successful implementation.

The routes of the Truck may be limited to certain vehicle types, the following are the most common (**Frank W.C. et al., 2000**):

- **Over dimensional truck routes:** These include designating special routes for vehicles that exceed specific legal mass, height, or size limits as shown in plate 2.3. Routes should be chosen with overhead clearance, appropriate turn radii at junctions, and minimal effect from other traffic, The routes should have strong structure to accommodate heavy vehicles and should be clearly signed.



Plate 2.3 Overloaded trucks.

➤ **Hazardous load routes:** These include designating specific routes for trucks transporting hazardous materials. A risk assessment approach should be used to designate truck routes and upgrade plans for the management of transporting hazardous commodities. The following characteristics should be present on roads used to carry hazardous products in urban areas:

- The roads should be as straight as possible.
- Routes should avoid densely populated areas such as shopping malls, schools, and hospitals.
- It is best to avoid rail level crossings.
- The route chosen must consider the potential levels of risk exposure.

2.6 The impact of efficient usage of infrastructure on freight flow

Transport development and logistics performance enhancement are critical challenges for countries seeking to increase their competitiveness in the global economic market. The good infrastructure supports trade flows and so

increases the chances of international commercial success while providing effective local solutions that improve access to excluded regions and allow them to participate in the national economy (**El Khayat M.,2014**).

Because it is sometimes difficult to extend existing roads in urban areas, the management and appropriate planning for infrastructure usage in terms of time and space are critical for urban planners. Some towns, for example, provide designated loading spaces or bays for commercial traffic to enhance working conditions for transport operators while also lessening the negative consequences of unloading and loading products. Both urban planners and transportation operators must provide efficient and dependable delivery to sustain the urban economy. The following are the essential issues that need to be taken into account in order to establish a sustainable and successful approach for efficient usage of infrastructure (**Russo F. and Antonio C., 2011**):

- The delivery vehicles should have few social and environmental side effects as feasible.
- For effective freight transportation, planners (from urban, city, municipal or local transport authorities) must collaborate with freight transportation companies.
- To minimize traffic congestion and environmental impact, transportation businesses must improve operating efficiency

Garth T. et al., (2007) demonstrate several approaches to achieving goods vehicle access and loading objectives in urban areas, as shown in Table 2.2.

Table 2.2 Reaching and loading cargo vehicles in urban areas approaches (Garth T. et al., 2007)

| Item | Objectives | Approaches available |
|------|---|--|
| 1 | Obtaining support from the freight industry for freight plans and initiatives | <ul style="list-style-type: none"> ▶ Freight transport partnerships |
| 2 | Improving journey time reliability of goods vehicles | <ul style="list-style-type: none"> ▶ Telematics for urban goods transport ▶ Signing ▶ Urban freight information and maps ▶ Allowing night deliveries ▶ Lorry lanes or no car lanes |
| 3 | Helping goods truck drivers on their journeys and decreasing goods vehicle trips and kilometers | <ul style="list-style-type: none"> ▶ Telematics for urban goods transport ▶ Signing ▶ Lorry routes ▶ Simplification & coordination of vehicle weight, size, and construction regulations ▶ Urban freight information and maps ▶ Urban consolidation centers |
| 4 | Supporting freight transport companies at the point of delivering and collection | <ul style="list-style-type: none"> ▶ Providing on-street loading bays. ▶ Nearby Delivery Area ▶ Urban consolidation centers |
| 5 | Reducing environmental impacts and the risk of accidents involving goods vehicles | <ul style="list-style-type: none"> ▶ Vehicle weight, size, and emissions standards regulations ▶ Time regulations for goods vehicle access and loading ▶ Allowing night deliveries ▶ Environmental zones ▶ Lorry lanes ▶ Infrastructure improvements ▶ Encourage the use of environmentally-friendly vehicles |

2.7 Urban road network expansion

Road networks are an essential factor in the economic growth of countries. Road networks have a major role in the process of freight transporting and distributing products and services around the world, in addition to their effective role in facilitating the movement of people between different

destinations such as workplaces, hospitals, schools, and others. Road network infrastructure is important in improving the efficiency and success of countries and raising the standard of living for people ,as countries that have a network of roads with a developed infrastructure are more expected to benefit from trade at the local and international levels.

Therefore, it is always necessary to develop plans and projects aimed at developing and maintaining road networks to ensure the quality of connectivity between different regions and cities **(Zhao G. et al., 2017)**.

In many countries, road networks in urban areas are usually severely congested, which causes long travel times and frequent stops during movement, and consequently inconvenience to passengers and vehicle drivers with the high noise level, air pollution, and traffic accidents **(Teodorovic D. and Janic M., 2016)**.

The road network is the backbone of urban planning, a major factor driving the development of the region, and one of the most important indicators of urban growth. The process of managing developing cities is a critical and complex issue because urbanization improves people's lives but at the same time poses numerous risks, the most dangerous of which is land scarcity as a result of urban expansion and population growth, pollution and others. As a result, studies of urban growth management, as well as studies related to transportation networks, particularly freight transport through the road network, have become very important to maintain the sustainability of cities **(Deng J.et al., 2009)**.

More researchers have recently become interested in road network expansion as an essential aspect of urban expansion, and also the secondary consequences on the environmental side and land use. In general, road network studies have a long history with many views, and the results of the study are usually temporal and regional **(Coffin A., 2007)**.

(**Strano E.et al., 2012**) investigated the growth pattern of the road network in the Groane area of Milan's metropolitan zone from 1833 to 2017 and observed that the road network grew under a pre-existing metropolitan layout with a high degree of centrality.

(**Rui Y. and Yifang B., 2014**) examined the correlation between both density of the road network and land usage and discovered that the two variables were strongly associated.

(**Dhanani A., 2016**) studied the development of the road network in two suburban areas of London, Surbiton and South Norwood London during the period from 1880 to 2013 using a complex network model and several methods to find out the patterns of network growth in addition to urban expansion and investigate the statistical relationships between road networks and urbanization. The study discovered that the road networks in Surbiton and South Norwood developed significantly during the period studied, resulting in the current dense and highly connected road network as it exists today. However, Surbiton has a lower road network density than South Norwood throughout all periods, with densities of 10.9km/km² and 13.6km/km², respectively. As the study showed the relationship between built area and network length over time is not linear, and as urbanization progresses, building structures develop at a faster pace than the network.

(**Liang D. et al., 2019**) studied the distribution of the roads and expansion patterns of the road network in Nanjing for the years 2012 and 2016. based on the line density estimation model. The study discovered that the road network is not regularly distributed throughout the city, as the highest density of the road network is concentrated in the city center and then decreases to the edges. There is also a clear concentration to the south of the Yangtze River with the spread of some areas along the river and then gradually dispersed towards the edges. From 2012 to 2016, the new expansion mainly happened in the suburban area

near the downtown region due to the new district construction planning, as shown in Figure 2.4.

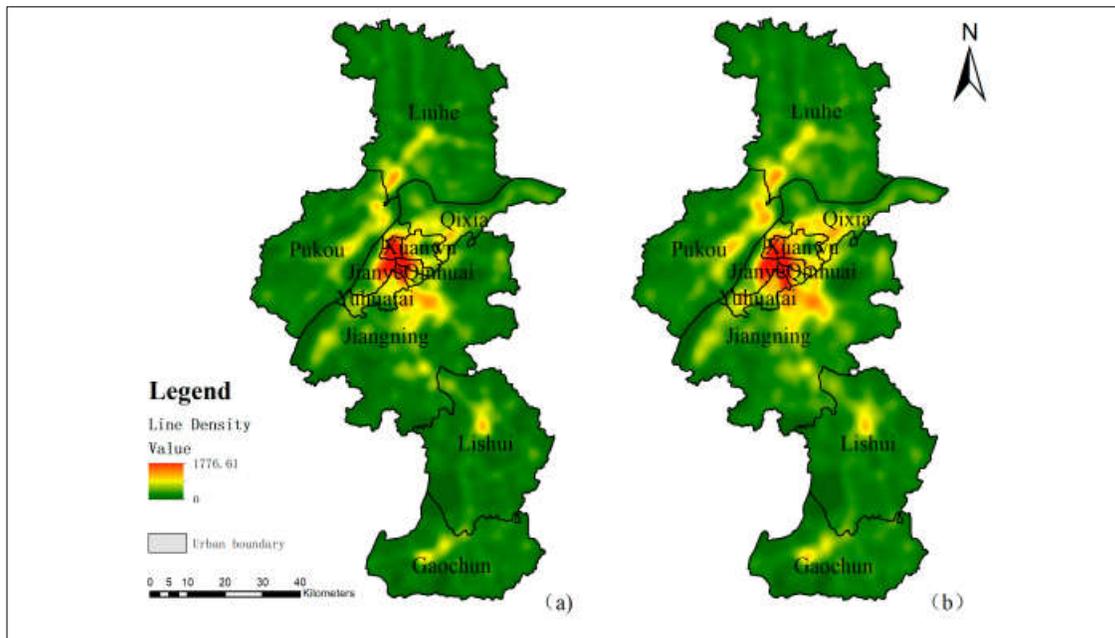


Figure 2.4 Line density of road network in Nanjing city. (a) Line density of road network in 2012, (b) Line density of road network in 2016, (Liang D. et al., 2019).

2.8 Freight consolidation center FCC

Freight consolidation is a logistics strategy where a shipper combines multiple shipments within a particular geographic region into a single shipping container that is then line hauled to a destination point where the smaller shipments that were part of the consolidation are broken down and shipped to their final destination or the single shipment is delivered directly through to final destination (Marcucci E. and Danielis R., 2008).

plate 2.5 shows a sample of the freight consolidation center.



Plate 2.5 Freight consolidation center FCC (Marcucci E. and Romeo D., 2008).

Freight consolidation centers have been developed for a variety of financial, environmental, and logistical reasons. The main objectives of establishing FCC as shown (Lewis A. et al., 2010):

- To minimize the flow of freight trucks on the roads within the areas it serves
- To eliminate the demand for storage and other logistical facilities in the surrounding region or at the place it serves
- To change the sort of freight vehicles that access a given region or place.

According to **Browne et al., (2005)**, establishing an FCC can help a city in a variety of ways, both environmental and social. Among the most important and common benefits are lower pollution, less noise, reduced traffic congestion as well as fewer traffic accidents, all as a result of fewer freight trucks inside the urban area.

Additional benefits of employing an FCC, according to **Björklund M. and Sara G., (2015)**, include a safer environment for customers and other road user due to fewer heavy vehicles, as well as enhanced delivery of products and work system. The environmental advantages may be considerably larger if more ecologically friendly automobiles were used. However, a notable disadvantage, at least from a social standpoint, is the increased traffic around an FCC as a result of greater inbound freight movement, for this reason, the location of an FCC is critical.

The ability of a freight consolidation facility (FCC) to function in a given environment is based on more than simply its technological or logistical design. To increase the chances of a successful freight consolidation center implementation, the design must include more than just technological or logistical aspects, such as organizational and financial aspects (**Maurits HM. and Van D., 2015**).

Michael et al., (2005) conducted a comprehensive literature review and field investigation in a total of 67 freight consolidation centers constructed between 1970 and 2005 in several countries including Japan, Canada, Europe, and the United States to analysis the variations in design between different urban consolidation centers and the impact of these design variances on FCC operation.

These design elements are detailed below:

- The Goals of an FCC.
- Distance between FCC and the delivery area.
- Coverage of space.
- The variety and kind of items handled.
- Modes of transportation used.
- Range of the services provided.

- Operational flexibility (for example fixed delivery schedules or on-demand).
- Funding and financial support issues.
- Responsibility for transport operations.
- The degree of permanence of the center and its operations.
- Local authorities and other public-sector entities' roles.
- For FCC users, it is either mandatory or voluntary.

2.9 Using inner-city night delivery

The term "night delivery within the city" refers to the deliveries of goods to retailers and shops in the inner-city areas during the night periods when the city is usually quiet and traffic is inactive, typical working hours often range from 10:00 pm to 7:00 am. Successful night delivery trials are done by substituting a (higher) number of vehicles operating during the day with a (lower) number of trucks operating at night (**Macharis C.et al.,2016**).

Transporting goods, in general, contributes to air pollution and environmental damage, noting that the harm is greater in the case of transporting goods within urban areas compared to long-distance transport operations due to stop-and-go situations on crowded urban roads, as well as old vehicles and the variety of goods delivery destinations in cities (**Fu, J. and Jenelius, E., 2018**)

Scheduling product delivery toward less crowded periods has a long history, and it was first utilized in roman law when Julius Caesar banned commercial movement during the day to alleviate street crowding. (**Sánchez-Díaz, I. et al.,2017**).

Night delivery can reduce traffic congestion and travel times for daytime road users; minimize the environmental impact (noise, and pollution); increase competitiveness for freight forwarders (e.g., less freight traffic conflicts with customers, as well as unloading and parking space available); increase delivery

reliability for receivers, give better flexible services; as well as enhance safety by decreasing collisions between trucks, passenger automobiles, and pedestrians (**Gatta V.et al., 2019**).

Some related issues must be taken into consideration during the night delivery to achieve more effective deliveries. Among them are the noise trouble caused by vehicle movement at night, as well as ensuring security for workers, cargo, and the facilities. Furthermore, having appropriate lighting is important since a lack of general lighting could impede delivery outside of business hours at night (**Yannis G.et al., 2006**).

The off-peak delivery study in New York City is one of the most comprehensive studies on this subject. Since 2002, the New York transportation department has investigated various techniques to improvement off-peak shipping in Manhattan and Brooklyn. The study focuses on developing delivery programs and assessing performance metrics. GPS-equipped mobile phones in the vehicles involved in the study were used to capture information such as position, speed, date, and time. The study found that the average travel speed of vehicles at night is higher than during the day, with less delivery time for goods, in addition to the economic benefits due to off-peak delivery in the New York metropolitan region which is represented in many aspects, including an increase in the efficiency of the shipping industry, and saving travel time for road users, as well as environmental benefits for society, all estimated at (147-193) million dollars per year, and reduction in New York City's emissions per kilometer could be as high as 60% due to shifting freight deliveries into off-peak hours (**Holguín-Veras, J.et al.,2005**).

2.10 Definition and applications of GIS

A geographic information system (GIS) is a set of hardware, software, and methodologies that facilitate the administration, modification, analytics,

modeling, presentation, and display of geographic information data to solve complex planning and management concerns. (Liu X. et al., 2017)

There is many GIS software like Esri ArcGIS, Google Earth Pro, BatchGeo, Maptitude, Scribble Maps, etc. they usually focused on gathering, analyzing, and displaying geographical data to manage business operations. Typical implementations can result in a savings in operational expenses. GIS often integrates with CAD, BIM, and other drafting and design software to enhance its analytics capabilities.

According to G2 Research Scoring Methodologies, Arc GIS consider as #1 geographic information system software. A more complete and simple definition of Arc GIS considers the arrangement of its data sets in layers as shown in Figure 2.6. A group of maps representing the same area of the land in which a specific place has the same coordinates in all of the maps in the system allows for a better understanding of this zone by analyzing its thematic and geographical aspects, (Escobar, F. et al., 2008)

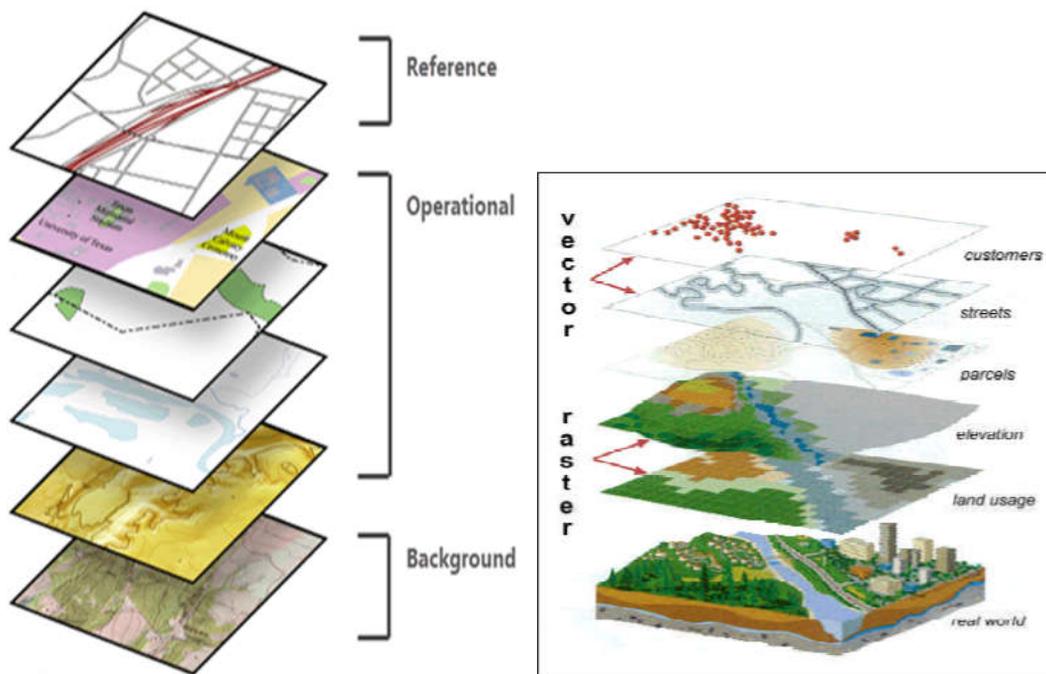


Figure 2.6 The concept of layers GIS ESRI layers image (Escobar, F. et al., 2008)

ArcGIS is widely used in transportation applications. Highway maintenance, traffic modeling, accident analysis, route design, and environmental assessment of road projects are examples of their typical uses. A well-organized road network is a basic requirement for data input for the ArcGIS software in transportation-related projects, as well as other information on the general terrain and land use **(Gupta P. et al., 2009)**.

According to **(Johnston K. et al., 2001)** Arc GIS is computer software that can collect, enter, process, display, and output descriptive and spatial information for certain objectives, and help decision-making in the planning of agriculture, urban planning, and residential development, in addition to the reading of any city's infrastructure through creation the layers. The program requires entering the geographical details (maps, aerial photographs, visual spaces), describing them in different forms (names, tables), processing them, storing, saving, rearranged, analyzing spatially and statistically, and displaying them in the form of maps, reports, graphics.

2.10.1 Importance of using ArcGIS in freight and urban planning

Urban planning can be defined as the technical, social, and political process that is focused on the development and the design of land use as well as the built environment, including air, water, and the infrastructure passing into and out of urban areas, such as transportation, communications, and distribution networks and their accessibility **(Van M. et al., 2019)**.

ArcGIS have a valuable and strong analytical technique for urban planning and administration. The characteristics of ArcGIS that make them important in urban planning are **(Easa S. and Yupo C., 2000)**:

- Data from several sources may be input and combined.
- Data consistency can be preserved.
- Data updates are simple to carry out.
- It is possible to accomplish flexible data storage and recovery.

ArcGIS contributes to sustainable urban planning and management through the following ways; analyzing the existing situation for adequate urban planning process; producing and maintaining geographical information which helps for planning of urban areas and cities; providing quick access of data to planners and other stakeholders which eases the urban planning and management process; enabling planners to make effective, efficient and informed decision with regards to urban planning and management; enabling monitoring, evaluation and provision of feedback with regards to implementation of urban plans (Reddy, P.S., 2021).

(Falzarano et al., 2007) described a process of creating an intermodal freight transportation network to analyzes freight traffic along the U.S. Eastern Seaboard by developing of the Geospatial Intermodal Freight Transportation (GIFT) model using ArcGIS program. The model can be used to identify energy, environmental, operating cost and time tradeoffs associated with intermodal freight transport to connect various modes (highway, rail, waterway) with transfer facilities and port terminals via artificial nodes and links.

Decision makers can use the model to explore tradeoffs between alternative routes across the three modes for freight transportation, and identify optimal routes for objective functions that feature energy and environmental parameters (e.g., minimize CO₂ emissions). It is possible to run a scenario in the model that simulates the impact of a congestion mitigation policy or the introduction of CO₂ reduction technologies.

2.10.2 The use of ArcGIS to analysis the characteristics of the road network.

The topological structure of road network is a significant factor that shapes the city. Evaluation of the road network is therefore an important aspect of urban transportation planning. Recent advancement in geographic information system has enhanced the understanding of the topographical properties of road

networks, ArcGIS program provides the possibility to study the topological pattern of the transport network and evaluate the urban road transport system, using graph theory that provides a basis for the identification of the network pattern (Ahmed R., 2017).

Kanksy studied the structure of transportation networks and developed various descriptive indices such as alpha, beta, gamma, indices for measuring the connectivity of networks. Network length, intersection density and network density are parameters which quantify the coverage of the road network (Daniel CB. et al., 2020)

Beta index (β)

The β index is calculated as follows:

$$\beta \text{ index} = \frac{e}{v}$$

The value of this index ranges between (0-1), zero means that the network consists of only nodes and has no links, and it is called unconnected network. But if the value of the indicator reaches one, then this indicates the existence of complete interconnection with the network, while if it rises above one, this indicates the presence of more integrated and developed network.

Alpha Index (α)

The α index is calculated as follows:

$$\alpha = \frac{e - (v - 1)}{2(v - 5)}$$

The alpha indicator represents another type of method for analyzing the degree of interconnection in urban transport networks. The value of the indicator ranges between (0-1), where zero means no network interconnection and one mean maximum network interconnection.

Gamma index (γ)

The γ index is calculated as follows

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

This index measures the theoretical maximum connectivity of a network. The value ranges from 0 to 1, with a higher value indicating a more connected network.

*(e) = Number of links, **and** (v) = Number of nodes.

(Alterkawi M., 2001) studied the road network in Riyadh using geographic information systems after creating a geographical database for roads to use in determining the network's strengths and weaknesses, as well as ease of access by determining the shortest path, service areas, and traffic congestion. The study concluded that ArcGIS technology is an excellent tool for evaluating spatial data and plays an important role in transportation planning by providing a database from which planners and decision-makers may benefit and also discovered that several Riyadh roads are suffering excessive traffic. The study proposed extending the usage of ArcGIS in the sector of transportation to identify the most significant defects and difficulties that road networks face and convey them to decision-makers so that they are taken into account in the planning processes.

(Sola O., 2011) analyzed the characteristics of the road network in Nigeria's Ekiti area. For the aim of evaluating the road network connectivity ratio in the region and identifying the most important nodes that can be easily accessed, as well as investigating the topographical characteristics of the road network in the study area, the graphic theory was used in measuring the road network connectivity ratio based on the beta, gamma, and alpha index. The study recommended that the present road network, particularly the exterior roads, should be rehabilitated and rebuilding the narrow bridges located on the highways to avoid traffic congestion and facilitate the movement of residents, goods, and services in the region.

(Patarasuk R., 2013) investigated the relationship between road network development and its connectivity in Thailand using statistical analysis and graph theory-based network indicators. Despite an increase in the overall length of the

road network in the research region, the study found that connection to the network is poor. This means that, even though the purpose of road development is to facilitate the access to the different land use activities, the connectivity of roads cannot be ascertained. connectivity of the region depends on where roads are developed, whether linking existing roads or developed as dead-ends.

2.10.3 Network analysis tools in Arc GIS software

Arc GIS network analysis is considered one of the most important tools in ArcGIS software that performs the process of spatial analysis of networks to provide many important services such as determining the best path with finding service areas and accessibility, in addition to finding paths related to the destination and origin areas. The work of this tool is based on a complex model that has been integrated with the ArcGIS program to carry out these works , when this tool is activated, the program uses a specific algorithm to discover the shortest path of roads, which was invented by Dijkstra in 1953, to decrease the time, money, and effort required to determine the optimum path between the origin and destination points, the algorithm divides the network into a group of nodes and the paths are represented as lines connecting these nodes, **(Rabab H. et al., 2013)**.

(Curtin, K.M., 2007) show that the network analysis method in ArcGIS application can execute efficiently to study and analysis any network, all the detailed data of the network must first be entered into the program, where a series of commands known as spatial commands provided by the program is activated to deal with this data and perform network analysis.

(Wazer Z. and Noor M., 2021) investigated the road freight network in Baghdad city to analysis freight traffic travel patterns, and identify potential locations for freight logistics facilities that can be created within the city using freight data and network analysis tools provided by the Arc GIS technique. The

proposed warehouses contribute to finding solutions for road users and especially (truck drivers) by facilitating the arrival of goods distributed.

(Kumar P. and Dinesh K., 2016) studied the road networks in India in terms of finding the most effective routes for the roads by determining the direction of movement and service areas based on the travel time and distance.

(Falih K. et al., 2016), studied the road network in the city of Nasiriyah using the network analysis tool in the ArcGIS program to find the best path for the movement of vehicles traveling to the city center based on the shortest distance and the least time to arrive.

2.11 Summary

Freight transportation is extremely important in determining the region's economy. The increasing importance of goods transporting in urban areas is connected to city population growth as well as increasing economic development, which leads to higher levels of demand for goods transport services which is proportional to the size of the city and its economic activity.

The transportation of goods on road networks has increased, and the excessive usage of roads by freight vehicles in addition to passenger cars has resulted in several negative social, environmental, and economic consequences.

To overcome these negative impacts, planners and decision-makers must adopt a comprehensive approach to planning and implementing initiatives that aim to improve transportation sustainability and deal with considering freight transportation alongside passenger transportation to balance the economic, social, and environmental impact of freight. These plans should take into consideration specific city conditions from a variety of perspectives, such as present traffic volumes and modal split, current transportation infrastructure and road design, as well as the city's size, population density, economic level, and geographical location.

ArcGIS enables transportation planners to analysis and store large amounts of data for population density, land use, and traffic patterns, etc. It is also considerably used in the analysis, planning, and management of complex road network systems that affect transportation effectiveness and vehicle movement management, such as analyzing the pattern of freight truck traffic within road networks.

By using ArcGIS software greatest accessibility for determining the optimal paths of freight trips in a city can be obtained, as well as analysis of transportation networks, and the calculation of the trip distances and total driving duration starting from a specific point to their destination. This knowledge can help in saving time and get the optimal cost-benefit ratio by reducing journey time and total distance traveled by vehicles, minimizing congestion, fuel consumption, and air pollution emissions.

Despite the importance of transporting goods and the significant increase in the number of trips resulting from the movement of freight vehicles through road networks within cities of Iraq, there is a deficiency in the studies related to the analysis and planning the freight transportation. In previous studies, there is a single study that was conducted in the city of Baghdad about this subject.

The current study showed the analysis of freight transportation in Hilla City, which can be classified as a receiving area for goods due to its geographical location, by analyzing the service areas, loading, and unloading sites, drawing an exact freight road network digital maps for the whole city, and determining the optimal path for the trips of freight vehicles across the network to evaluate traffic conditions within these paths and then identifying problems and proposing potential solutions for them.

Chapter 3

Methodology and Data Collection

3.1 General

This chapter provides a general explanation of the study methodology, starting with an explanation of the study area and the road network, in addition to the data collected and the surveys that were conducted to analyze the freight road network in Hilla city. The diagram methodology has been illustrated in the 3.1.

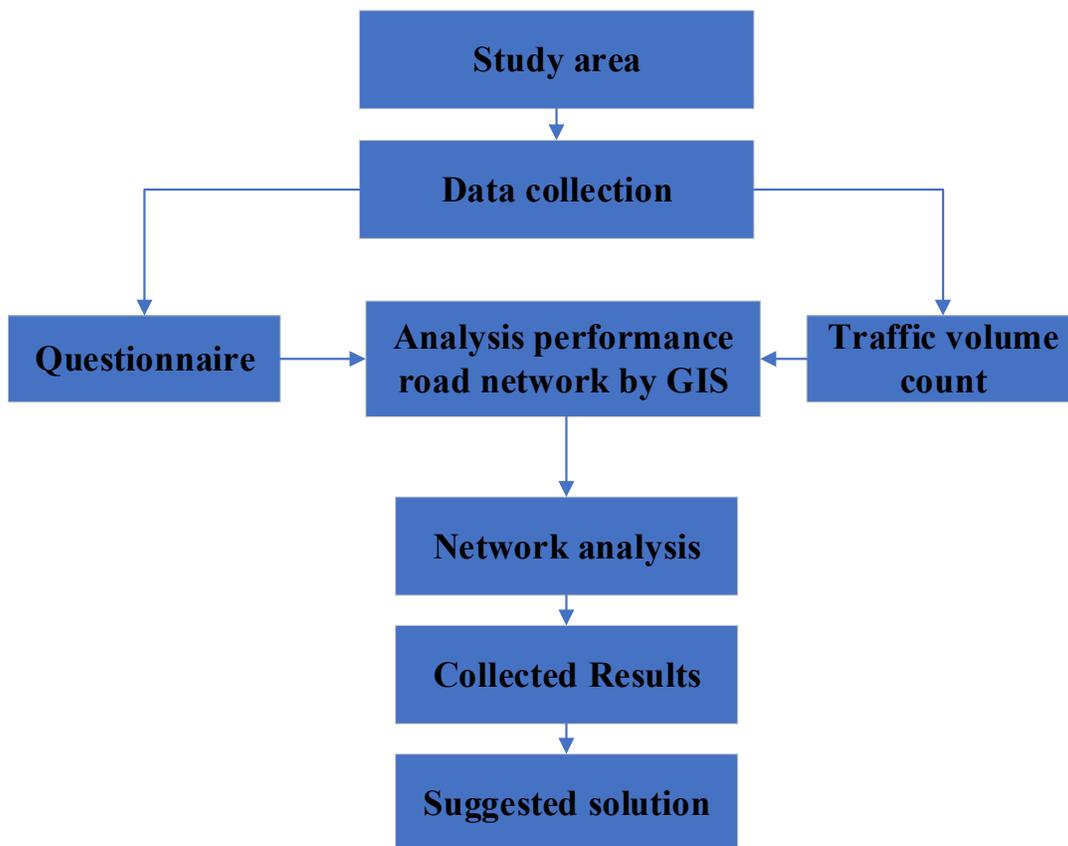


Figure 3.1 Diagram methodology.

3.2 Study area

The study area is the city of Hilla, the center of Babylon's province. It is located at 32.29 degrees north of the equator and 44.28 degrees east of Greenwich, about 100 kilometers south of Baghdad, the capital of Iraq.

Babylon province is located in central Iraq and occupies the northern part of the middle Euphrates region. It is surrounded on the north by Baghdad province, on the southeastern by Qadisiya province, on the east by Wasit Province, on the west by Anbar and Karbala province, and on the south by Najaf province.

The area of Hilla city was about 161km. As shown in Figure 3.2, this site mediates a number of administrative districts of Babylon Governorate, including (Al-Hashimiyah, Al- Mahawil, Al-Qasim, and Al-Musayiab). According to Babil Statistics Department data, the population of Hilla City is approximately 28.19% of the total population of Babil Governorate, which is 2,288,102 people.

The city of Hilla is distinguished by the importance of its strategic location in linking the mainland trade between neighboring provinces as well as other districts of Babylon province through the five main entrances to the city (Nile entrance, Athar entrance, Hilla - Karbala entrance, Hilla - Najaf entrance, and Hilla - Diwaniyah entrance), as shown in Figure 3.3 and Figure 3.4.

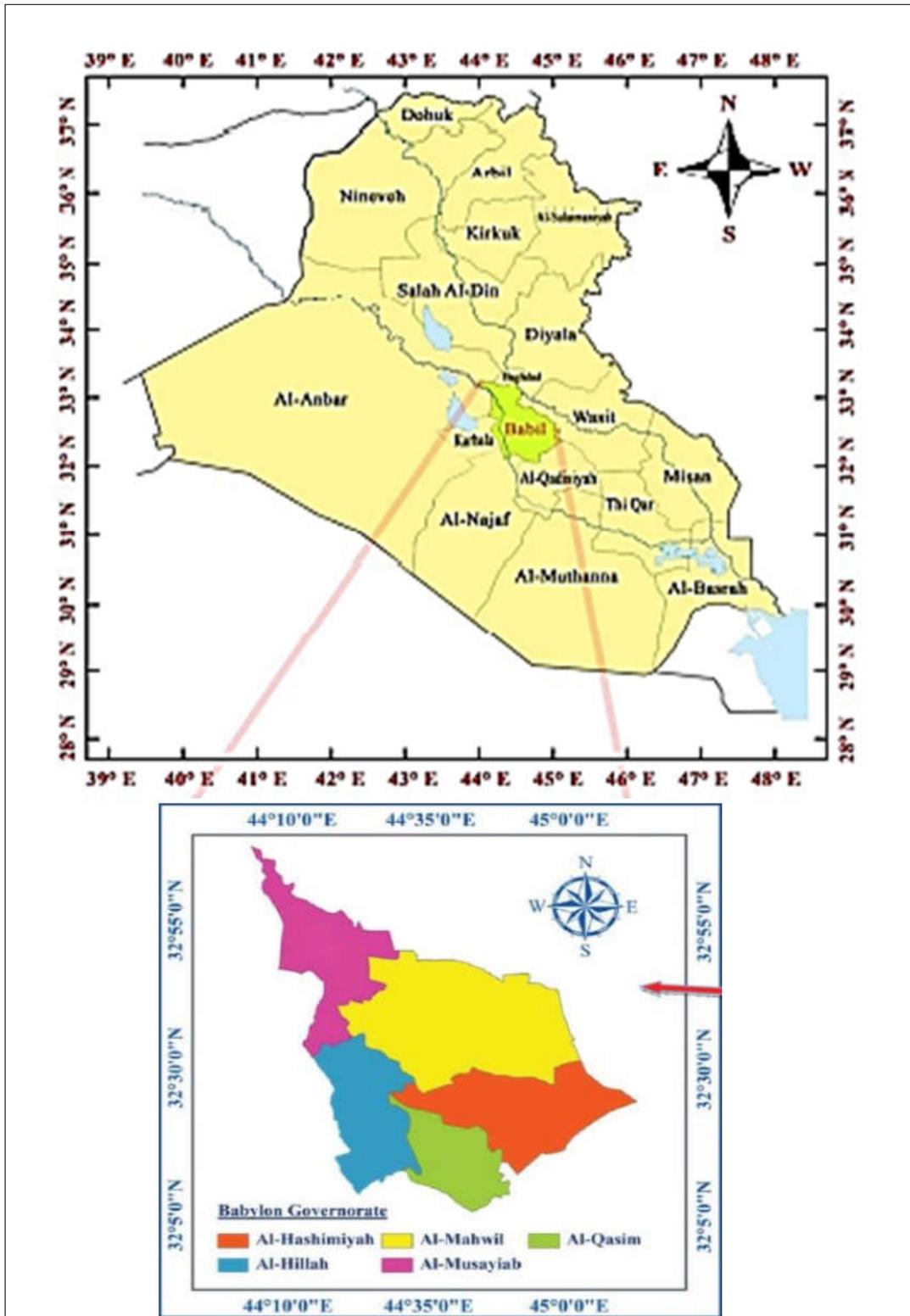


Figure 3.2 Geographic location of Hilla city (According to Hilla Municipality Directorate).

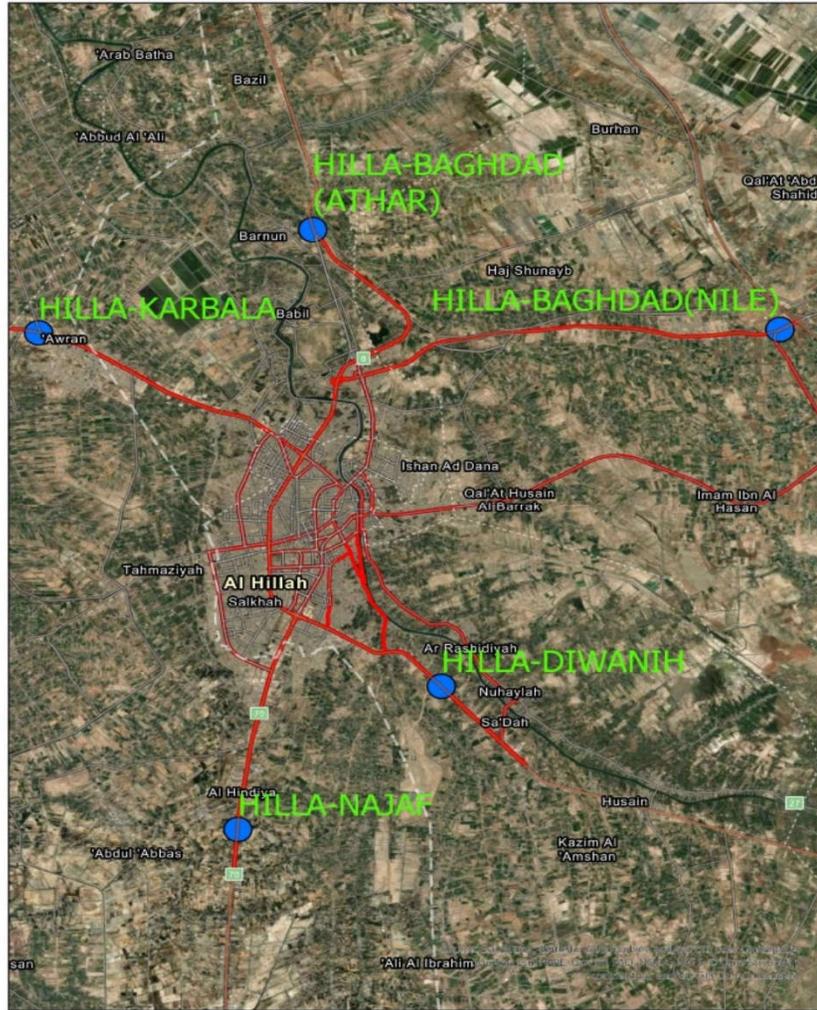
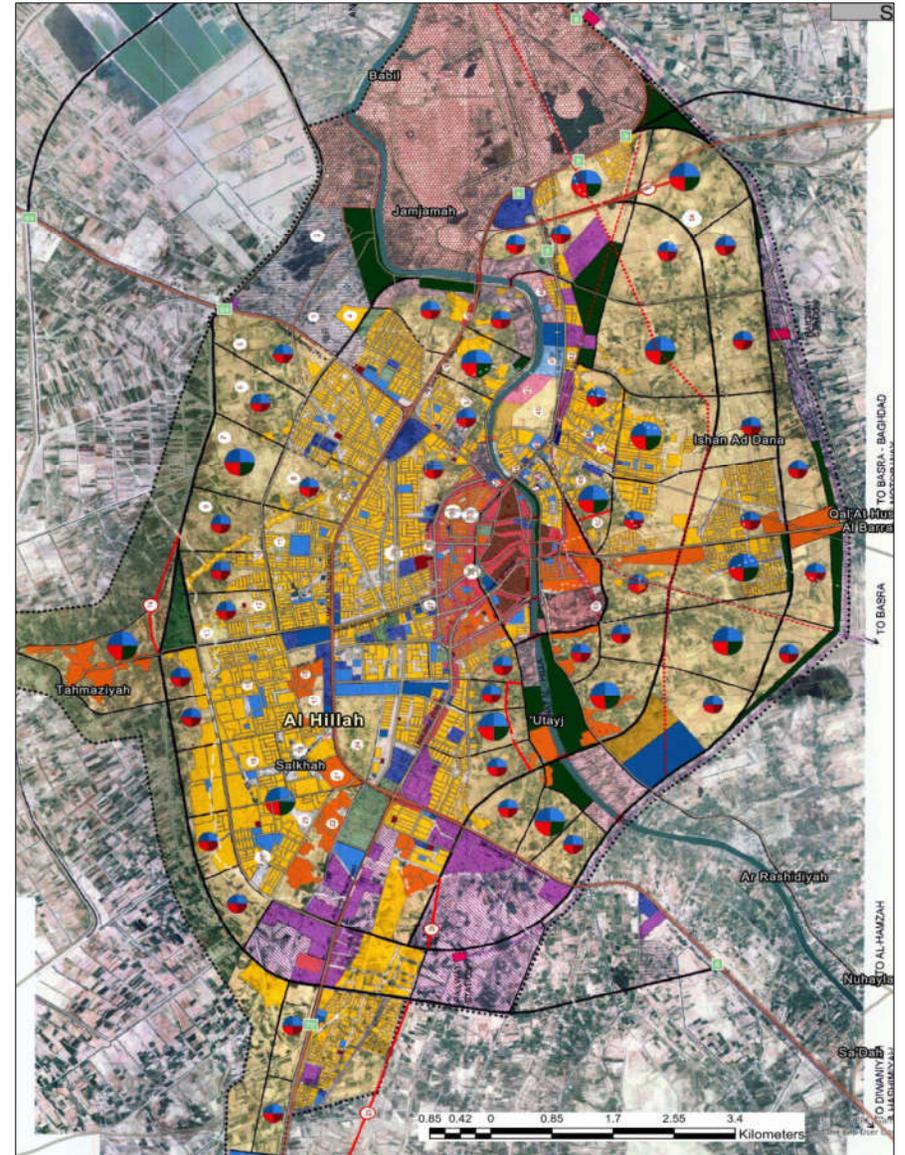


Figure 3.4 Hilla main entrances.



**Figure 3.3 Hilla master plan
(According to Municipality Directorate of Hilla).**

3.3 Freight traffic data in Hilla city.

The movement of goods within urban areas is vital since cities are the center of economic and social life. The sustainability of cities cannot be viewed without giving considering the role of goods transport. Therefore, Freight vehicles constitute an important component of the traffic flow on the road system in Hilla city.

The process of analyzing freight movement primarily includes activities related to the collection and analysis of freight data, knowing the main places for goods to enter the city of Hilla and the areas that represent destinations for freight vehicles within the city to unload their cargo to ensure an efficient and sustainable general movement of freight traffic in the city of Hilla.

3.3.1 Main entrances of Hilla city (Origins of freight vehicles)

The city of Hilla has five main entrances, linking the traffic between the city center and the districts of Babylon province, as well as the neighboring provinces. The entrances and exits of the city of Hilla are the main outlets for trade exchange between the city of Hilla and the neighboring provinces due to its strategic location of Hilla, where it is considered the main road node leading to southern Iraq.

The first entrance to the city of Hilla is the northeastern entrance and is called the Nile entrance (EN1). It is considered one of the most important entrances to the city because it connects the city of Hilla with the international highway, which is one of the most important roads in Iraq, linking Baghdad with the southern provinces, as well as linking the country with Syria and Jordan through Anbar province.

The second entrance to the city of Hilla in the northern entrance and is known as the Athar entrance (EN2). which connects the city of Hilla with the districts of Babylon province from the north, as well as connects the province of

Babylon to the city of Baghdad and the northern provinces through Hilla-Baghdad Road.

The third entrance is the northwest entrance of the city and is known as the Karbala entrance (EN3), which connects the city of Hilla with the city of Karbala through Hilla-Karbala Road.

The fourth entrance is the southern entrance to the city of Hilla and is known as the Najaf entrance (EN4) , which connects the city of Hilla with the Al-Kifl district and the city of Najaf through Hilla- Najaf Road.

The fifth and last entrance to the city is called the Diwaniyah entrance (EN5). It connects Hilla city with the districts of Babylon province from the southeastern side of the city, as well as linking the province of Babylon with the city of Diwaniyah through Hilla -Diwaniyah Road.

The Location and coordinates of each entrance are shown in the Table 3.1 and Figure 3.5:

Table 3.1 Coordinates of Hilla city entrances.

| No. | Entrance | Coordinates | |
|-----|--------------------|---------------|---------------|
| | | X Coordinates | Y Coordinates |
| EN1 | Nile Entrance | 460551.8193 | 3600392.2344 |
| EN2 | Athar Entrance | 445928.0371 | 3603986.2005 |
| EN3 | Karbala Entrance | 437349.7323 | 3600273.5886 |
| EN4 | Najaf Entrance | 443583.5089 | 3582387.7083 |
| EN5 | Diwaniyah Entrance | 449935.2284 | 3587521.2082 |

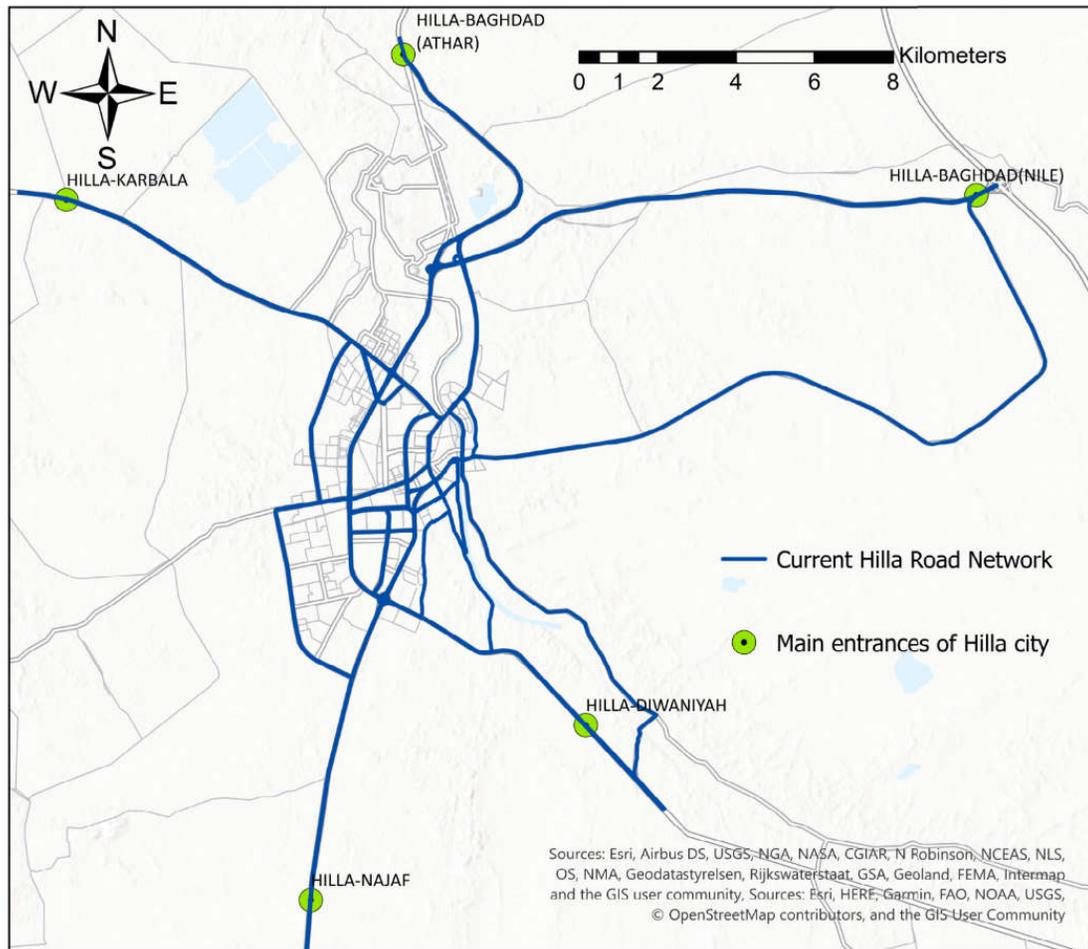


Figure 3.5 Main entrances of Hilla city by ArcGIS 10.4 software

3.3.2 The main road network in Hilla city

The main road network within Hilla city can be classified according to the requirements of highways as shown below

Major Arterials: These are generally 3-lane dual carriageways with a limited number of access points. They serve areas within the city which are usually long-distance traffic and responsible for linking the city's sectors to each other and to the external roads. It is considered a vital part of the road network in the city with high traffic volume, characterized by the free flow speed of 80 km/hr for the vehicles therein and is provided with a number of traffic signs, with a total length of 77.412 km.

Minor Arterials: These are generally 2-lane dual carriageways with a large number of access points. They provide links between major arterials and represents the main distribution network for the main streets in addition to being dedicated to serving the different sectors of the city and sometimes to the residential neighborhoods as well as providing commercial, industrial, and recreational services with a total length of 35,082 km.

3.3.3 Trucks classification

Trucks are usually classified based on their size, weight, numbers of axles, type of operations and commodities they haul. There is not a unique classification system for trucks. Generally, agencies categorize trucks based on the number of axles, carrying capacity, or weight. FHWA (Federal Highway Administration's) and VIUS (Vehicle Inventory and Use Survey), categorizes trucks based on their GVWR (gross vehicle weight rating). This classification system, shown in Figure 3.6 has eight classes ranging from 1 to 8 (**Matthew C., et al, 2017**).

According to this type of classification, trucks can be grouped as bellow:

- 1- Light Duty including class number (1 & 2) vehicles.
- 2- Medium Duty including class number (3, 4, 5, & 6) trucks.
- 3- Heavy Duty including class number (7 & 8) trucks.

The analysis of freight trucks in this study based on truck classification from (class 3 to 8).

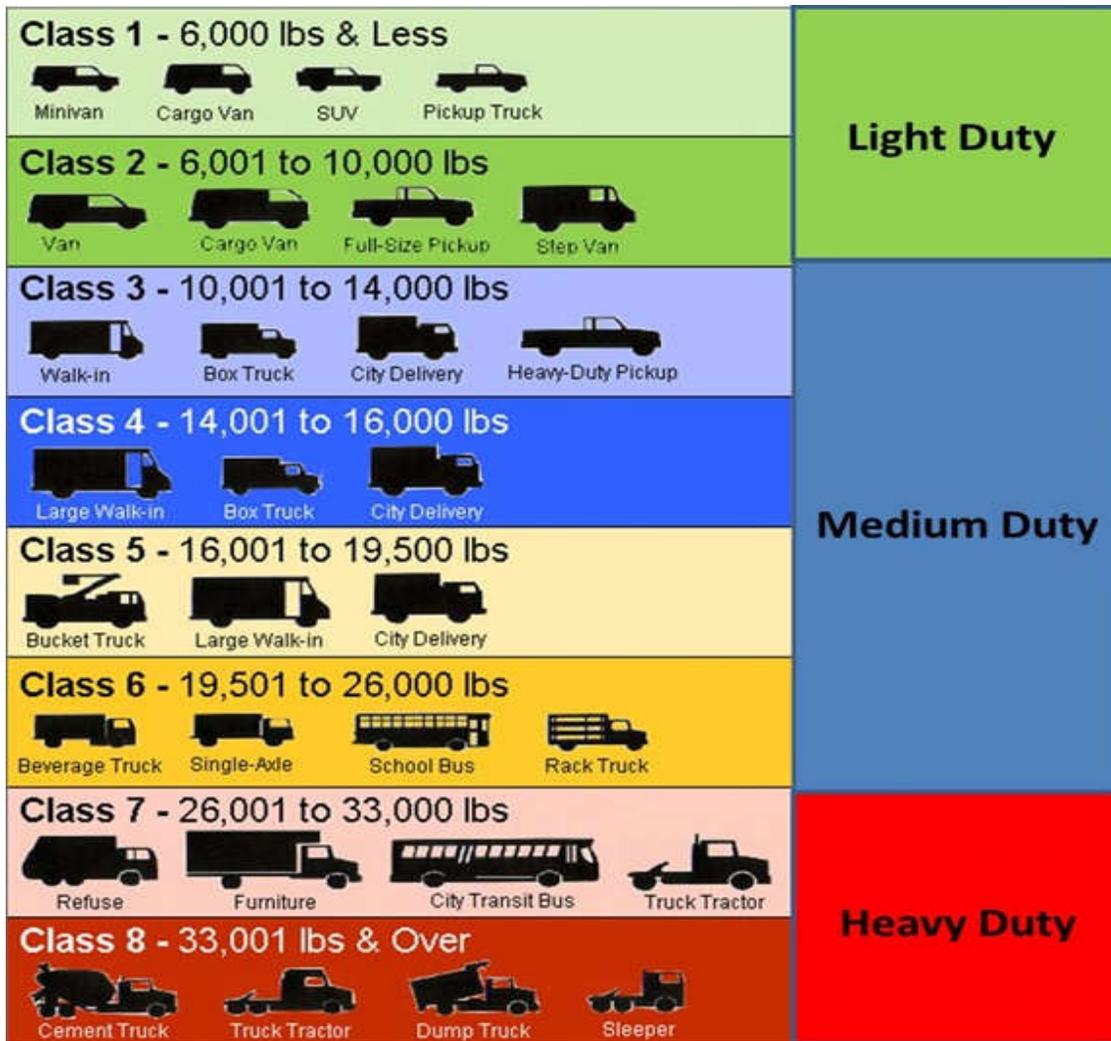


Figure 3.6 GVWR. Truck classification according to the Vehicle Inventory Use Service (VIUS) and (FHWA).

3.3.4 Freight data collection

The freight data collected for the analysis of the freight road network in Hilla city at main entrance includes the following:

- Calculating the traffic volume of freight vehicles entering and exiting the city of Hilla.
- Traffic speed data for freight vehicles.
- Origin and destination surveys of freight vehicles.
- Data of road network used to transport goods in the city of Hilla.
- Travel time data for freight vehicles.

- Vehicle classification counts.

To collect the required information as stated above two types of surveys are necessary to be conducted: Traffic volume counting survey and roadside interview survey (Questionnaire).

Vehicle traffic count survey

Vehicle counting is an essential traffic analytics strategy, The main objectives of the traffic count survey are to obtain the current traffic volume on the main lanes, and analyze the current traffic situation. To analyze the traffic of freight vehicles in the city of Hilla, the freight trucks volume at the main entrances to the city will be calculated by the manual counting method using a portable video camera installed on each side of the road for the vehicles entering and exiting the city at each entrance, taking into account the following considerations:

- Selection of the day in the week to conduct the survey: The choice of survey days is critical in the scanning process because it greatly influences which traffic will be relied upon in the analysis. Therefore, the days for the survey were chosen to take into account the increase in truck traffic on weekdays and its decrease on weekends, and as a result, Monday was chosen at the beginning of the week and Wednesday at the end of the week to get the most effective and actual movement of trucks.
- Selection of the time in a day to conduct the survey: Time is one of the important factors that are used to evaluate the performance of freight transport, by selecting the effective movement times during peak hours, The survey time was chosen after conducting field interviews with freight truck drivers and check point employees responsible for checking and entering freight trucks at each entrance to the city of Hilla to determine the times with the highest traffic volume for trucks entering the city. Therefore, two periods were determined to calculate the traffic volume

based on the A.M and P.M periods. Each period was two hours, the morning period (10.00 -12.00) AM, and the evening period (4.00-6.00) PM. The hour with the highest traffic volume in the morning and evening period is selected as the peak time for freight vehicles entering Hilla city. After calculating the traffic volume of freight vehicles at the city entrances in the morning period (10.00-12.00) AM, the traffic volume at the hour (11.00-12.00) AM was the largest, as listed in Table 3.2.

Table 3.2 Traffic vol. of freight vehicles in the morning period

| Day in week | Entrances At (11 -12) | Entering freight volume | | Exiting freight volume | |
|-------------|-----------------------|---------------------------|-------------------|----------------------------|-------------------|
| | | Traffic volume (Truck/hr) | Entrances ratio % | Traffic volume (Truck /hr) | Entrances ratio % |
| Monday | Nile | 325 | 26.57 | 319 | 26.72 |
| | Athar | 125 | 10.22 | 161 | 13.48 |
| | Karbala | 290 | 23.71 | 300 | 25.13 |
| | Najaf | 298 | 24.37 | 263 | 22.03 |
| | Diwaniyah | 185 | 15.13 | 151 | 12.65 |
| | Total | 1223 | | 1194 | |
| Wednesday | Nile | 309 | 27.06 | 330 | 27.97 |
| | Athar | 110 | 9.63 | 154 | 13.05 |
| | Karbala | 264 | 23.12 | 279 | 23.64 |
| | Najaf | 269 | 23.56 | 274 | 23.22 |
| | Diwaniyah | 190 | 16.64 | 143 | 12.12 |
| | Total | 1142 | | 1180 | |

It is evident from the above table that the total measured traffic volume for freight vehicles in the morning period at Monday is more than Wednesday. It was 1223 (veh/hr) for vehicles entering the city and 1194 (veh/hr) for vehicles leaving on Monday, while on Wednesday it was 1142 (veh/hr) for entering vehicles and 1180 (veh/hr) for exiting vehicles, so data for Monday will be adopted as a basis for comparison with the traffic volumes in the evening period because it is greater

than Wednesday by (6.62%), and (1.17%) for vehicles entering and exiting the city respectively.

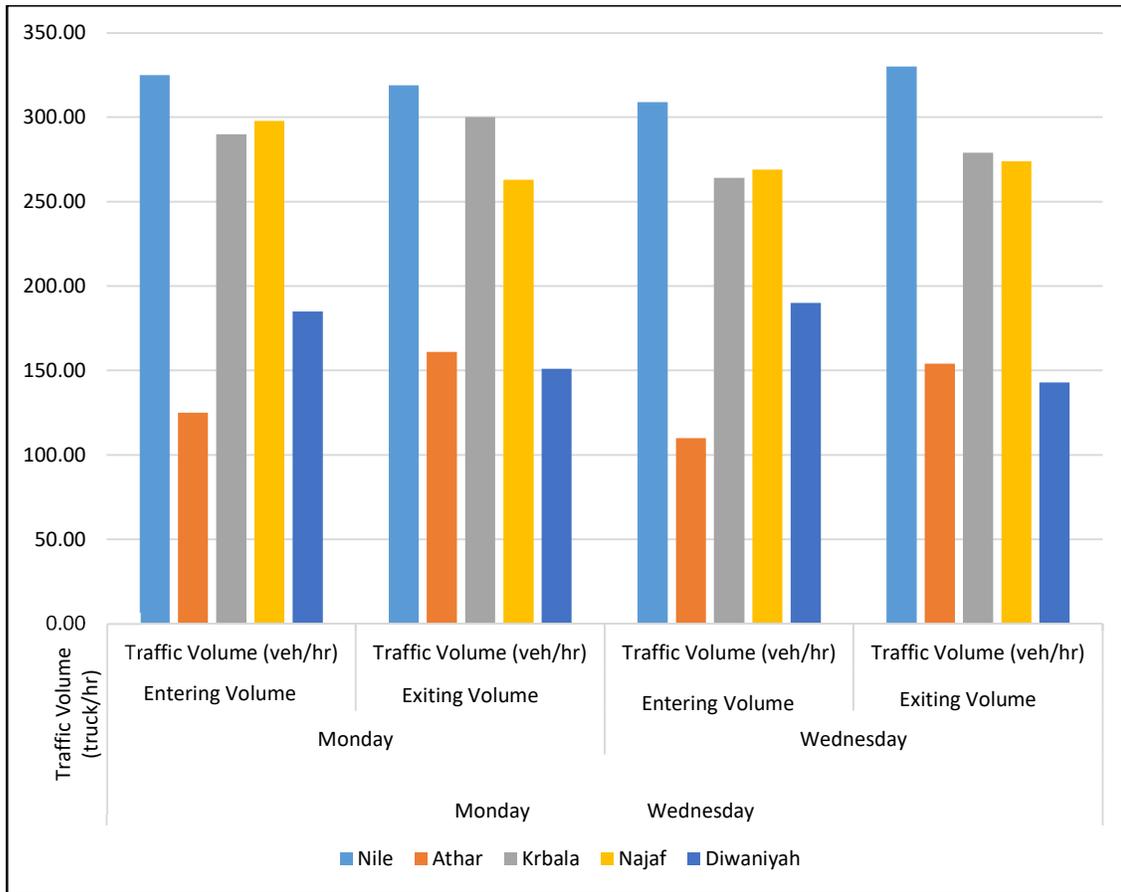


Figure 3.7 Comparison of traffic volume of entrances by days in the morning period.

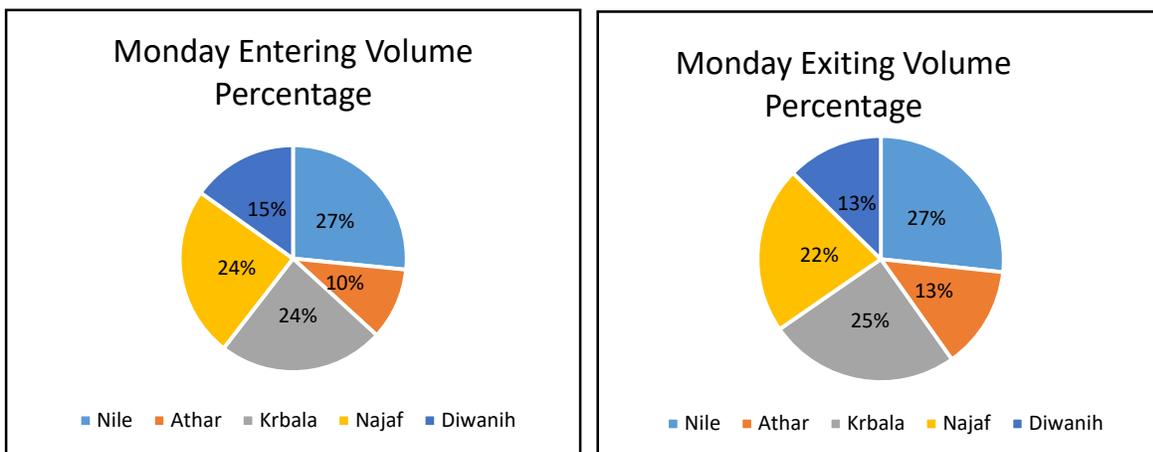


Figure 3.8 Percentage of traffic volume at each entrance from total volume for freight vehicles in the morning period.

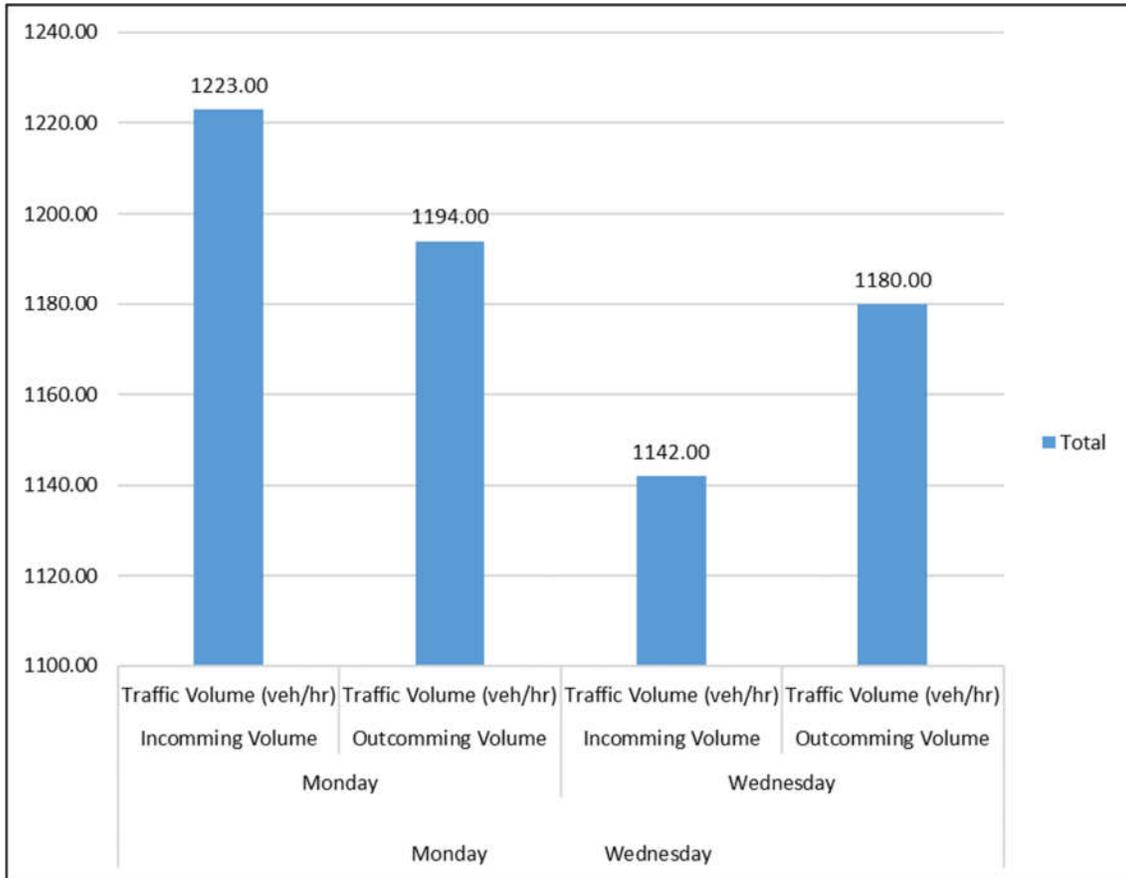


Figure 3.9 Comparison of total traffic volume of entrances by days in the morning period.

After calculating the traffic volume of freight vehicles at the city entrances for the evening period (4.00-6.00) PM The traffic volume at the hour (4.00-5.00) PM was the largest, as listed in Table 3.3.

Table 3.3 Traffic Volume of freight vehicles in the evening period

| Day in week | Entrance at (4-5) | Entering freight volume | | Exiting freight volume | |
|-------------|-------------------|---------------------------|-------------------|---------------------------|-------------------|
| | | Traffic Volume (Truck/hr) | Entrances ratio % | Traffic Volume (Truck/hr) | Entrances ratio % |
| Monday | Nile | 198 | 24.75 | 217 | 25.47 |
| | Athar | 67 | 8.38 | 107 | 12.56 |
| | Karbala | 166 | 20.75 | 164 | 19.25 |
| | Najaf | 236 | 29.50 | 264 | 30.99 |
| | Diwaniyah | 133 | 16.63 | 100 | 11.74 |
| | Total | 800 | | 852 | |
| Wednesday | Nile | 211 | 26.81 | 216 | 30.17 |
| | Athar | 78 | 9.91 | 101 | 14.11 |
| | Karbala | 185 | 23.51 | 143 | 19.97 |
| | Najaf | 188 | 23.89 | 157 | 21.93 |
| | Diwaniyah | 125 | 15.88 | 99 | 13.83 |
| | Total | 787 | | 716 | |

It is evident from the above table that the total measured traffic volume for freight vehicles for the evening period on Monday is more than on Wednesday. It was 800 (veh/hr) for vehicles entering the city and 852 (veh/hr) for vehicles leaving on Monday, while on Wednesday it was 787(veh/hr) for entering freight vehicles and 716 (veh/hr) for exiting freight vehicles, so data for Monday will be adopted as a basis for comparison with the traffic volumes in the morning period because it is greater than Wednesday by (1.63%), and (15.96%) for vehicles entering and leaving the city respectively.

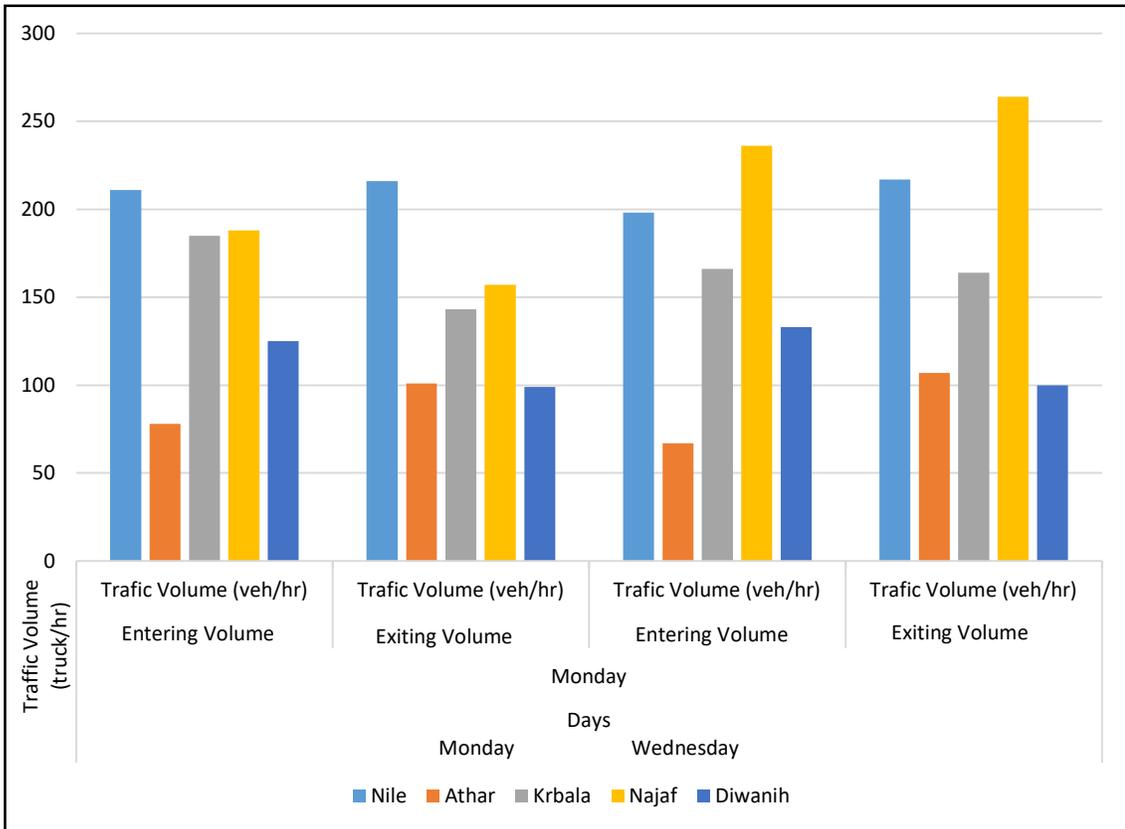


Figure 3.10 Comparison of traffic volume of entrances by days in the evening Period.

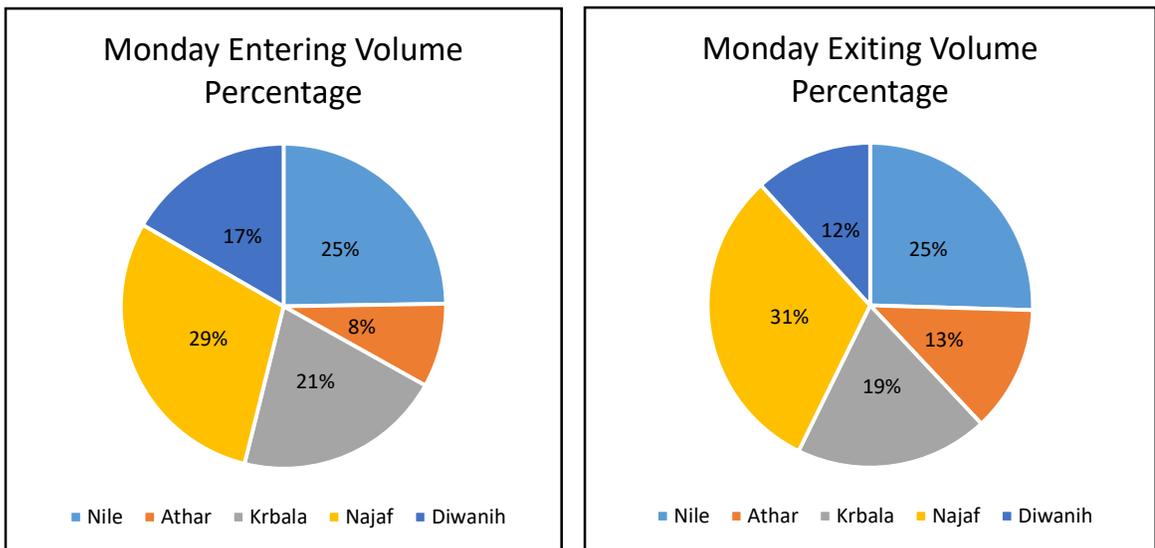


Figure 3.11 Percentage of traffic volume at each entrance from total volume for freight vehicles in the evening period.

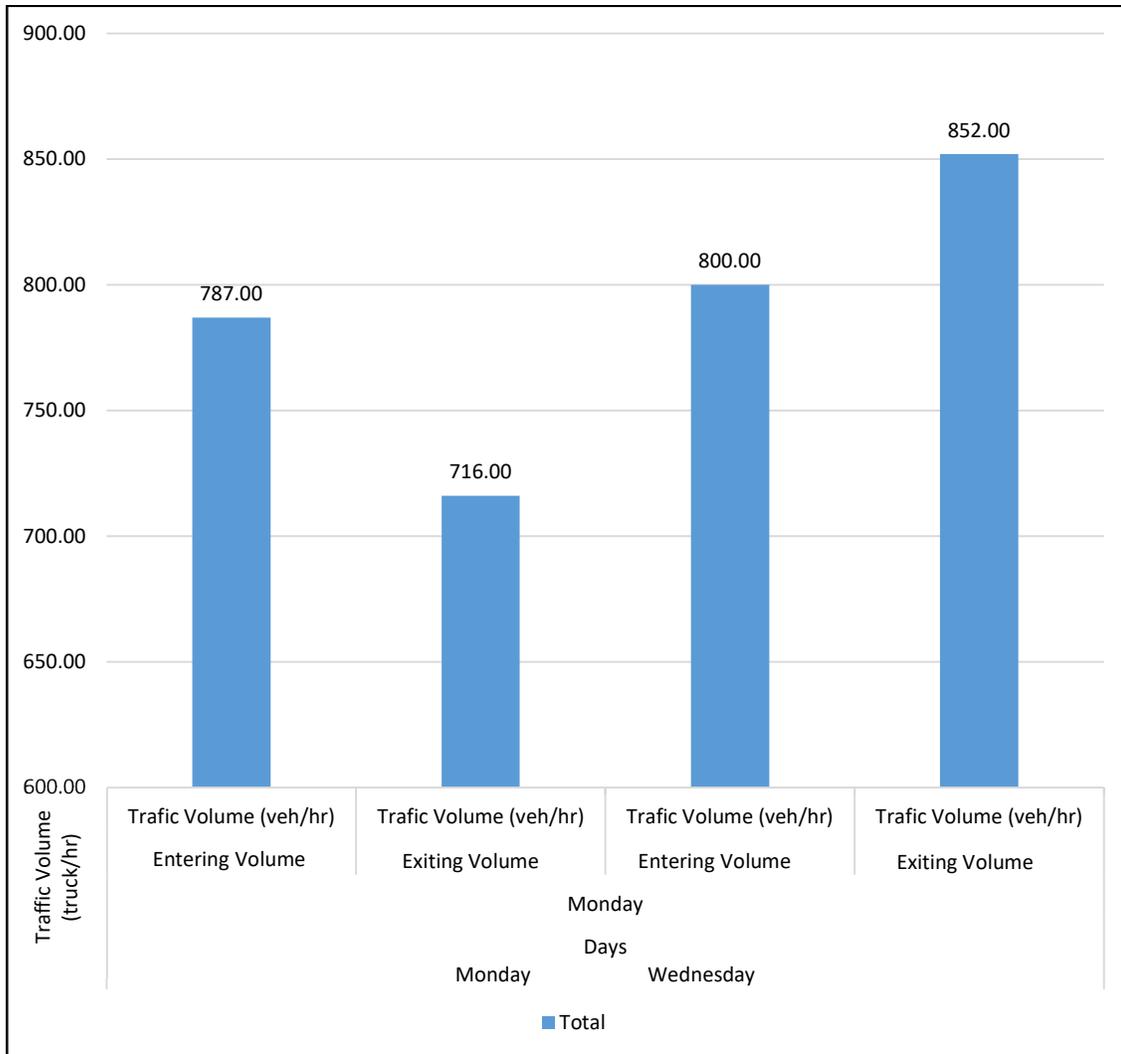


Figure 3.12 Comparison of total traffic volume of entrances by days in the evening period.

After comparing the measured traffic volumes at the entrances to the city on Monday between the morning and evening period, find that the traffic volume of freight vehicles in the morning period is more than in the evening period by (34.59%), (28.64%) for the vehicles entering and leaving the city respectively.

Therefore, the traffic volumes measured at the hour (11.00-12.00) A.M will be adopted in the analysis process.

Sample size calculation

The sample size is very important to obtain accurate and statistically significant results and the success of the study. When surveying a large number of peoples, it is not realistically possible to get answers from everyone. Therefore, samples that are part of the total number of people targeted for the study are taken at random.

In the city of Hilla, the number of trucks entering the city through the five main entrances at the peak hour (11.00-12.00) AM varied values ranging from 325 (Truck/hr) at the Nile entrance to 125 (Truck /hr) at the Athar entrance, so the sample size will be calculated based on these values.

To know the appropriate number of people (freight drivers) to be represented in the questionnaire conducted at each entrance, the sample size is calculated using (Steven k. Thompson) formula. As shown below

$$n = \frac{N * p[1 - p]}{\left[\left(N - 1 * \left[\frac{d^2}{z^2} \right] \right) + p(1 - p) \right]} \quad \text{Equation 3.1}$$

Where:

n: sample size

N: Population size

Z: Confidence level at 95% (1.96)

d: Error proportion (0.05)

p: probability (50%)

After applying the above equation to the total traffic volumes amounting to 1223 (veh/hr) freight vehicles at all entrances, find that the total number of samples required for the questionnaire (728), which is equivalent to a percentage (59.5%) from the total volume distributed among the five entrances as shown in Table 3.4.

Table 3.4 Calculated sample size for freight vehicles at peak hour

| Entrances | Traffic volume (N) on (Monday) | Sample size calculated | |
|--------------|-----------------------------------|------------------------|---------------------|
| | | Sample size | % Form total volume |
| Nile | 325 | 176 | 14.4 |
| Athar | 125 | 94 | 7.7 |
| Karbala | 290 | 165 | 13.5 |
| Najaf | 298 | 168 | 13.7 |
| Diwaniyah | 185 | 125 | 10.2 |
| Total | 1223 | 728 | 59.5 |

Roadside interview survey (Questionnaire)

This survey is a questionnaire that was conducted manually at the entrances to the city of Hilla from the drivers of freight vehicles to collect detailed information about the vehicle and the trip, The most important of this information, as shown in the attached questionnaire in (Appendix A) includes:

- Type of truck government or private.
- Vehicle's axles and payload weight.
- The type of goods transported.
- The type of trip (External-External) or (External-Internal).
- Most of the roads that drivers take in the city.
- Destinations of trips within the city center.
- Traffic problems experienced by road users.
- Travel time it takes to reach the destination of the vehicle.
- Speed of driving on city streets.

Analysis of the results of the questionnaire

Each question in the questionnaire form is analyzed with percentages of the total questionnaires at each entry as shown in Table 3.5 below.

Table 3.5 Analyze the results of the Questionnaire

| No. | Question | Entrance Of Hilla City (%) | | | | |
|-----|---------------------------------------|----------------------------|-------|-------|---------|-----------|
| | | Nile | Athar | Najaf | Karbala | Diwaniyah |
| 1 | Type of vehicle? | | | | | |
| | - Governmental | 0.21 | 0.19 | 0.13 | 0.16 | 0.04 |
| | - private | 0.79 | 0.81 | 0.87 | 0.84 | 0.96 |
| 2 | Type of goods? | | | | | |
| | -Construction | 0.40 | 0.45 | 0.39 | 0.60 | 0.36 |
| | -Oil | 0.15 | 0.18 | 0.19 | 0.25 | 0.21 |
| | -Electric | 0.12 | 0.15 | 0.11 | 0.04 | 0.07 |
| | -Food | 0.15 | 0.10 | 0.16 | 0.05 | 0.16 |
| | -Other Goods | 0.18 | 0.12 | 0.15 | 0.06 | 0.20 |
| 3 | The number of axles in trucks? | | | | | |
| | -2 Axle | 0.27 | 0.23 | 0.24 | 0.26 | 0.41 |
| | -3 Axle | 0.23 | 0.32 | 0.26 | 0.31 | 0.13 |
| | -4 Axle | 0.24 | 0.27 | 0.14 | 0.18 | 0.19 |
| | -More Than 4 Axle | 0.26 | 0.18 | 0.36 | 0.25 | 0.27 |
| 4 | Type of freight vehicles trip? | | | | | |
| | - (External -External) Trip | 0.59 | 0.67 | 0.61 | 0.68 | 0.60 |
| | - (External -Internal) Trip | 0.41 | 0.33 | 0.39 | 0.32 | 0.40 |

The most important notes on the questionnaire analysis are:

- The above results show that the type of freight vehicles varies according to their revenue (governmental and non-governmental), government trucks have a lower percentage than non-governmental trucks, as it ranged between (4%) at the Diwaniyah entrance to (21%) at the Nile entrance, and most of them are loaded with products of oil derivatives, non-governmental trucks are vehicles belonging to the sector Special transports different types of goods according to users' needs.
- The largest percentage of freight vehicles were loaded with construction materials at all entrances to the city, with varying proportions amounting

between (36%) at the Diwaniyah entrance to (60%) at the Karbala entrance.

- Although the classification of freight trucks in the study area was based on gross vehicle weight rating (GVWR) as shown in the figure 3.6, the questionnaire form also included a questionnaire from vehicle owners about the number of vehicle axles to cover the limits of the study and obtain the best results.
- The largest proportion of freight vehicles enters the city of Hilla for transiting to other districts of Babylon province and the neighboring provinces due to the strategical location of Hilla city, which connects Baghdad with the southern provinces, making it an important transit route. The percentage of these vehicles which represent (External -External) trips ranged from (59%) at the Nile entrance to (68%) at Karbala entrance. This is a higher percentage than the (external _internal) trips, which ranged from 32% at Karbala entrance to 41% at the Nile entrance.

3.4 Preparing data to analysis Hilla road network by (ArcGIS) 10.4 software

The definition of ArcGIS software is a geographical information system (GIS) software that allows handling and analyzing geographic information by visualizing geographical statistics through layer building maps like climate data or trade flows. The strength of this software comes from its ability to integrate large amounts of information as well as the wide range of tools that can be used for data study and analysis.

The main feature of the ArcGIS software is that it enables the user to determine the spatial relationships between different map features. As well as creating maps with different scales, projections, and colors. This program is not just a mapping tool, it acts as an analytical tool by providing new ways to read,

link, and analyze data by displaying tabular data in the maps in addition to integrating data from different and various sources.

3.4.1 ArcGIS implementation in analysis of road network

A model has been created to analyze the movement of freight vehicles within the city of Hilla using the ArcGIS 10.4 software, illustrating the process of choosing the best route for freight vehicles between the point of origin (the city entrances) and the destination of the vehicles. Figure 3.13 shows the procedure to find the best route (fastest route) for freight vehicles through road network.

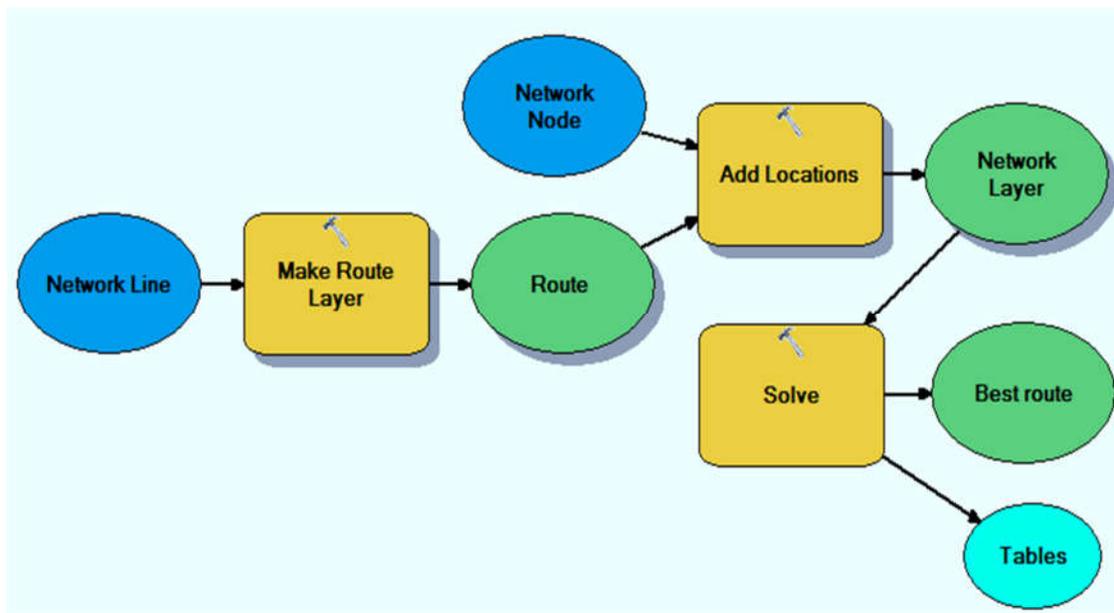


Figure 3.13 Modeling for finding the fastest route by using ArcGIS10.4.

3.4.2 Study area network

After the stage of data collection, which was previously explained in details, the data is now entered in a satellite image for Hilla city, while the coordinates are entered according to the geographical location of Hilla city. On this basis, the road network was built, which begins with preparing the satellite image for the drawing, as shown in the Figure 3.14.

A network dataset can be constructed in a geodatabase or shapefile workspace. Network datasets are well suited to model transportation networks. They are created from source features, which can include simple features (lines and points). When network analysis is required, it is always done on a network dataset.

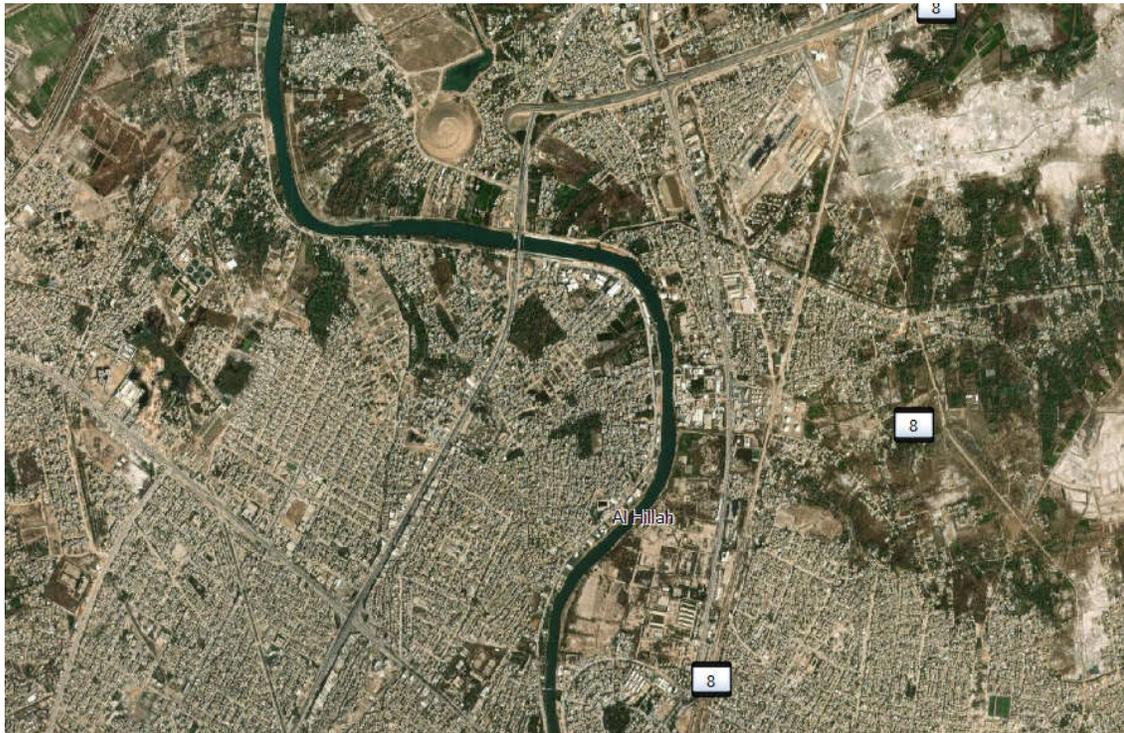


Plate 3.14 Hilla satellite image.

3.4.3 Preparing the layers of the road network.

To conduct road network analysis, it is necessary to prepare road network files; and draw the network with all its details including streets, intersections, and bridges in Hilla city using the ArcGIS 10.4 software. The first step is preparing and creating the required necessary files those contained the **Geodatabase** file and downloading the satellite image according to the coordinates and geographical location and merge them with main **Feature Dataset** file, as shown in the plate 3.15.

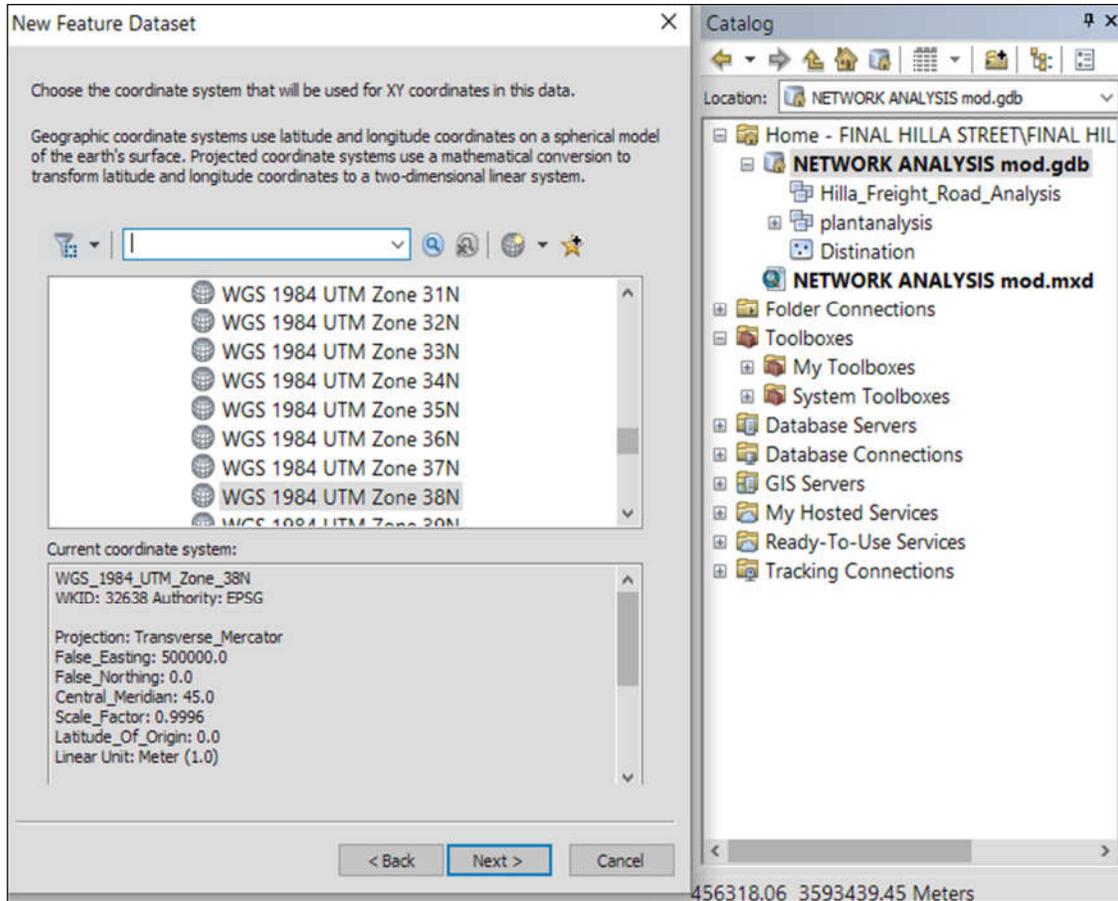


Plate 3.15 Building the main layers (feature data set) of freight road network using Arc catalog program.

The second step is creating new **Feature Classes** in the main feature data set file. These **Feature Classes** which are also called shapefiles are created for the all-road network items including (point, polyline, and polygon) feature, polyline represents the layer of the main roads and bridge in Hilla city which include (898) link while the point feature represented node layer which includes (642) nodes, zones layer represented the polygon areas on the map as shown in the plate 3.16.

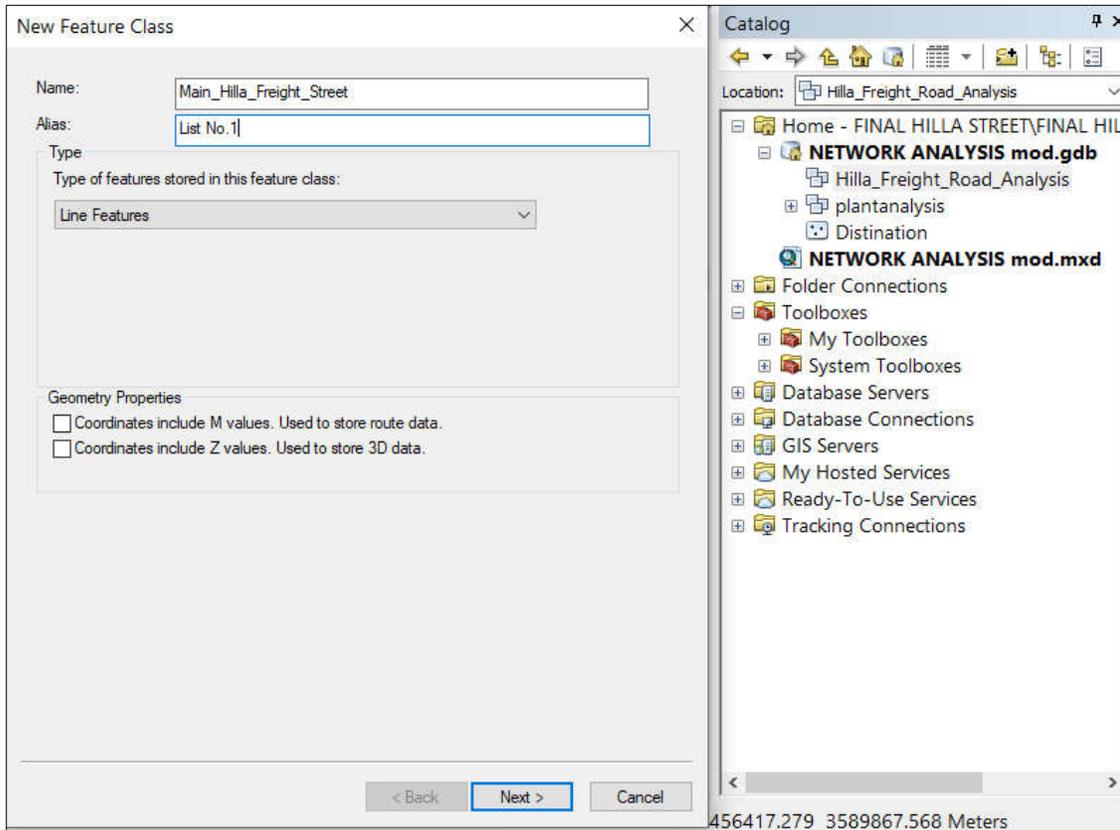


Plate 3.16 Building the sub-layers (Feature Class) of freight road network using Arc Catalog Program.

3.4.4 Preparing the database of attribute table for Hilla road network.

The data that was entered in the attribute table for Hilla Road Network includes three main types:

The first type is descriptive data that describes the road link, including (length, width, number of lanes, and speed). The length of the roads is calculated automatically by the Arc GIS program when drawing. The information regarding the width of the road and the number of lanes was taken from the Municipality of Hilla Directorate, the speed data was collected using field surveys to investigate average travel speed for freight trucks at each entrance and roadway section and compare it to speed data obtained from the Babil Traffic Directorate in addition to the questionnaire information. The questionnaire form included a

question about vehicle speed to identify the driver's behavior in using the trucks traffic lanes in the study area.

The second type data is cost attributes and includes travel time in minutes, it is extracted depending on speed, it is very important data in network analysis when finding the best route for vehicles.

The third type of data is called restriction attributes, and it is also important data in network analysis which included direction of roads movement (One way or two way), where they are distinguished by giving the number (1) for one-way roads and (0) for roads that are in two directions, in addition to specifying closed roads. Figures 3.17 and 3.18 show the final feature class of freight road links in Hilla while Figure 3.19 shows some of these features Data, and the full data are tabulated in Appendix B.

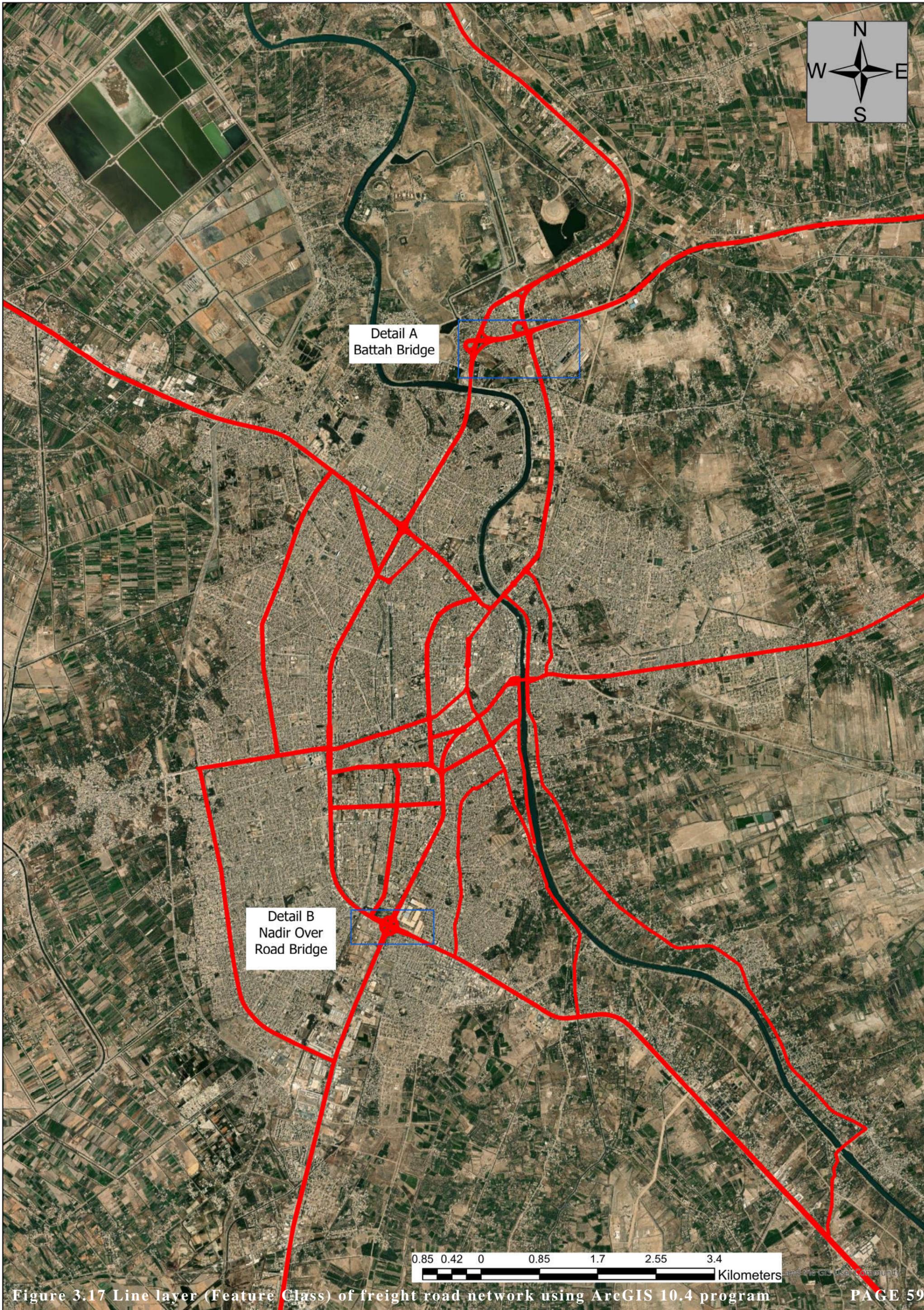


Figure 3.17 Line layer (Feature Class) of freight road network using ArcGIS 10.4 program

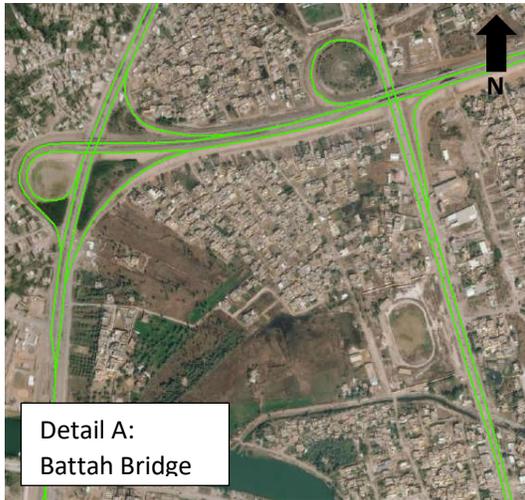


Figure 3.18 Details A and B in Figure 3.17.

Table

Main Hilla road network

| OBJECTID* | Shape* | osm_id | type | oneway | bridge | Shape_Length | time_minit_ | speed_km_hr_ | capacity | effective_width_m |
|-----------|----------|----------|----------------|--------|--------|--------------|-------------|--------------|----------|-------------------|
| 10 | Polyline | 47921140 | major arterial | 1 | 0 | 52.743521 | 0.079099 | 40 | 3200 | 8 |
| 11 | Polyline | 47921145 | major arterial | 1 | 0 | 217.553145 | 0.326264 | 40 | 3200 | 8 |
| 12 | Polyline | 47921150 | major arterial | 0 | 0 | 167.577563 | 0.251316 | 40 | 3200 | 8 |
| 13 | Polyline | 47921151 | major arterial | 1 | 0 | 214.294642 | 0.321378 | 40 | 3200 | 8 |
| 14 | Polyline | 47921153 | major arterial | 1 | 0 | 150.829215 | 0.226199 | 40 | 3200 | 8 |
| 15 | Polyline | 47921157 | minor arterial | 1 | 0 | 330.484396 | 0.660637 | 30 | 2800 | 7 |
| 16 | Polyline | 47921159 | major arterial | 1 | 0 | 152.90092 | 0.229306 | 40 | 3200 | 8 |
| 17 | Polyline | 47921161 | major arterial | 1 | 0 | 153.772799 | 0.230613 | 40 | 3200 | 8 |
| 18 | Polyline | 47921165 | major arterial | 0 | 0 | 113.924036 | 0.170852 | 40 | 3200 | 8 |
| 19 | Polyline | 47921166 | major arterial | 1 | 0 | 213.153225 | 0.319666 | 40 | 3200 | 8 |
| 20 | Polyline | 47921168 | major arterial | 1 | 1 | 86.864171 | 0.064965 | 80 | 4400 | 11 |
| 21 | Polyline | 47921170 | major arterial | 1 | 1 | 58.325411 | 0.043735 | 80 | 4400 | 11 |
| 22 | Polyline | 47921173 | major arterial | 1 | 0 | 10697.661237 | 8.021642 | 80 | 4400 | 11 |
| 23 | Polyline | 47921178 | major arterial | 1 | 0 | 334.447112 | 0.250785 | 80 | 4400 | 11 |
| 24 | Polyline | 47921188 | major arterial | 1 | 0 | 267.147973 | 0.200321 | 80 | 2800 | 7 |
| 25 | Polyline | 47921192 | secondary | 1 | 0 | 461.679664 | 0.923175 | 30 | 2800 | 7 |
| 26 | Polyline | 47921196 | secondary | 1 | 0 | 428.192698 | 0.856214 | 30 | 2800 | 7 |
| 27 | Polyline | 47921200 | major arterial | 1 | 0 | 504.63249 | 0.378399 | 80 | 4400 | 11 |
| 28 | Polyline | 47921202 | major arterial | 1 | 1 | 83.658336 | 0.062731 | 80 | 4400 | 11 |
| 29 | Polyline | 47921207 | minor arterial | 1 | 0 | 394.441979 | 0.788726 | 30 | 2800 | 7 |
| 30 | Polyline | 47921218 | minor arterial | 1 | 0 | 366.978213 | 0.73381 | 30 | 2800 | 7 |
| 31 | Polyline | 47921220 | major arterial | 1 | 1 | 88.220977 | 0.066153 | 80 | 4400 | 11 |
| 32 | Polyline | 47929474 | major arterial | 1 | 0 | 113.783674 | 0.170641 | 40 | 3200 | 8 |
| 33 | Polyline | 47929475 | major arterial | 1 | 1 | 65.049874 | 0.097555 | 40 | 2800 | 7 |
| 34 | Polyline | 47929477 | major arterial | 1 | 0 | 51.77014 | 0.07764 | 40 | 3200 | 8 |
| 35 | Polyline | 47929488 | major arterial | 1 | 0 | 54.635377 | 0.081937 | 40 | 3200 | 8 |
| 37 | Polyline | 47929498 | major arterial | 1 | 0 | 1921.757047 | 1.921373 | 60 | 3200 | 8 |
| 38 | Polyline | 47930750 | major arterial | 1 | 0 | 198.109854 | 0.297105 | 40 | 2800 | 7 |
| 39 | Polyline | 47930751 | major arterial | 0 | 0 | 97.89799 | 0.195757 | 30 | 3200 | 8 |
| 40 | Polyline | 47930752 | major arterial | 1 | 0 | 2422.796233 | 3.633468 | 40 | 3200 | 8 |
| 41 | Polyline | 47930753 | major arterial | 1 | 0 | 342.775634 | 0.514061 | 40 | 3200 | 8 |
| 42 | Polyline | 47930761 | major arterial | 1 | 0 | 2443.638036 | 3.664724 | 40 | 3200 | 8 |
| 43 | Polyline | 47930768 | major arterial | 1 | 0 | 2337.578142 | 3.505666 | 40 | 4800 | 12 |
| 44 | Polyline | 47930769 | secondary | 1 | 0 | 80.465267 | 0.160898 | 30 | 2800 | 7 |
| 45 | Polyline | 47930771 | major arterial | 1 | 0 | 8710.971284 | 6.531922 | 80 | 2940 | 7.35 |
| 46 | Polyline | 47930772 | minor arterial | 0 | 0 | 28.93545 | 0.057859 | 30 | 2800 | 7 |
| 47 | Polyline | 47930788 | major arterial | 1 | 0 | 2246.883398 | 3.369651 | 40 | 4800 | 12 |
| 48 | Polyline | 47930807 | minor | 1 | 0 | 80.491915 | 0.160952 | 30 | 3200 | 8 |

(0 out of 347 Selected)

Main Hilla road network

Figure 3.19 Part of the data set of links attributes.

3.4.5 Database of nodes shapefile

The database of nodes layer contained the number and the geographic coordinate of nodes (E and N). An example of these attributes is shown in Table 3.6 and Figure 3.20, these were inserted in the attributed table of nodes layer. The attribute of nodes is necessary for network analysis of road networks for the study area.

Table 3.6 Part of nodes and intersections attributes

| ID | (E) Coordinate (m) | (N) Coordinate (m) |
|-----------|---------------------------|---------------------------|
| 1 | 436139.1283 | 3600456.92 |
| 2 | 436141.0173 | 3600477.75 |
| 3 | 438124.541 | 3600009.606 |
| 4 | 438130.1589 | 3600022.11 |
| 5 | 439712.8469 | 3599185.417 |
| 6 | 439725.4014 | 3599203.8 |
| 7 | 440602.8152 | 3598637.465 |
| 8 | 440616.5074 | 3598654.644 |
| 9 | 440616.762 | 3598627.904 |
| 10 | 440629.2453 | 3598645.523 |
| 11 | 441903.7714 | 3592167.039 |
| 12 | 441911.7366 | 3592153.65 |
| 13 | 442073.3339 | 3597803.064 |
| 14 | 442081.7601 | 3597821.074 |
| 15 | 442138.7433 | 3592219.003 |
| 16 | 442138.745 | 3592218.992 |
| . | . | . |
| 642 | 461072.6777 | 3600639.504 |

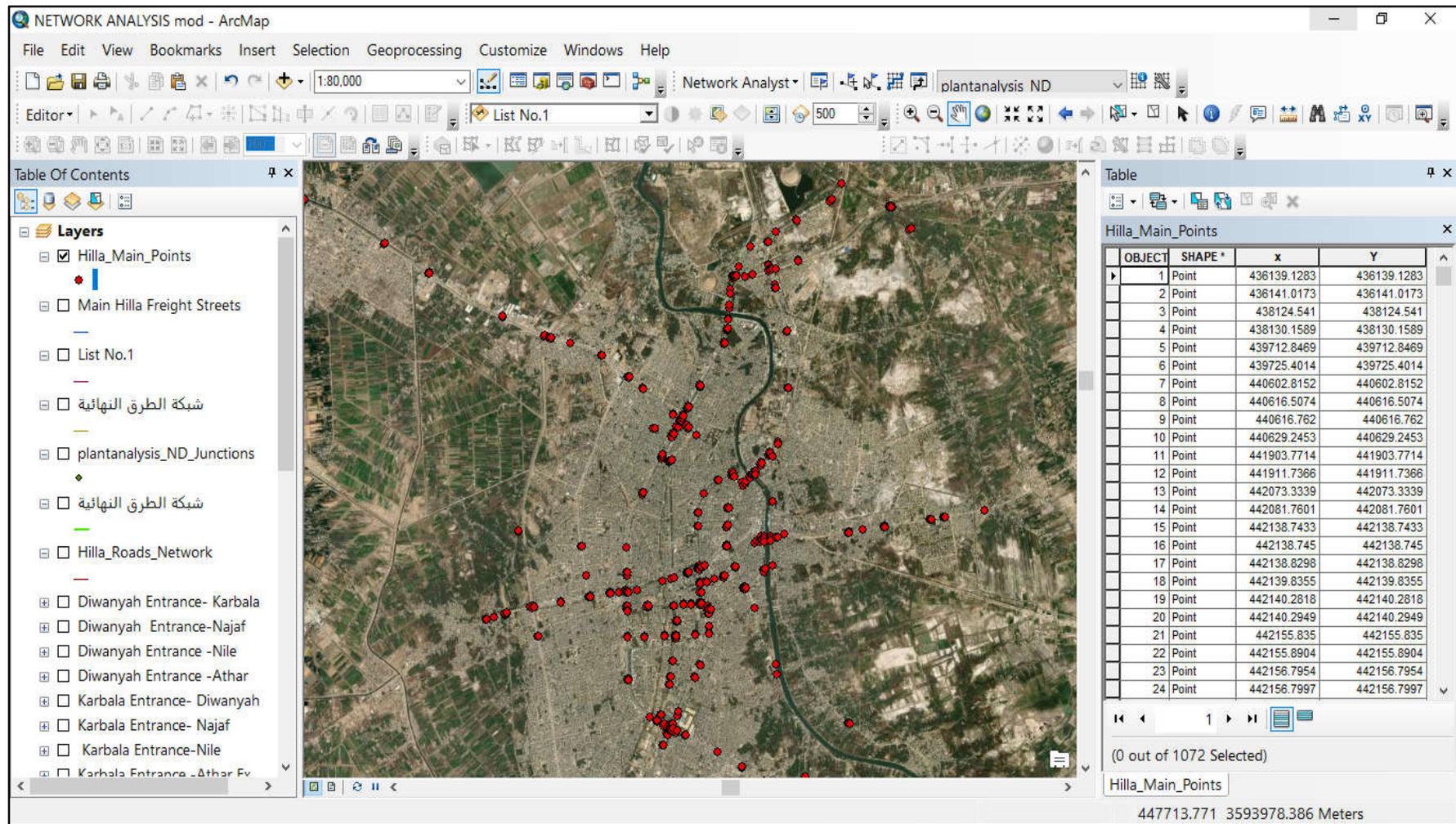


Figure 3. 20 Layer of nodes of Hilla city fright road network.

3.4.6 Applying the network topology to the layers of the road network

After completing the drawing of the road network with all its details, the topological correction features available in the ArcGIS10.4 software is activated, it is to provide a difficult automated method for cleaning and validating data entry errors. By digitizing all the lines, building the structure, naming the polygons, then cleaning up the splinters, protrusions, and extra lines, and building the structure again, according to a set of rules and laws imposed by the program and repeating the cleaning and building stages as many times as necessary.

One of the most important rules that have been applied to the road network of Hilla city, which was drawn previously, are (Must not overlap, must not intersect, must not have dangles, must not be a single part, and must be inside)

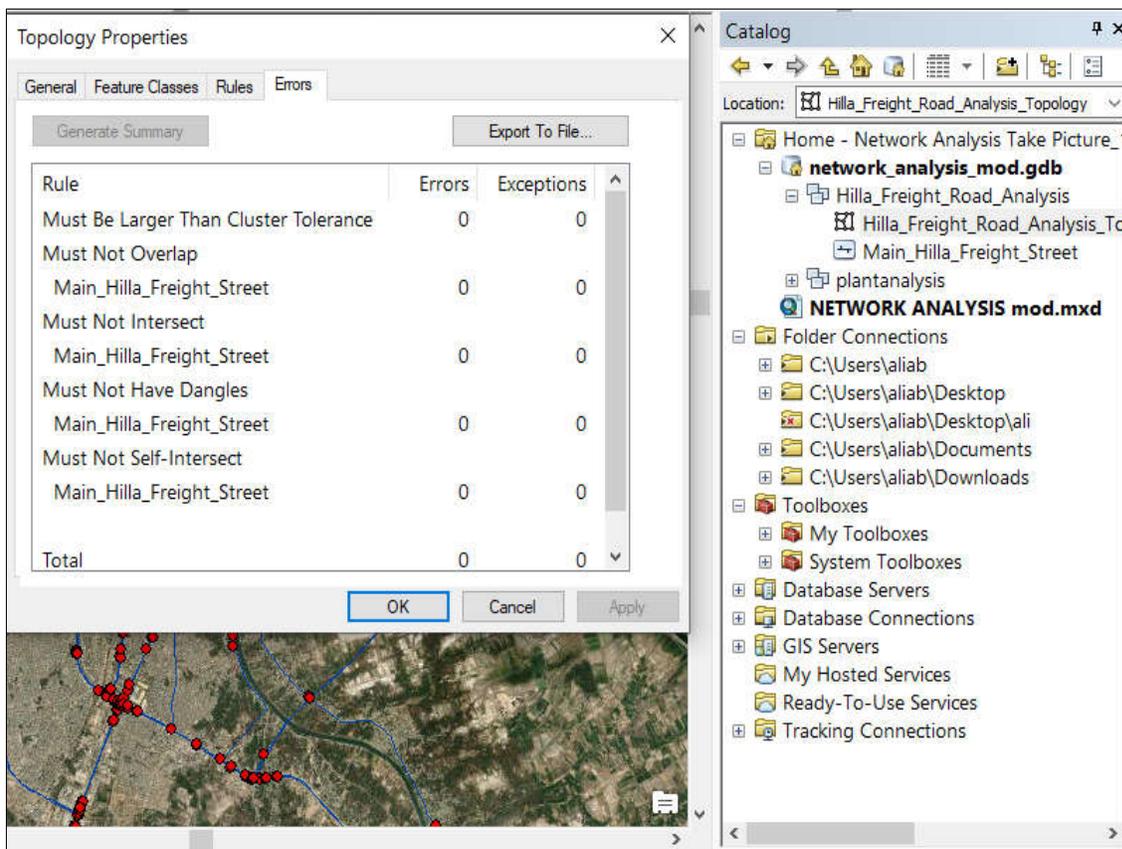


Figure 3.21 Topology error window in ARC GIS program.

After applying all the above rules, the sum of the errors shown in the drawing must be equal to zero as an indication that the required corrections have been made as shown in Figure 3.21 above.

3.5 Analysis of the Hilla road network using statistical methods and the ArcGIS program.

The first step in analyzing the road network is to transform it into a topological network consisting of a group of nodes and links. The nodes have spatial locations. The links represent the connections between these nodes. Where the arrangement and connection of nodes and links within a network are called a topology.

Many scales and indicators are used to assess topology, the most important of which are graph-theoretical scales, which can be used to assess the configuration of a transport system depending on some indicators and statistical measures such as connectivity and coverage.

3.5.1 Connectivity

Connectivity measures evaluate the intensity of connections between road segments. Connectivity refers to directness of travel between destinations. A well-connected network has many short links, numerous intersections, and minimal dead-ends providing continuous, direct routes to destinations.

There are some quantitative indicators to measure the connectivity of networks using the graph theory, including the Beta Index, Alpha Index, and Gamma Index.

The following is the result of applying the Connectivity equations (which explained in chapter two previously) to the road network of Hilla city.

- Number of link(e) =898
- Number of nodes (v) =642

1- Beta index (β)

$$\beta \text{ index} = \frac{e}{v} = \frac{898}{642} = 1.39$$

The value of the beta index from the above equation is (1.39), which indicates that the network is interconnected and integrated according to this indicator. However, this indicator is used in networks where the lines are not crowded within a narrow urban range, so it is not considered an acceptable basis for relying on it in analyzing the degree of network interconnection (Aziz M., 2003).

2- Alpha Index (α)

$$\alpha = \frac{e - (v - 1)}{2(v - 5)} = \frac{898 - (642 - 1)}{2(642 - 5)} = 0.2$$

3- Gamma index (γ)

$$\gamma = \frac{e}{3(v - 2)} = \frac{898}{3(642 - 2)} = 0.47$$

Table 3.7 Connectivity result for Hilla road network.

| No. | Index type | Index limit | Result | Notes |
|-----|----------------|-------------|--------|-----------------------------------|
| 1 | β index | 0-1 | 1.39 | Neglectable value (out of ranges) |
| 2 | α index | 0-1 | 0.2 | Poor connectivity |
| 3 | γ index | 0-1 | 0.47 | Poor connectivity |

According to the above results, Hilla city's road network needs to be expanded and improved by constructing more road links to increase the network's adequacy and degree of connectivity while achieving balanced regional development between all urban nodes and full coverage of the city.

3.5.2 Coverage

The coverage measure describes the density of the network. It is one of the important criteria that shows the efficiency of the network and gives a reflection on the economic development of cities. So that when the network density is high, this indicates that the city has a good network. Conversely, if the density is low, it means that there is a shortage in parts of the city and that the network is weak. The network density is one of the simplest quantitative methods, and it is expressed by the length of the network concerning the unit of area or the number of the population, but measuring the density of the network depending on the proportion of the population gives a more accurate and important indicator than calculating it depending on the area because the population is the users of roads and is considered the operator of economic resources and the growth of commercial activity.

The road network density is calculated as follows:

$$\text{Network Density} = \frac{L}{P_o} * 100000$$

Where:

L = Total Length of roads in (Km) and it equals 2345 Km.

P_o = Population of Hilla city and it equals 645016 persons.

$$\text{Hilla Network Density} = \frac{2345}{645016} * 100000 = 364$$

The value of the network density for the city of Hilla from the above equation is (364) per 100 thousand inhabitants, and it is considered a low density when compared to the international standards included (496 km) per 100 thousand inhabitants (**Falih K., 2016**). This is due to several reasons, the most important of which is the increase in the population of the city of Hilla and the lack of adding new roads to the road network.

Chapter 4

Analysis Results and Discussions

4.1 Arc GIS network analysis

The effectiveness of road networks has a significant impact on people's living standards and the distribution of services and goods. As a result, analyzing road networks is one of the most important tasks that must be completed to keep up with the rapid growth of the population and their needs (**Qasim Z.et al., 2018**).

The ArcGIS Network Analysis extension allows for the creation and analysis of effective plans for the transportation of goods, based on actual road variables such as length, width, travel time, speed, the direction of travel, etc. for both current and future road networks.

It performs an intelligent analysis of the transportation network and makes better decisions, to create strategic plans for the future. This saves time and money when creating and implementing the best route plans for the transportation network, as well as provided easier solutions for vehicle movement troubleshooting. And provide a practical analysis of the networks and express them in digital data, before connecting with that network over several processes that compute the needed pathways and show them to the people in a simple idea.

4.2 ArcGIS stages for freight travel analysis

After the freight road network of Hilla city has been created using the (Arc GIS10.4) software as described in the previous chapter, it is ready for analysis. The study will be separated into two parts. The first one is the analysis and determination of the optimal path between origin and destination points, while the second is to produce the original and destinations cost matrix (O-D Matrix). Figure 4.1 illustrates the two parts of the Hilla roads network analysis.

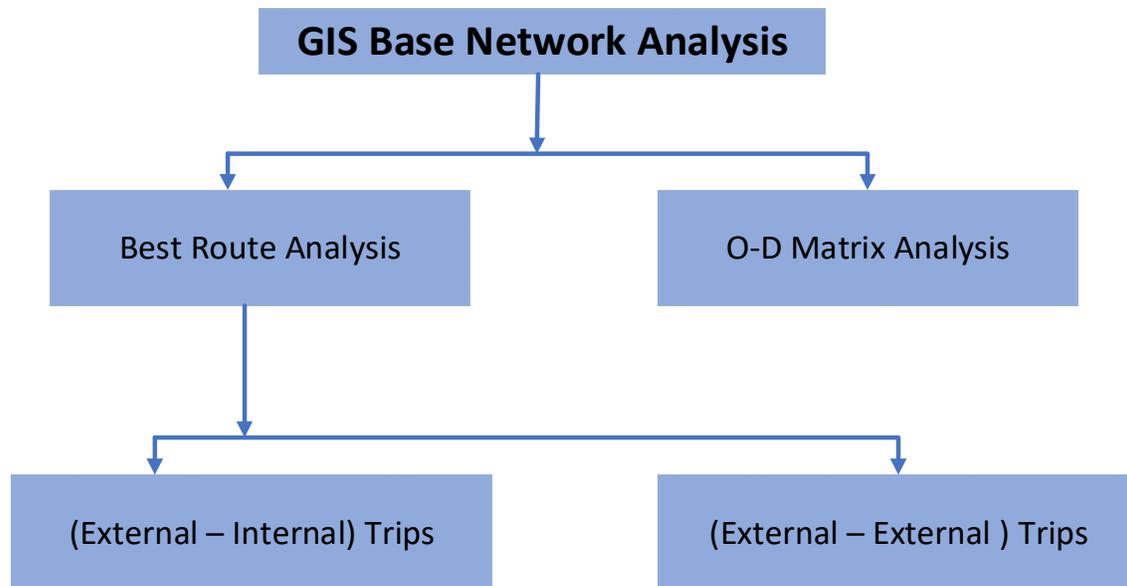


Figure 4.1 Network analysis process.

4.3 Best routes

Using the network analysis feature provided by the (Arc GIS10.4) program, the best route for the movement of freight vehicles is found from the main entrances of the city (the point of origin), which are considered fixed points for entry of freight vehicles (the destination points), which are different places based on the vehicles' destinations and according to this, the best routes are analyzed in two cases:

4.3.1 (External – Internal) trip:

It Includes freight vehicles that enter from each entrance of Hilla city towards the city center to unload their cargo, the most important commercial locations that could be a destination for freight vehicles inside the city center were determined based on the questionnaire that was conducted with the drivers of freight vehicles at the entrances to the city. These destinations were set on the map of the road network that was prepared by using (the Arc GIS10.4) program as listed below:

- **Destination to the (building material stores)**

Represented by the sites for selling construction materials spread on 80 Street (Al-Siklat), their locations were determined using the (GPS) device, and a unified location was assigned to them on the road network map. This site is considered the most important destination for freight vehicles that enter the city because most of the vehicles are loaded with construction materials.

- **Destination to the (Hilla Oil Depot):**

Hilla oil depot is a destination for vehicles loaded with petroleum products.

- **Destination to the (Al-Jebal Street) :**

Al-Jebal Street is considered a destination for vehicles loaded with foodstuffs and equipment, as there are stores for them in this area, in addition to the nearness of this site to the Great Hilla Market, trading locations at 40th and Al-Jemiyah Street, which are considered important commercial roads in Hilla city.

- **Destination to the (AL-Wardiyah Food Store):**

Destination for vehicles loaded with fruits and vegetables for the northern part of the city.

- **Destination to the (Babel Food Store):**

Destination for vehicles loaded with fruits and vegetables for the southern part of the city.

The results of the best routes analysis for the movement of freight vehicles from each entrance towards the city center are shown below:

4.3.1.1 Best route from Nile entrance towards the destination points in the city center

The Nile entrance is the northeastern entrance to the city of Hilla, and it is considered one of the most important entrances to the fact that the largest proportion of freight vehicles enter through it.

The measured traffic volume for the freight vehicles that enter and exit Hilla city through this entrance at peak hour are (325 and 319 Truck/hr) respectively.

The best routes are chosen by the geographic information system from this entrance (origin point) to each of five destination points in the city center taking into account the least distance and time required for freight vehicles to reach their target destinations as shown in the Figure 4.2. The properties of each route are illustrated in Table 4.1

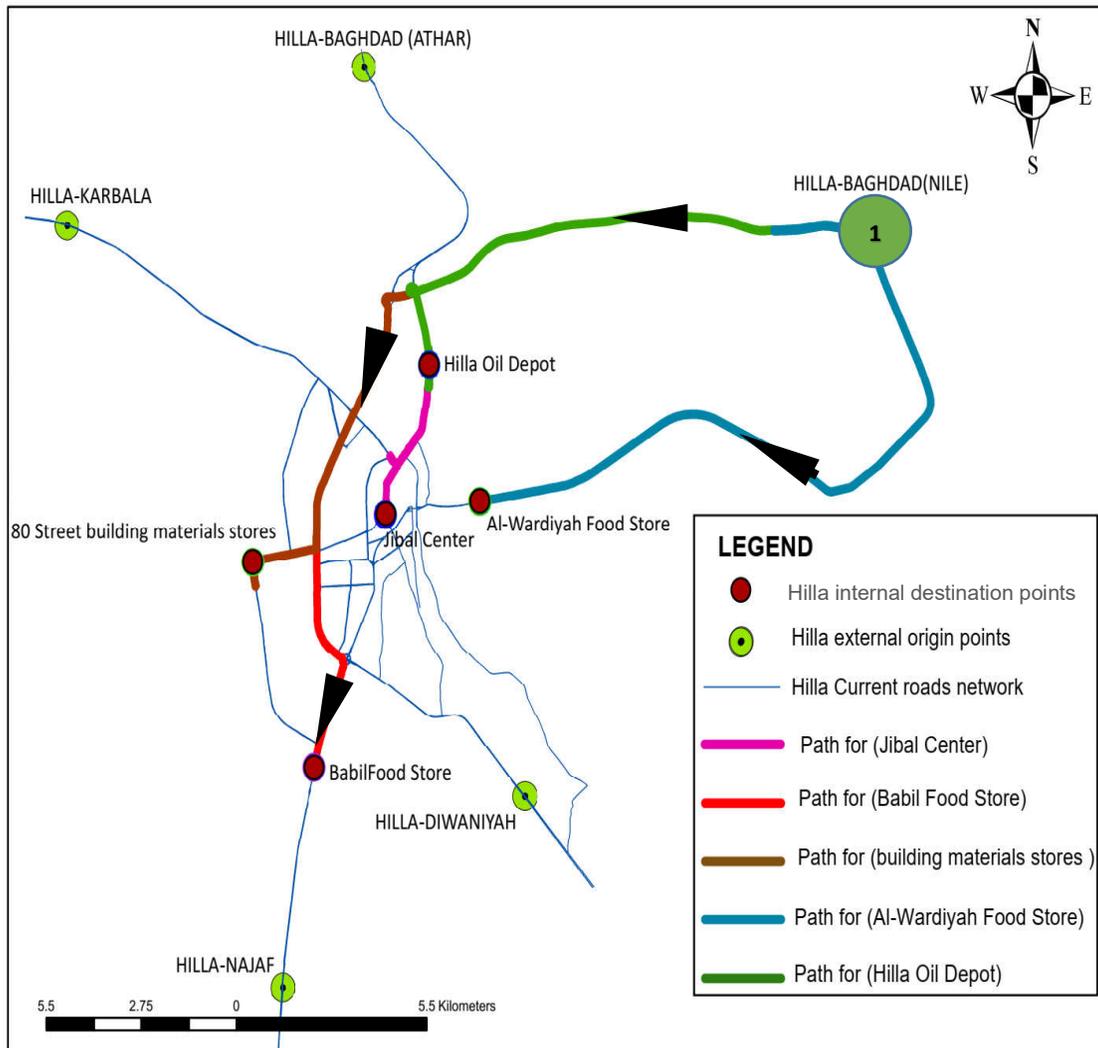


Figure 4.2 Best route from Nile entrance to suggested destination points.

Table 4.1 Route properties of Nile Entrance.

| Destinations | Nile Entrances | |
|----------------------------|----------------|-----------|
| | Distance (Km) | Time(min) |
| Jebal Street | 20.40 | 22 |
| Hilla oil depot | 16.90 | 17 |
| 80 St. Construction stores | 23.94 | 25 |
| Babel food store | 27 | 29 |
| Wardiyah food store | 25 | 28 |

Figure 4.3 represents the direction window of the (ArcGIS) program for the best route starting from the Nile entrance to the location of (80 St. Construction stores) passing through (Hilla -Kish, Hilla – Baghdad, 60 Street, and Tohmaziah) roads with a total length (23.9 km) and total time 25 min).

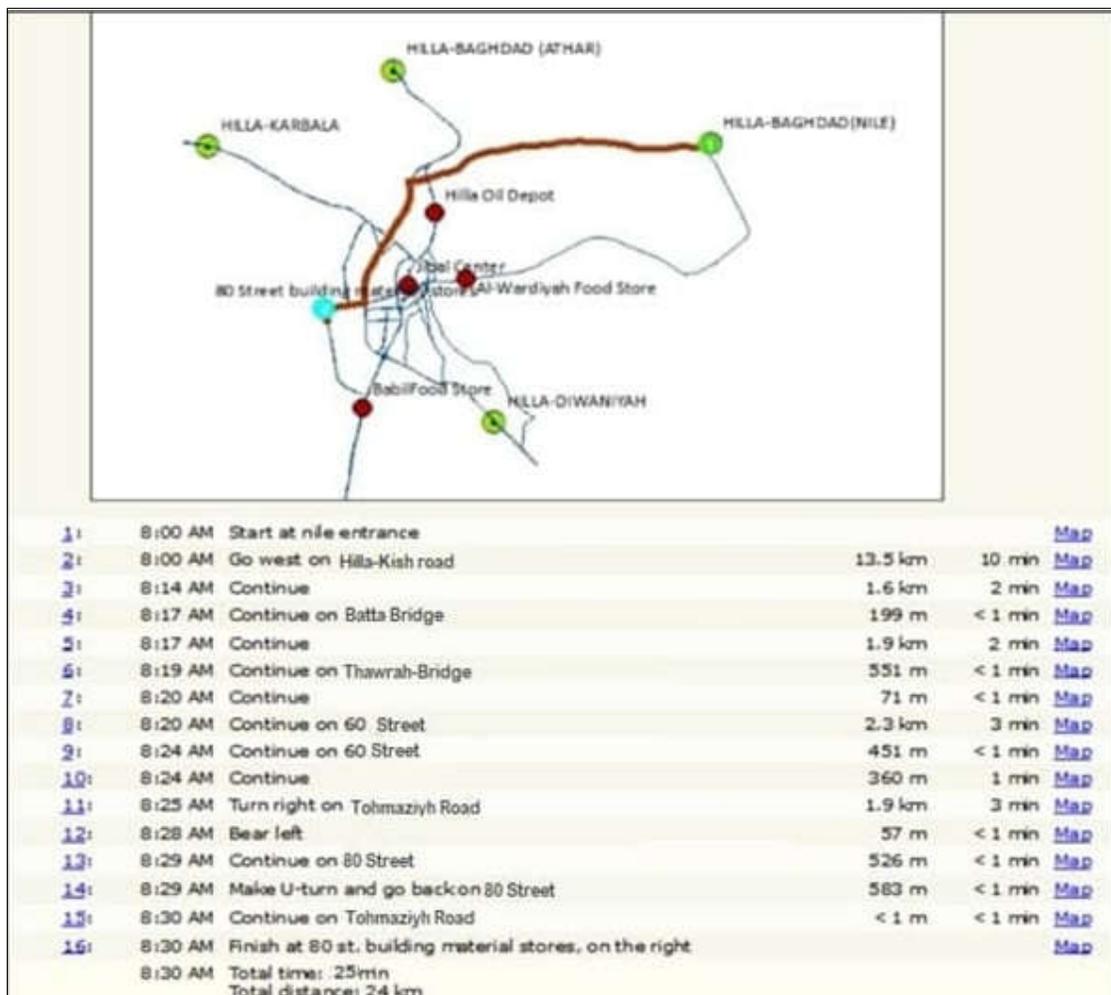


Figure 4.3 Direction of Nile entrance toward 80 street best route.

4.3.1.2 Best route from AL- Athar entrance towards the destination points in the city center

AL- Athar entrance is the second northern entrance, linking the city center with the northern governorates as well as the northern districts of Babylon province, where the measured traffic volume reached for freight vehicles at peak hour entering (125 Truck/hr) and exiting (161 Truck/hr), which is the least irrigated volume compared to other entrances.

The best routes are chosen by the geographic information system from this entrance (origin point) to each destination point in the city center as shown in the Figure 4.4. The properties of each route are illustrated in Table 4.2, taking into account the least distance and time required for freight vehicles to reach their target destinations in the city center.

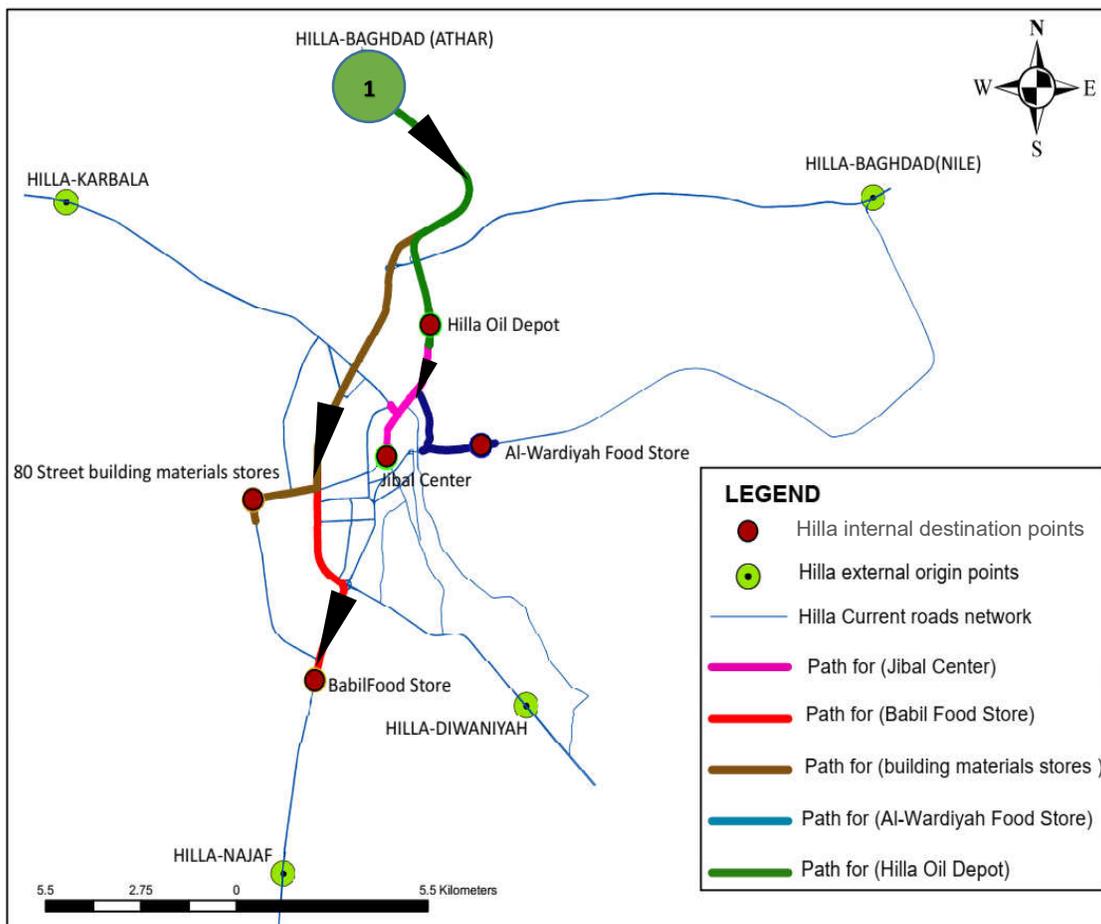


Figure 4.4 Best route from Athar entrance to suggested destination points.

Table 4.2 Route properties of Athar entrance.

| Destinations | Athar entrances | |
|----------------------------|-----------------|-----------|
| | Distance (Km) | Time(min) |
| Jebal street | 13.50 | 15 |
| Hilla oil depot | 10 | 10 |
| 80 St. construction stores | 17.20 | 19 |
| Babel food store | 19.70 | 23 |
| Wardiyah food store | 18 | 35 |

Figure 4.5 represents the direction of the route from AL- Athar entrance to the location of the Hilla oil depot passing through the (Hill-Baghdad) road, then south until reaching their destination with a total length (10 km), and total time (10min).

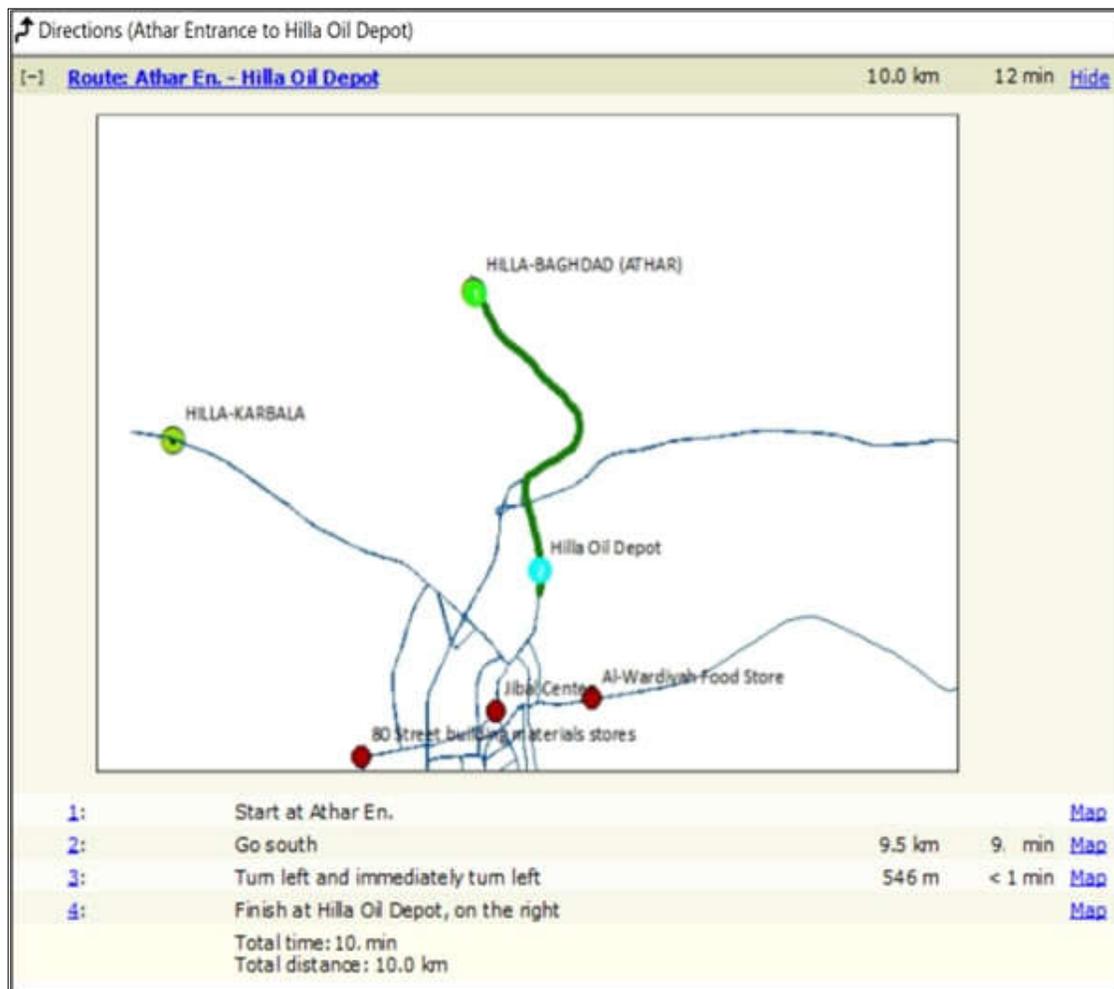


Figure 4.5 Direction of Athar entrance toward Hilla oil depot best route.

4.3.1.3 Best route from Karbala entrance towards the destination points in the city center

It is the northwestern entrance to the city, linking the city center of Hilla with the Hindiyh district and the city of Karbala, and it is an important entry through which a large number of freight vehicles loaded with construction materials pass. This is due to the presence of quarries of construction materials in the city of Karbala, the measured traffic volume at this entrance for freight vehicles at peak hour entering and leaving it is (290 and 300 Truck/hr) respectively. The result of the analysis best route for the movement of freight vehicles from this entrance (origin point) to each destination point in the city center is shown in the Figure 4.6 and the properties of each route are illustrated in Table 4.3 taking into account the least distance and time required for freight vehicles to reach their target destinations in the city center.

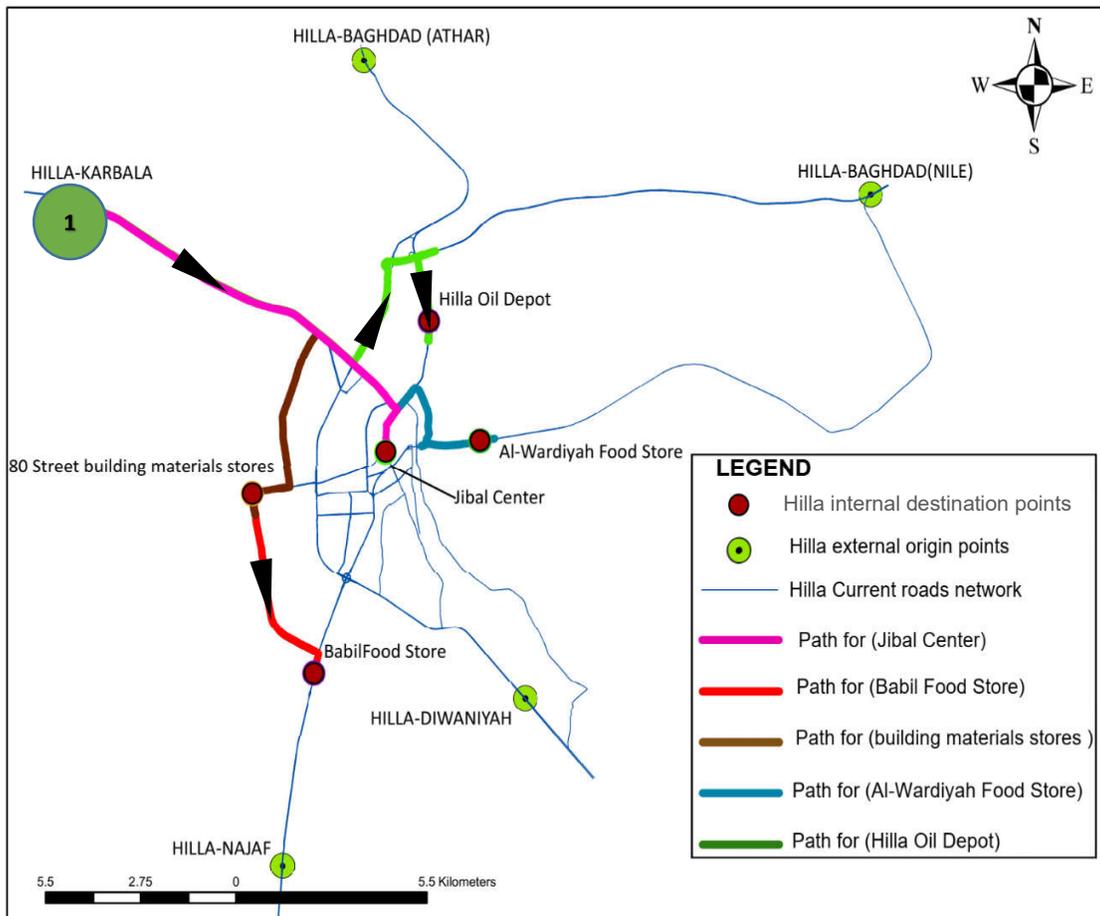


Figure 4.6 Best route from Karbala entrance to suggested destination points.

Table 4.3 Route properties of Karbala entrance.

| Destinations | Karbala entrances | |
|----------------------------|-------------------|-----------|
| | Distance (Km) | Time(min) |
| Jebal street | 12.60 | 14 |
| Hilla oil depot | 17.20 | 19 |
| 80 St. construction stores | 14.80 | 16 |
| Babel food store | 19.30 | 21 |
| Wardiyah food store | 16.40 | 20 |

Figure 4.7 represents the direction of a route from the Karbala entrance to the location of Babel food stores, passing through (Hill- Karbala, 80 Street, and Tohmaziah) roads with a total length (19.3km) and a total time of (21min).

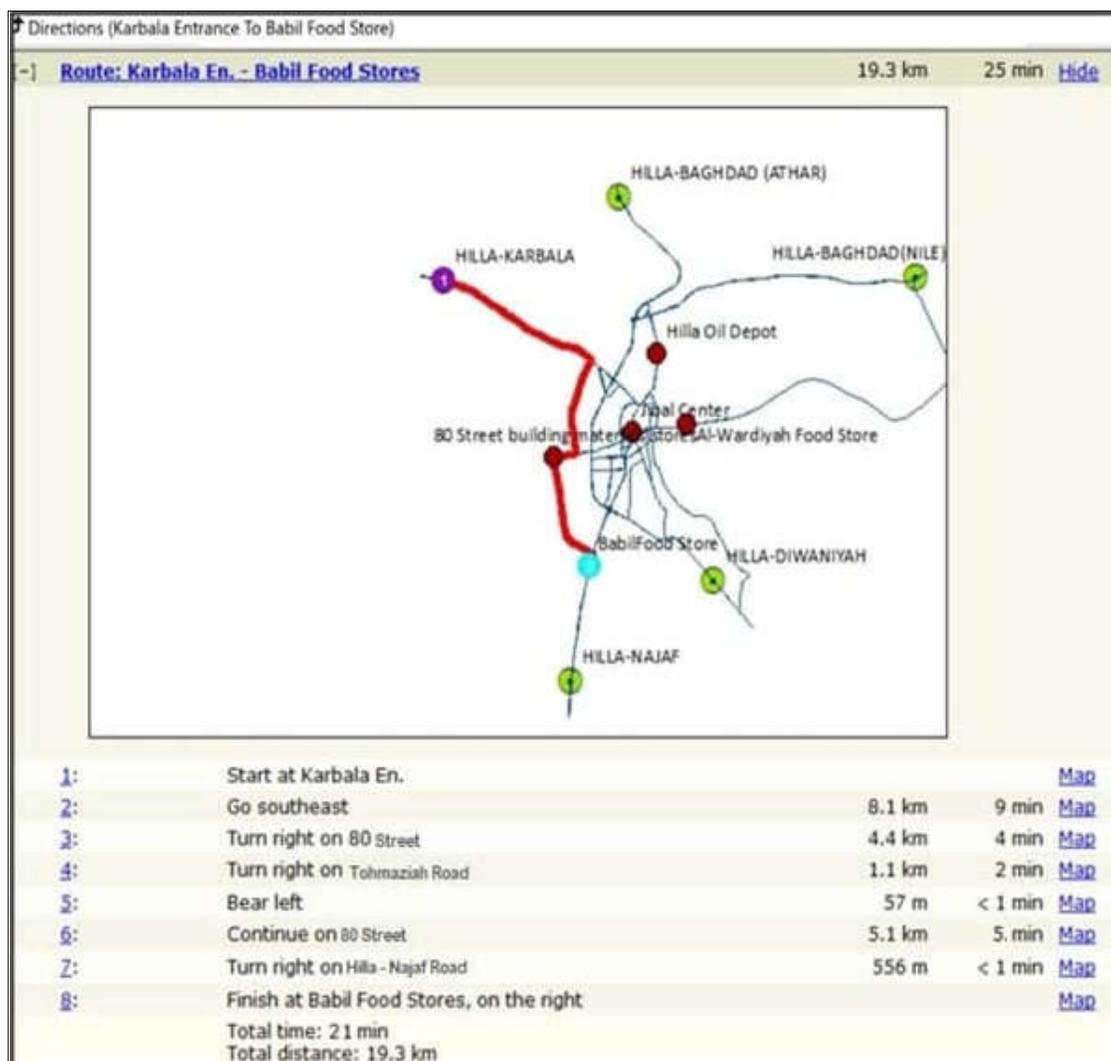


Figure 4.7 Direction of Karbala entrance toward Babel food store's best route.

4.3.1.4 Best route from Najaf entrance towards the destination points in the city center

Najaf entrance is the southern entrance linking Hilla city and the city of Najaf, as well as linking the Al-Kifl district with the city center, where the measured traffic volume at this entrance for freight vehicles at peak hour entering and leaving are (298 and 263 Truck/hr) respectively.

After performing the network analysis, the best routes from this entrance (origin point) to each destination point in the city center are shown in the Figure 4.8 and the properties of each route are illustrated in Table 4.4 taking into account the least distance and time required for freight vehicles to reach their target destinations in the city center.

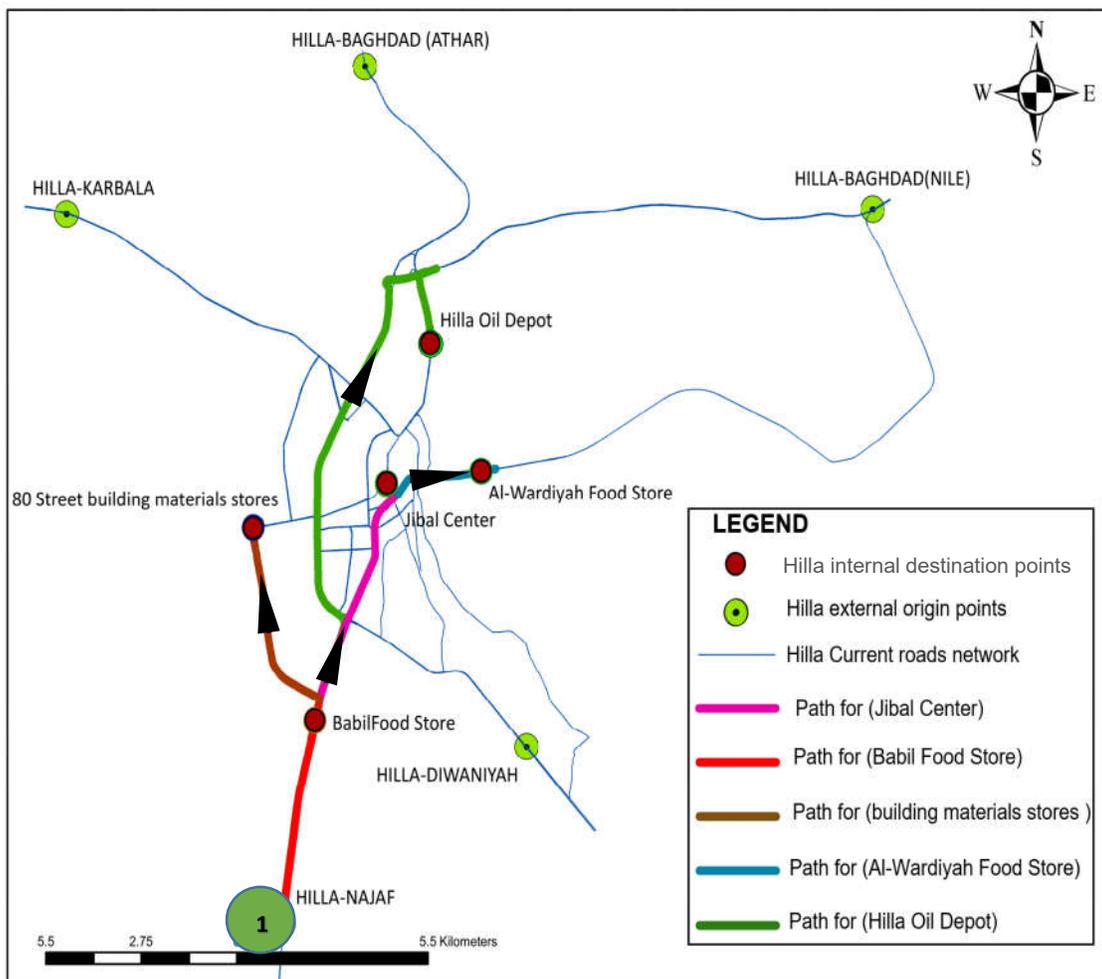


Figure 4.8 Best route from Najaf entrance to suggested destination points.

Table 4.4 Route properties of Najaf entrance.

| Destinations | Najaf entrances | |
|----------------------------|-----------------|-----------|
| | Distance (Km) | Time(min) |
| Jebal street | 11.80 | 16 |
| Hilla oil depot | 21 | 25 |
| 80 St. construction stores | 10.90 | 13 |
| Babel food store | 5.90 | 7 |
| Wardiyah food store | 15 | 21 |

Figure 4.9 represents the direction of a route from the Najaf entrance to the location of Jebal Passing through (Hilla -Najaf) road, then Nader Main Road with a total length (11.80 km) and total time (16 min).

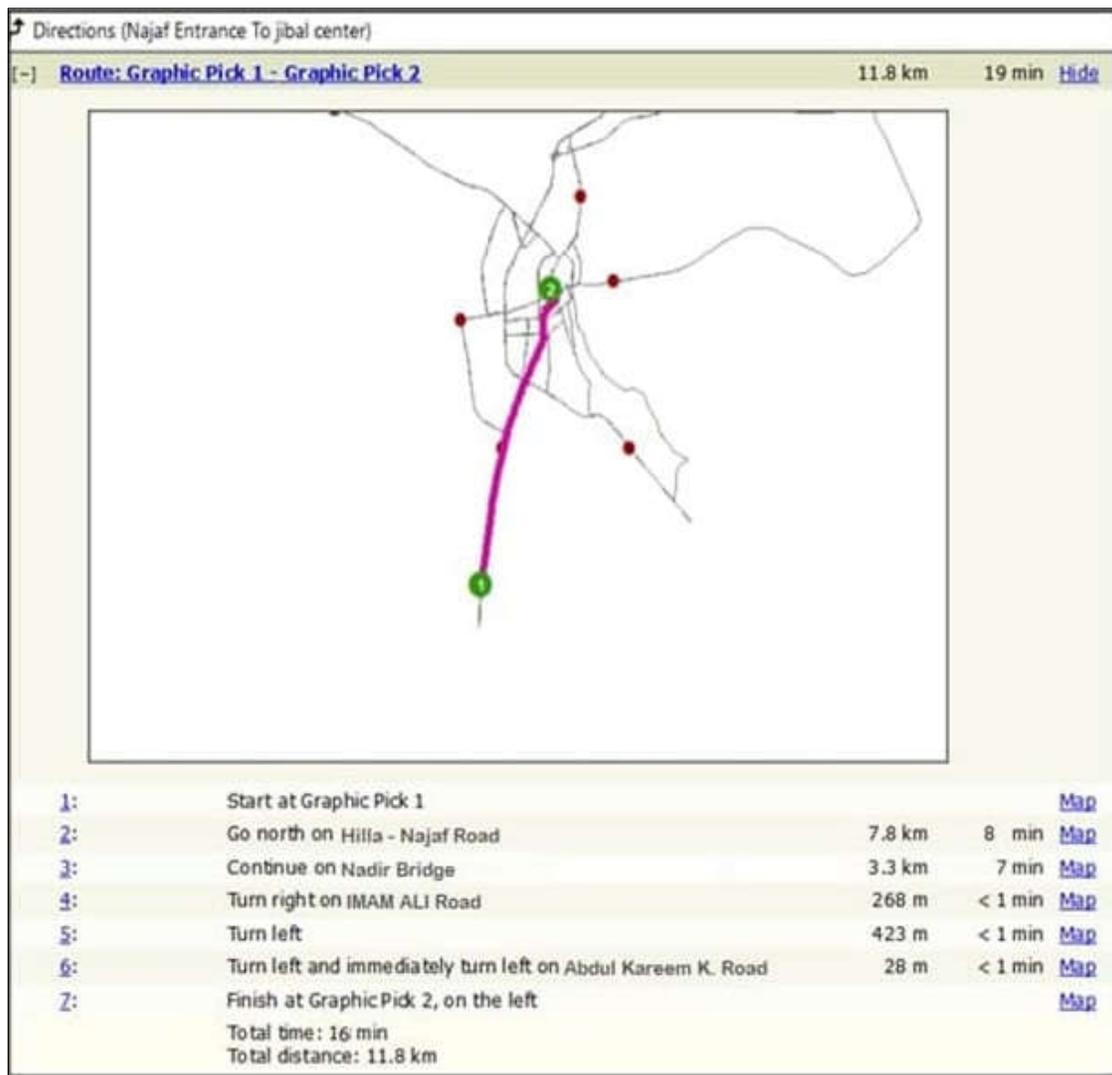


Figure 4.9 Direction of Najaf entrance toward Jebal best route.

4.3.1.5 Best route from Al-Diwaniyah entrance towards the destination points in the city center.

Al-Diwaniyah entrance is the southeastern entrance that connects Hilla city with the city of Diwaniyah, as well as linking the city center with the other southern districts of the Babylon province, where the measured traffic volume at this entrance for freight vehicles at peak hour entering and leaving are (185 and 151 Truck/hr) respectively.

The best routes are chosen by the geographic information system from this entrance (origin point) to each destination point in the city center shown in the Figure 4.10 and the properties of each route are illustrated in table 4.5 taking into account the least distance and time required for freight vehicles to reach their target destinations in the city center.

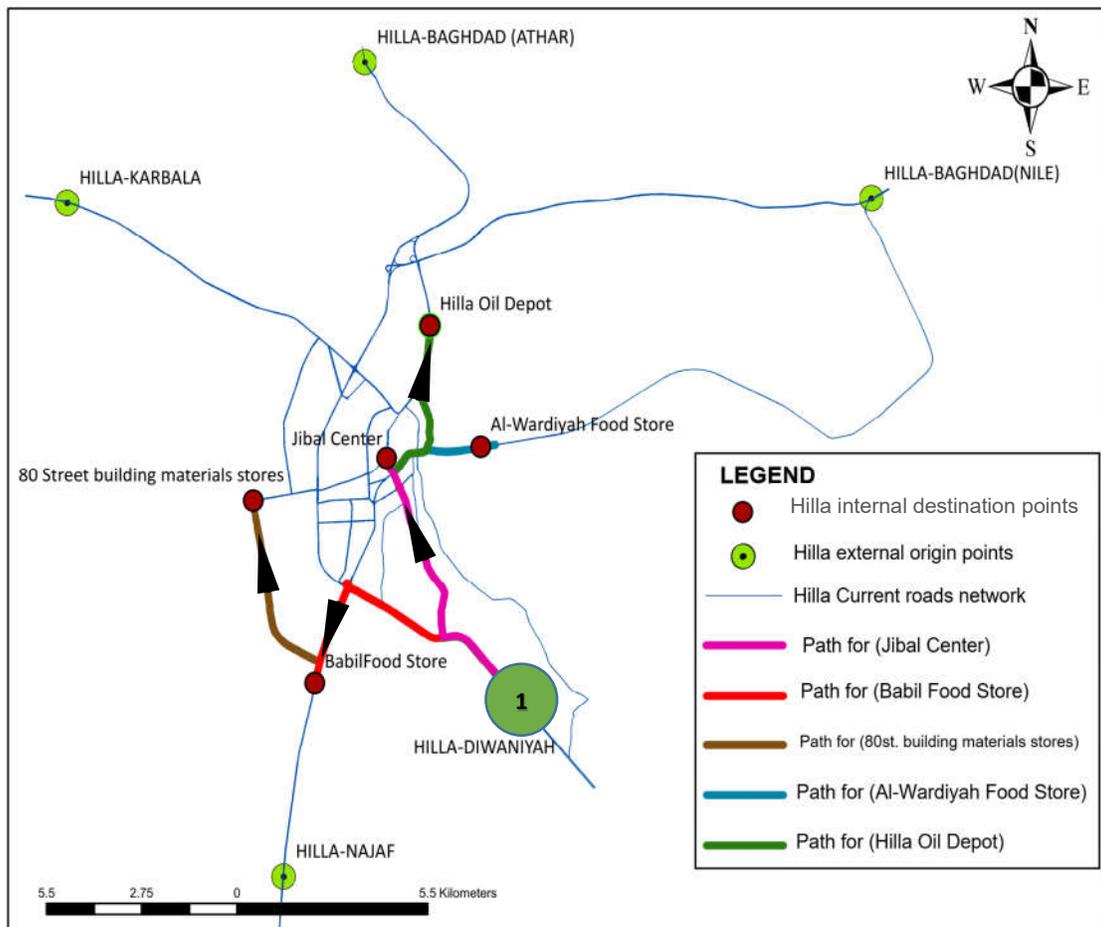


Figure 4.10 Best route from Al Diwaniyah entrance to suggested destination points.

Table 4.5 Route properties of Diwaniyah entrance.

| Destinations | Al Diwaniyah entrances | |
|----------------------------|------------------------|-----------|
| | Distance (Km) | Time(min) |
| Jebal street | 7.50 | 11 |
| Hilla oil depot | 11.8 | 19 |
| 80 St. construction stores | 12.80 | 14 |
| Babel food store | 8.40 | 9 |
| Wardiyah food store | 10.70 | 17 |

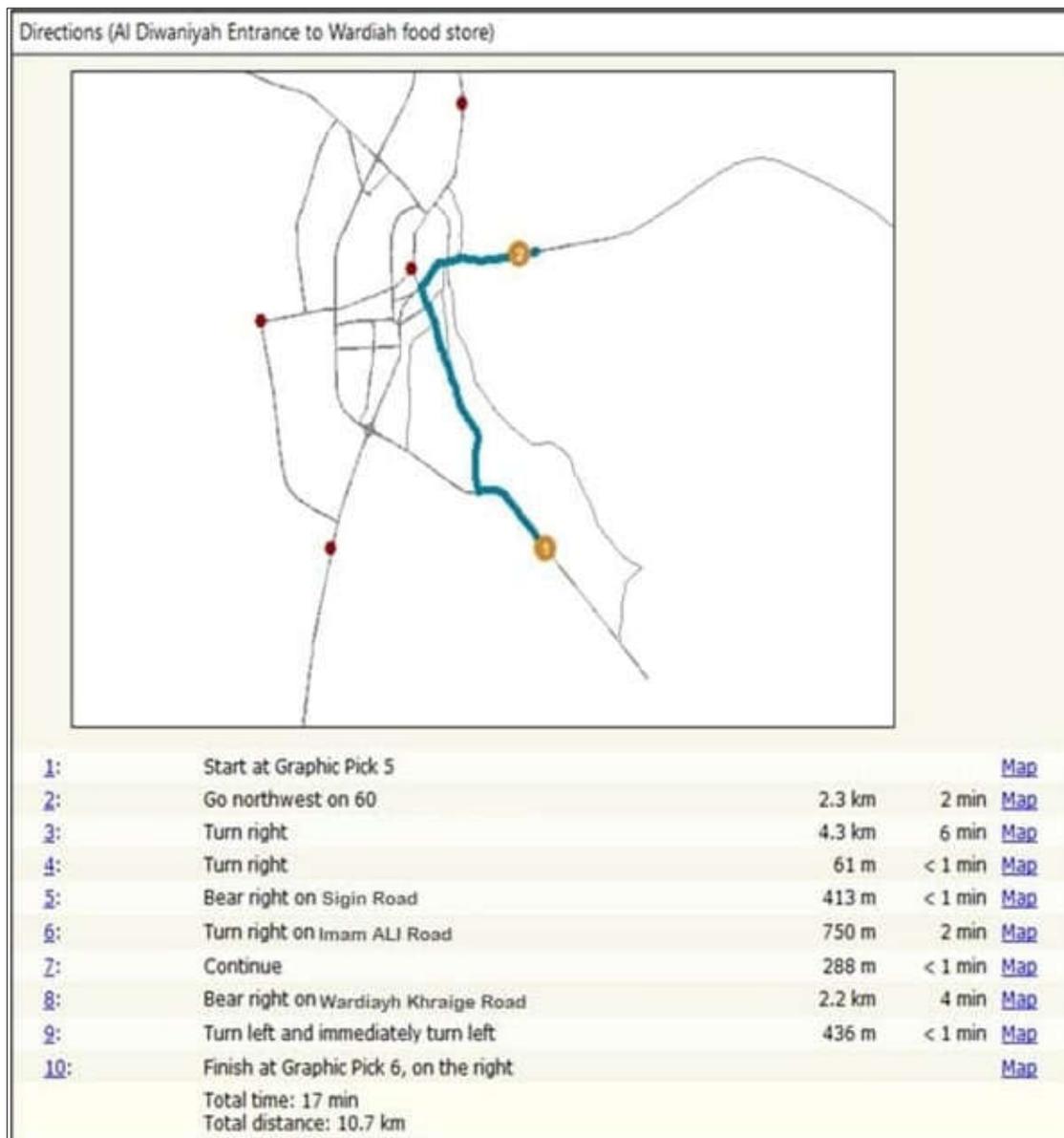


Figure 4.11 Direction of Diwaniyah entrance towards Wardiyah food store.

and Imam Ali, then to Wardiyah) roads, with a total length (10.70 km) and total time (17 min).

4.3.2 (External – External) trip:

Represents the freight vehicles that enter Hilla city for transiting to other districts of Babylon province and the neighboring governorates through Hilla road network.

By using network analysis, the result of the best routes for freight vehicles from each entrance (representing the points of origin) towards other exits of Hilla city (representing the destination points) are shown below:

4.3.2.1 Best route from Nile entrance to another exit of Hilla city

The volume of freight traffic measured at the Nile entrance at peak hour is (325 veh / hr). According to the questionnaire, the percentage of freight vehicles entering the city of Hilla to unload their cargo in the city center (41%) and the remaining (59%) entering the city for going to its destinations located outside Hilla city. The result of best routes analysis by ArcGIS network analysis tool is shown in the Figure 4.12 and the properties of each route are illustrated in Table 4.6.

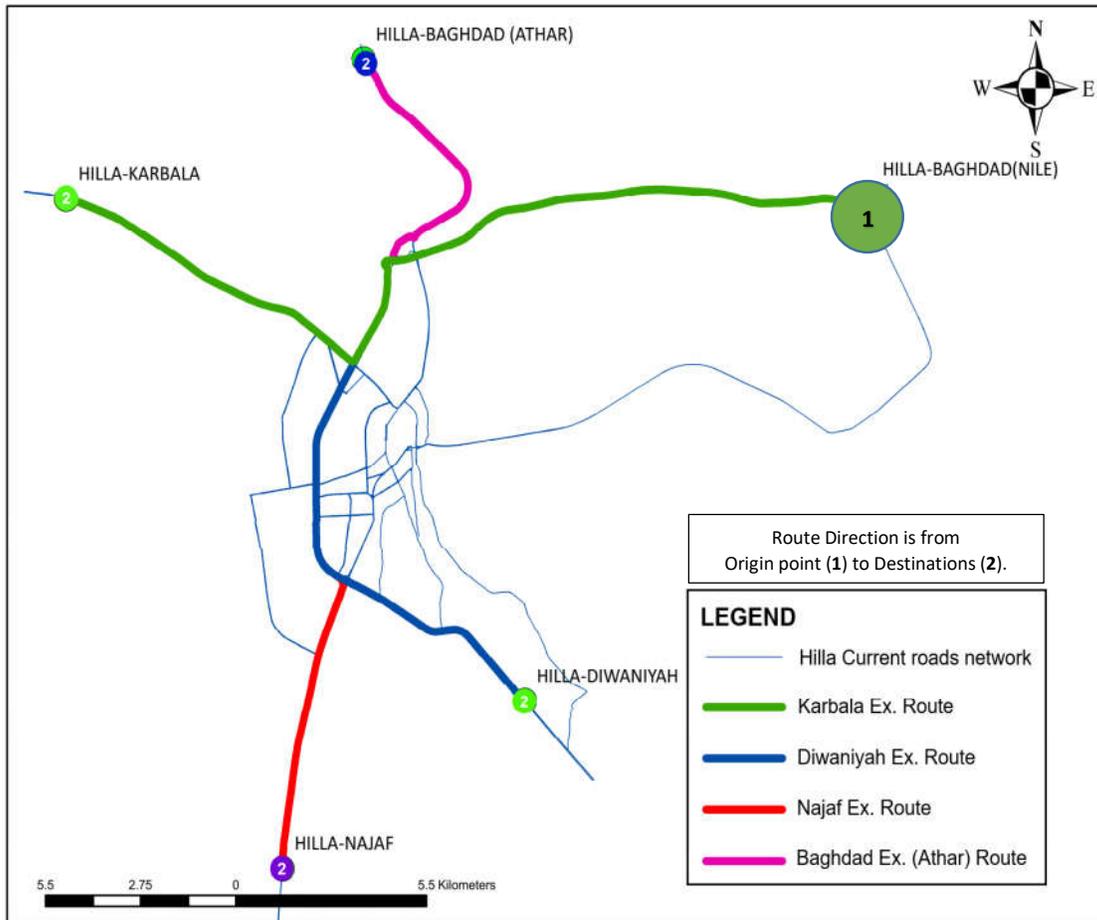


Figure 4.12 Best route from Nile entrance to exterior destination points.

Table 4.6 Properties of Nile entrance- Ex. destination points routes

| Destinations | Nile entrances | |
|---------------|----------------|-----------|
| | Distance (Km) | Time(min) |
| Nile Ex. | 0 | 0 |
| Athar Ex. | 22 | 20 |
| Karbala Ex. | 27 | 26 |
| Najaf Ex. | 32 | 34 |
| Diwaniyah Ex. | 29 | 30 |

4.3.2.2 Best route from Athar entrance to another exit of Hilla city

The measured traffic volume at Athar entrance for freight vehicles at peak hour is (125 veh/hr) and according to the questionnaire, the percentage of freight vehicles entering the city of Hilla to unload their cargo in the city center is (33%) and the remaining (67%) enter the city for going to its destinations located outside

Hilla city. The result of best routes analysis by ArcGIS network analysis tool is shown in the Figure 4.13 and the properties of each route are illustrated in Table 4.7.

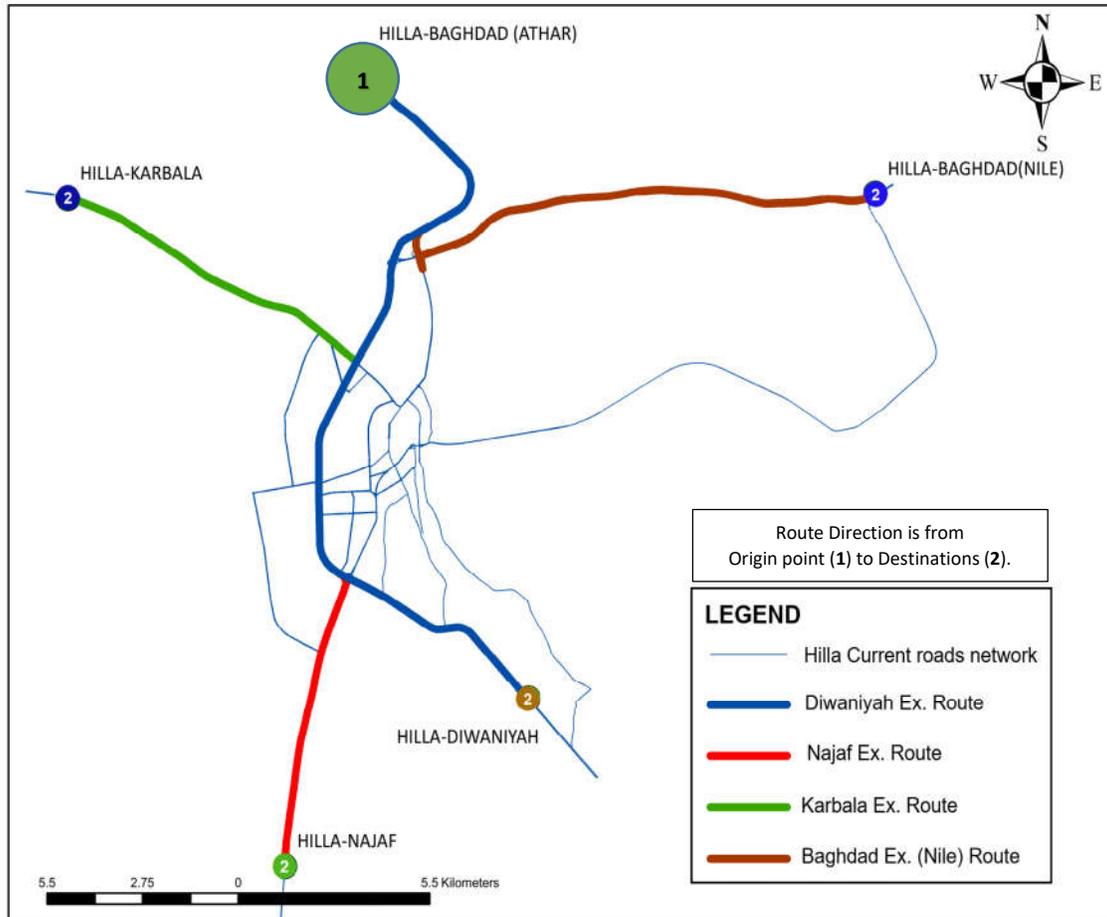


Figure 4.13 Best route from Athar entrance to exterior destination points.

Table 4.7 Properties of Athar entrance- Ex. destination points routes

| Destinations | Athar entrances | |
|---------------|-----------------|-----------|
| | Distance (Km) | Time(min) |
| Nile Ex. | 21 | 20 |
| Athar Ex. | 0 | 0 |
| Karbala Ex. | 20 | 19 |
| Najaf Ex. | 25 | 28 |
| Diwaniyah Ex. | 22 | 23 |

4.3.2.3 Best Rout from Karbala entrance to another exit of Hilla city

The measured traffic volume at Karbala entrance for freight vehicles at peak hour is (290 veh/hr) according to the questionnaire, the percentage of freight vehicles entering the city of Hilla to unload their cargo in the city center (32%) and the remaining (68%) enter the city for going to its destinations located outside Hilla city.

The result of best routes analysis by ArcGIS network analysis tool is shown in the Figure 4.14 and the properties of each route are illustrated in Table 4.8.

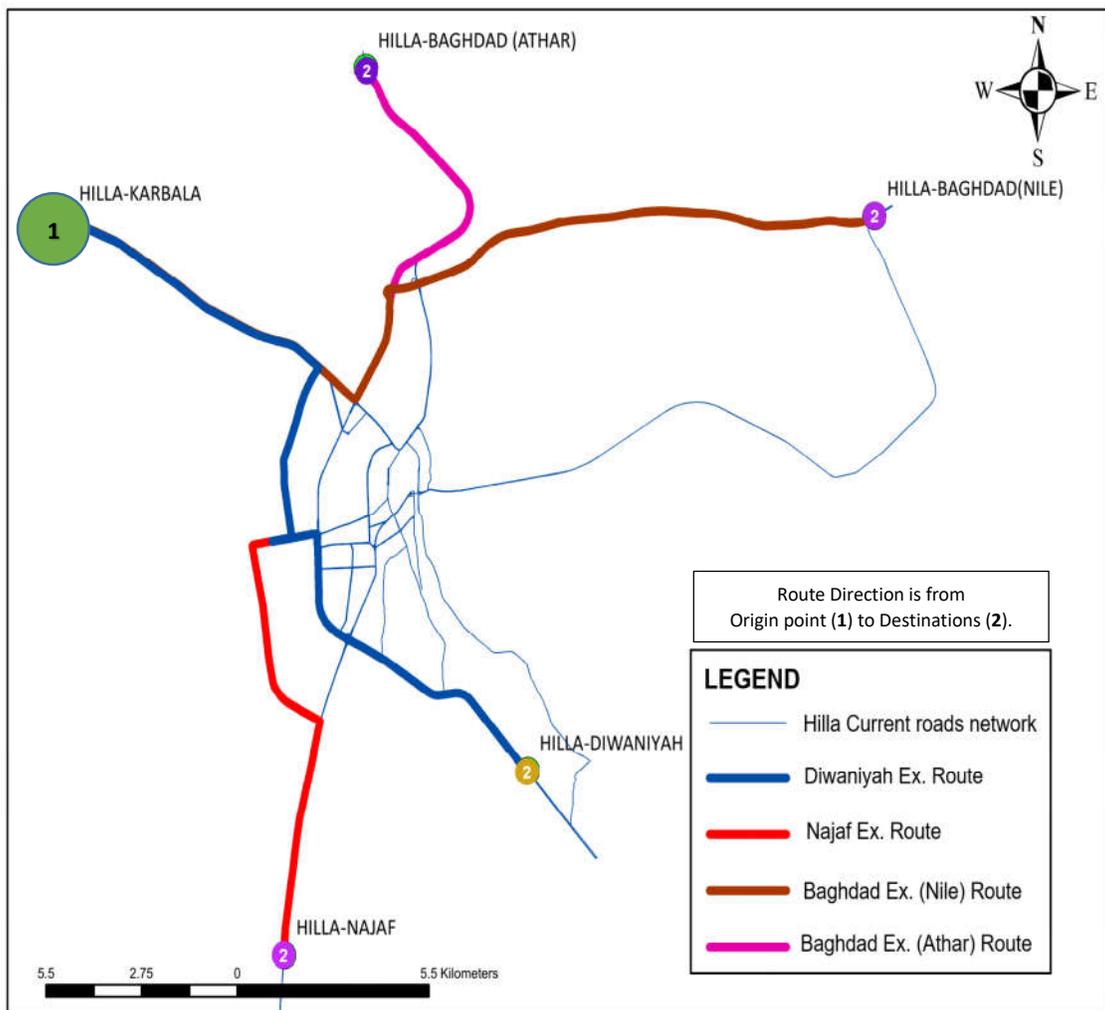


Figure 4.14 Best route from Karbala entrance to exterior destination points.

Table 4.8 Properties of Karbala entrance- Ex. destination points routes

| Destinations | Karbala entrances | |
|---------------|-------------------|-----------|
| | Distance (Km) | Time(min) |
| Nile Ex. | 27 | 26 |
| Athar Ex. | 20 | 19 |
| Karbala Ex. | 0 | 0 |
| Najaf Ex. | 25 | 27 |
| Diwaniyah Ex. | 23 | 25 |

4.3.2.4 Best route from Najaf entrance to another exit of Hilla city

The measured traffic volume at Najaf entrance for freight vehicles is (298 veh/hr) and according to the questionnaire, the percentage of freight vehicles entering the city of Hilla to unload their cargo in the city center (39%) and the remaining (61%) enter the city for going to its destinations located outside Hilla city.

The result of best routes analysis by ArcGIS network analysis tool is shown in the Figure 4.15 and the properties of each route are illustrated in Table 4.9.

Table 4.9 Properties of Najaf entrance- Ex. destination points routes

| Destinations | Najaf entrances | |
|---------------|-----------------|-----------|
| | Distance (Km) | Time(min) |
| Nile Ex. | 29 | 30 |
| Athar Ex. | 25 | 28 |
| Karbala Ex. | 25 | 27 |
| Najaf Ex. | 0 | 0 |
| Diwaniyah Ex. | 13 | 15 |

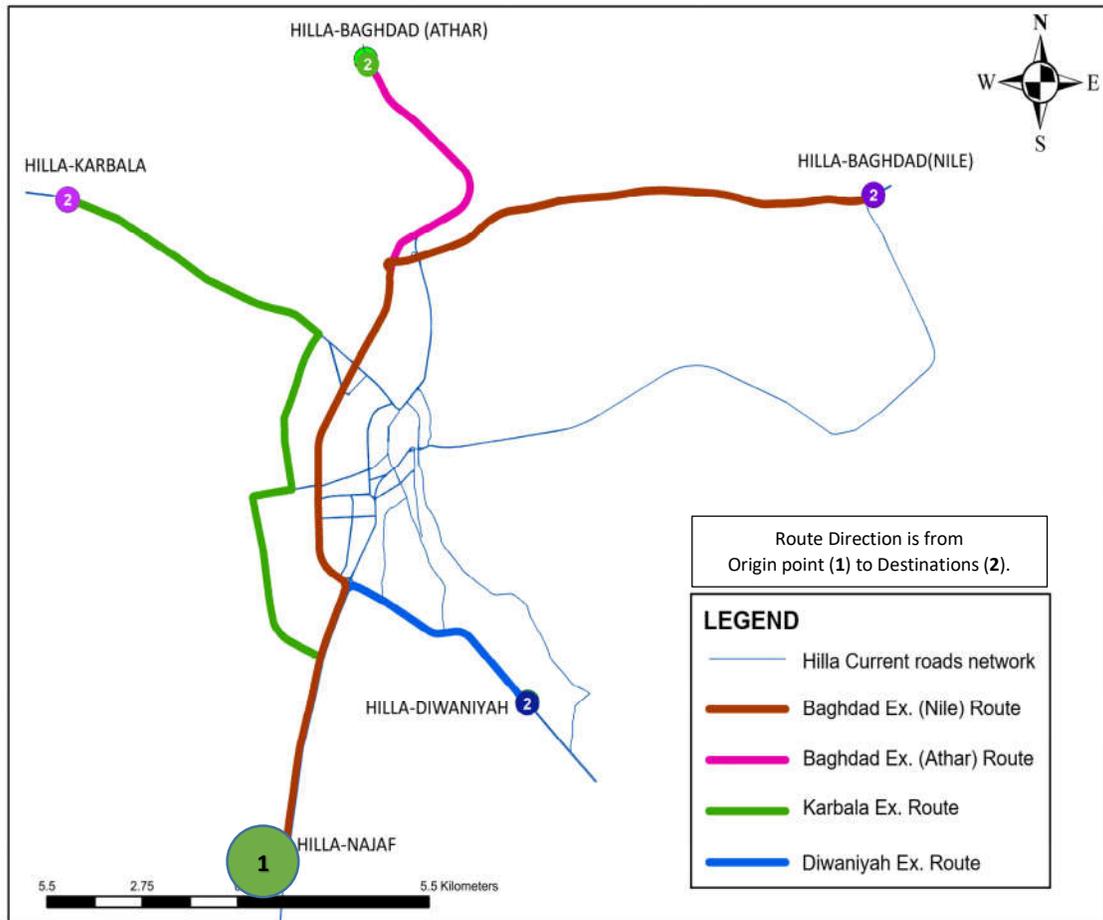


Figure 4.15 Best route from Najaf entrance to exterior destination points.

4.3.2.5 Best route from Diwaniyah entrance to another exit of Hilla city

The measured traffic volume at Diwaniya entrance for freight vehicles is (185veh/hr) and according to the questionnaire, the percentage of freight vehicles entering the city of Hilla to unload their cargo in the city center (40%) and the remaining (60%) enter the city for going to its destinations located outside Hilla city.

The result of best routes analysis by ArcGIS network analysis tool is shown in the Figure 4.16 and the properties of each route are illustrated in Table 4.10.

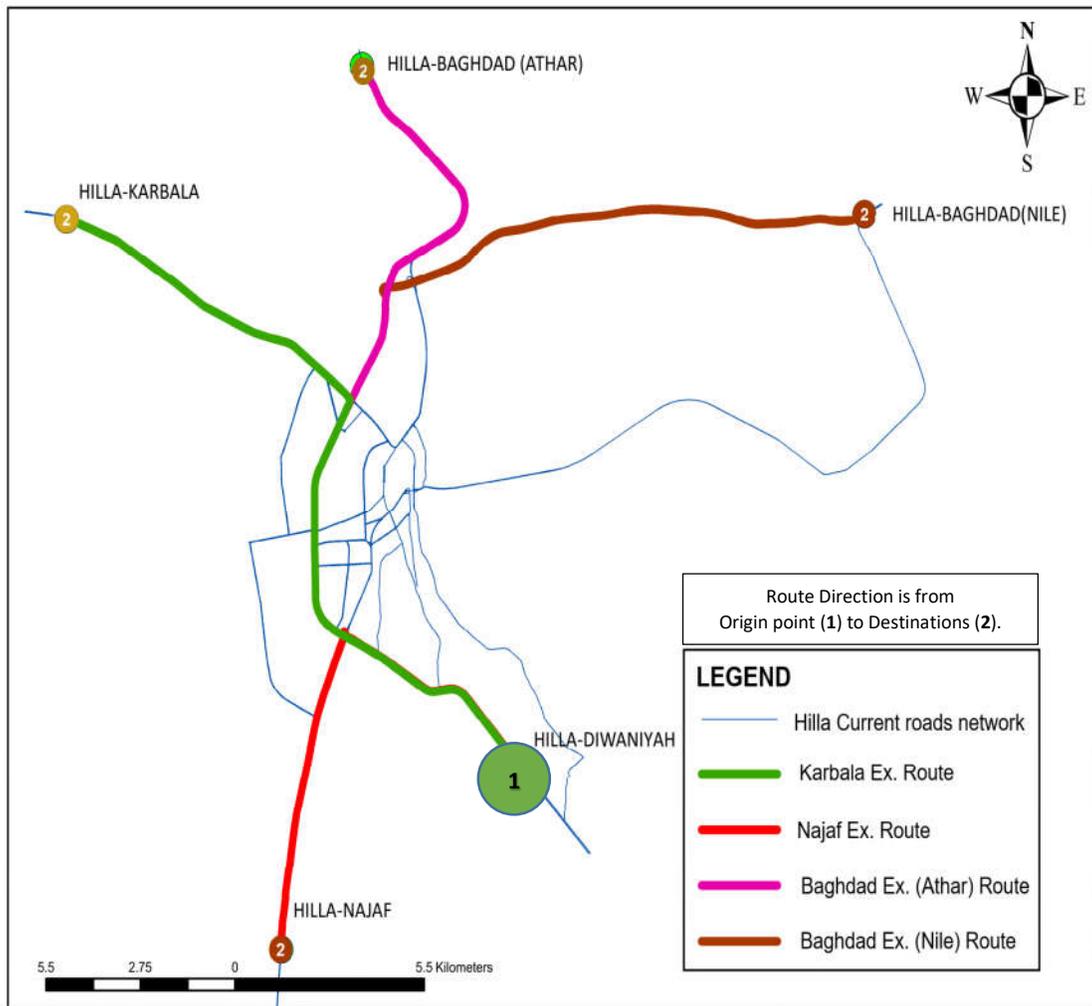


Figure 4.16 Best route from Diwaniyah entrance to exterior destination points.

Table 4.10 Properties of Diwaniyah entrance- Ex. destination points routes

| Destinations | Diwaniyah entrances | |
|---------------|---------------------|-----------|
| | Distance (Km) | Time(min) |
| Nile Ex. | 32 | 34 |
| Athar Ex. | 22 | 23 |
| Karbala Ex. | 23 | 25 |
| Najaf Ex. | 13.2 | 15 |
| Diwaniyah Ex. | 0 | 0 |

4.4 Generating a cost matrix for (origin and destination)

It is a matrix that shows the journey time and distance from each source to each destination. Five places at the city's entrances were chosen as originating points for freight trucks, while five locations in the city center were selected as unloading vehicle destination points. The matrix's findings may be used to identify the pathways that will be activated from each location. After the analysis procedure (Network Analysis), the result was shown in the Figures 4.17, and [Table 4.11](#).

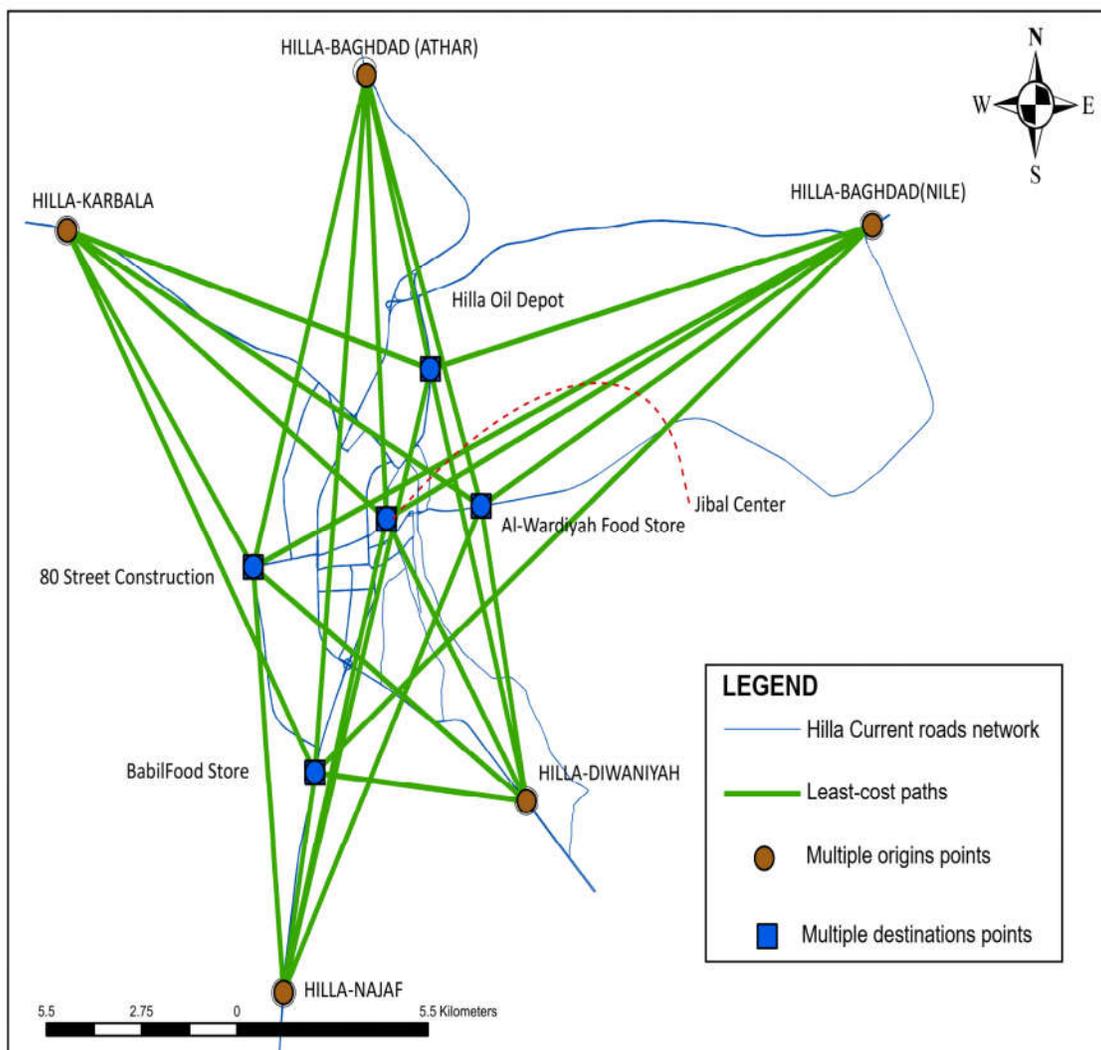


Figure 4.17 The resulting routes for least-cost paths along with the network from multiple origins to multiple destinations (O-D matrix)

Table 4.11 Lines attribute table of the O-D matrix

| Object ID | Shape | Name | Origin ID | Destination ID | Destination Rank | Total Length | Total Time |
|-----------|----------|---------------------------------|-----------|----------------|------------------|--------------|------------|
| 126 | Polyline | NILE - HILLA OIL DEPOT | 1 | 5 | 1 | 16.948306 | 17.195000 |
| 127 | Polyline | NILE - JIBAL | 1 | 3 | 2 | 20.403165 | 21.965000 |
| 128 | Polyline | NILE - WARDIYAH FOOD STORE | 1 | 4 | 3 | 25.14265 | 28.219000 |
| 129 | Polyline | NILE - 80 STREET CON. | 1 | 2 | 4 | 23.944700 | 24.861000 |
| 130 | Polyline | NILE - BABEL FOOD STORE | 1 | 1 | 5 | 26.834178 | 29.036700 |
| 131 | Polyline | ATHAR - HILLA OIL DEPOT | 2 | 5 | 1 | 10.058776 | 9.856400 |
| 132 | Polyline | ATHAR - JIBAL | 2 | 3 | 2 | 13.513634 | 14.832560 |
| 133 | Polyline | ATHAR - WARDIYAH FOOD STORE | 2 | 4 | 3 | 18.26540 | 35.0655 |
| 134 | Polyline | ATHAR - 80 STREET CON. | 2 | 2 | 4 | 17.167151 | 18.835870 |
| 135 | Polyline | ATHAR - BABEL FOOD STORE | 2 | 1 | 5 | 19.74662 | 22.937531 |
| 136 | Polyline | KARBALA - JIBAL | 3 | 3 | 1 | 12.552203 | 14.187300 |
| 137 | Polyline | KARBALA - HILLA OIL DEPOT | 3 | 5 | 2 | 17.204120 | 19.16590 |
| 138 | Polyline | KARBALA - 80 STREET CON. | 3 | 2 | 3 | 14.811844 | 16.168400 |
| 139 | Polyline | KARBALA - WARDIYAH FOOD STORE | 3 | 4 | 4 | 16.364711 | 19.856340 |
| 140 | Polyline | KARBALA - BABEL FOOD STORE | 3 | 1 | 5 | 19.301801 | 21.003500 |
| 141 | Polyline | NAJAF - BABEL FOOD STORE | 4 | 1 | 1 | 5.884488 | 7.203540 |
| 142 | Polyline | NAJAF - JIBAL | 4 | 3 | 2 | 11.836522 | 16.100680 |
| 143 | Polyline | NAJAF - 80 STREET CON. | 4 | 2 | 3 | 10.901130 | 13.155310 |
| 144 | Polyline | NAJAF - WARDIYAH FOOD STORE | 4 | 4 | 4 | 15.039156 | 21.177020 |
| 145 | Polyline | NAJAF - HILLA OIL DEPOT | 4 | 5 | 5 | 21.255381 | 25.355869 |
| 146 | Polyline | Diwaniyah - JIBAL | 7 | 3 | 1 | 7.49781 | 11.352203 |
| 147 | Polyline | Diwaniyah - BABEL FOOD STORE | 7 | 1 | 2 | 8.388513 | 9.155748 |
| 148 | Polyline | Diwaniyah - WARDIYAH FOOD STORE | 7 | 4 | 3 | 10.690444 | 16.897293 |
| 149 | Polyline | Diwaniyah - 80 STREET CON. | 7 | 2 | 4 | 12.790589 | 14.238249 |
| 150 | Polyline | Diwaniyah - HILLA OIL DEPOT | 7 | 5 | 5 | 11.840083 | 18.820418 |

4.5 Summary of network analysis

After completing the network analysis process, find that the largest number of routes proposed by the Arc GIS program for freight vehicles entering the city from the five main entrances pass-through (Hilla-Baghdad,60 Street, Al-Tohmaziah, Hilla- Karbala, 80 Street, and Hilla – Diwaniyah) roads.

Knowing that a large percentage of these vehicles are (External – Externa) trips, this causes an additional load on these roads, which are considered one of the main effective roads in the city and suffer from high traffic density.

While trucks play a vital role in road freight movement, they are also a significant contributor to traffic accidents and congestion. Trucks have a strong influence on road capacity and overall efficiency, due to the physical and operating characteristics of the trucks such as size and acceleration/deceleration.

Therefore, the total traffic volume and the percentage of freight traffic on each of the above-mentioned roads will be calculated to determine the level of service.

4.6 Traffic volume, capacity, and level of service for main effective roads in Hilla

By integrating the results of the current network analysis. The traffic volume and capacity are calculated for 12 sections, each section has two links representing the main effective roads in Hilla city (arterial roads) to check the level of service for these links. Color theme maps were created for these links by using Trans CAD 4.5 program after modifying and updating the characteristics and attribute values of the network file which contains line and node layers that are prepared using, Arc GIS 10.4 program discussed previously.

4.6.1 Traffic volume

The traffic volume was calculated for each road by manual counting method using portable video camera installed on the side of the road for both directions at (11-12) A.M, which represents the peak hour for freight trucks at the selected measured morning and evening period as explained earlier in Chapter Three.

The result of the traffics volume calculation is listed in Table 4.15.

4.6.2 Road Capacity

The absolute capacity of the road link between (1300 & 1500) PC/hr/ln. By using an average of 1400 PCU per ground width of 3.5 m, then obtain the absolute capacity equals 400 PC/hr for every meter width of a carriageway. Therefore, the

actual capacity of the road link is calculated by multiplying the absolute capacity which equals (400 PCU per meter) by the "effective" width of the carriageway. The effective carriageway width has been calculated by reducing the actual width of the carriageway due to different factors affecting the capacity (parking, encroachment and land use).

$$\text{Effective width of carriageway} = \text{Actual width of carriageway} \times (1 - \text{landuse} / 100) - \text{Parking space} - \text{Encroachment.}$$

$$\text{Capacity of road link} = \text{Effective width of carriageway} \times 400 \text{ PCU}$$

The reduction due to parking and encroachment is shown in Table 12. Land use along the road link affects the capacity and the reduction in capacity due to this factor is shown in Table 13 (Subramani T. et al., 2012).

Table 12 The Reduction Due to Parking and Encroachment

| Type of parking \ Severity of Encroachment | Reduction (m) |
|--|---------------|
| Parking prohibited on either side | 0 |
| Parking permitted on one side | 2.5 |
| Parking permitted on either side | 5 |
| No Encroachment | 0 |
| Marginal Encroachment | 1 |
| Substantial Encroachment | 2 |

Table 13 Reduction in capacity due to land use

| Predominant land use | Reduction (percent) |
|----------------------|---------------------|
| Open space | 0 |
| Residential | 5 |
| Institutional | 10 |
| Industrial | 15 |
| Commercial | 30 |

The reduction due to parking and encroachment for each selected road is equal to (zero), and for Land use is 30%. The capacity for each selected road is listed in Table 4.15.

4.6.3 Level of service

The level of service is a qualitative measure used to symbolize the quality of traffic services. It is used to examine roads by categorizing traffic flow and allocating quality levels based on performances like speed, density, delay, and many more. The key to an effective LOS is the ability of a transportation system to provide safe and reliable service for its users.

The method used to determine the level of service for Hilla main roads in this study is based on calculating the volume to capacity ratio (V/C) for road links according to HCM criteria as shown in Table 4.12. LOS is symbolized by capital letters from A to F, with LOS A representing the best-operating conditions and LOS F the worst.

Table 4.14 HCM criteria for roadway links based on Volume-to-Capacity ratios

| LOS | V/C |
|-----|----------------------|
| A | $V/C \leq 0.6$ |
| B | $0.6 < V/C \leq 0.7$ |
| C | $0.7 < V/C \leq 0.8$ |
| D | $0.8 < V/C \leq 0.9$ |
| E | $0.9 < V/C \leq 1$ |
| F | $V/C > 1$ |

The results of the level of service for main roads in Hilla city are listed in Table 4.15 and represented by the Trans CAD 4.5 program in Figure 4.18.

Table 4.15 The accounts of traffic volume, capacity, and level of service for main road in Hilla city

| Link No. | Direction | Road name | Effective width (m) | Capacity (PC/hr/Lane) | Volume details | | Equivalent total volume (PCU)* | Volume capacity ratio | LOS. | Avg. LOS. |
|----------|-----------|-------------------------------|---------------------|-----------------------|-------------------------|--------------------|--------------------------------|-----------------------|------|-----------|
| | | | | | Total volume (veh / hr) | Truck percentage % | | | | |
| 1 | ↑ | 80 ROAD (SECTION 1) | 7.35 | 2940 | 2184 | 11.7 | 2712 | 0.92 | E | E |
| | ↓ | 80 ROAD (SECTION 1) | 7.35 | 2940 | 2256 | 10.3 | 2752 | 0.93 | E | |
| 2 | ↓ | 80 ROAD (SECTION 2) | 7.35 | 2940 | 1816 | 11.7 | 2256 | 0.76 | C | C |
| | ↑ | 80 ROAD (SECTION 2) | 7.35 | 2940 | 1732 | 10.4 | 2108 | 0.71 | C | |
| 3 | ← | HILLA-KARBALLA ROAD | 9 | 3600 | 2672 | 11.1 | 3296 | 0.91 | E | E |
| | → | KARBALLA-HILLA ROAD | 9 | 3600 | 3216 | 10.2 | 3896 | 1.08 | F | |
| 4 | ← | TOHMAZIA ROAD (SECTION 1) | 7.35 | 2940 | 2073 | 10.7 | 2519 | 0.85 | D | D |
| | → | TOHMAZIA ROAD (SECTION 1) | 7.35 | 2940 | 2109 | 10.4 | 2547 | 0.86 | D | |
| 5 | → | TOHMAZIA ROAD (SECTION 2) | 7.35 | 2940 | 2328 | 11.7 | 2888 | 0.98 | E | E |
| | ← | TOHMAZIA ROAD (SECTION 2) | 7.35 | 2940 | 2324 | 11.0 | 2836 | 0.96 | E | |
| 6 | ↓ | HILLA-BAGHDAD ROAD | 7 | 2800 | 2580 | 12.1 | 3236 | 1.15 | F | F |
| | ↑ | HILLA-BAGHDAD ROAD | 7 | 2800 | 2558 | 13.5 | 3274 | 1.16 | F | |
| 7 | ↓ | 60 ROAD (SECTION 1) | 7.35 | 2940 | 2324 | 13.4 | 2980 | 1.01 | F | E |
| | ↑ | 60 ROAD (SECTION 1) | 7.35 | 2940 | 2320 | 12.2 | 2920 | 0.93 | E | |
| 8 | ↓ | 60 ROAD (SECTION 2) | 7.35 | 2940 | 2344 | 11.4 | 2920 | 0.93 | E | E |
| | ↑ | 60 ROAD (SECTION 2) | 7.35 | 2940 | 2512 | 11.6 | 3112 | 1.05 | F | |
| 9 | ↓ | 60 ROAD (SECTION 3) | 7.35 | 2940 | 2040 | 12.3 | 2544 | 0.86 | D | D |
| | ↑ | 60 ROAD (SECTION 3) | 7.35 | 2940 | 2032 | 11.3 | 2494 | 0.84 | D | |
| 10 | → | HILLA- DIWANIYAH ROAD | 9 | 3600 | 1968 | 10.2 | 2392 | 0.66 | B | B |
| | ← | HILLA- DIWANIYAH ROAD | 9 | 3600 | 1788 | 7.8 | 2084 | 0.57 | A | |
| 11 | ↓ | HILLA- NAJAF ROAD (SECTION 1) | 12.75 | 5100 | 3848 | 7.4 | 4488 | 0.88 | D | D |
| | ↑ | HILLA- NAJAF ROAD (SECTION 1) | 12.75 | 5100 | 3816 | 8.1 | 4536 | 0.88 | D | |
| 12 | ↓ | HILLA- NAJAF ROAD (SECTION 2) | 12.75 | 5100 | 3442 | 9.8 | 4146 | 0.81 | D | D |
| | ↑ | HILLA- NAJAF ROAD (SECTION 2) | 12.75 | 5100 | 3487 | 10.1 | 4241 | 0.83 | D | |

*Equivalent passenger car units (PCU) for bus and heavy-duty trucks equal to 3 and for medium duty truck is 2.5.

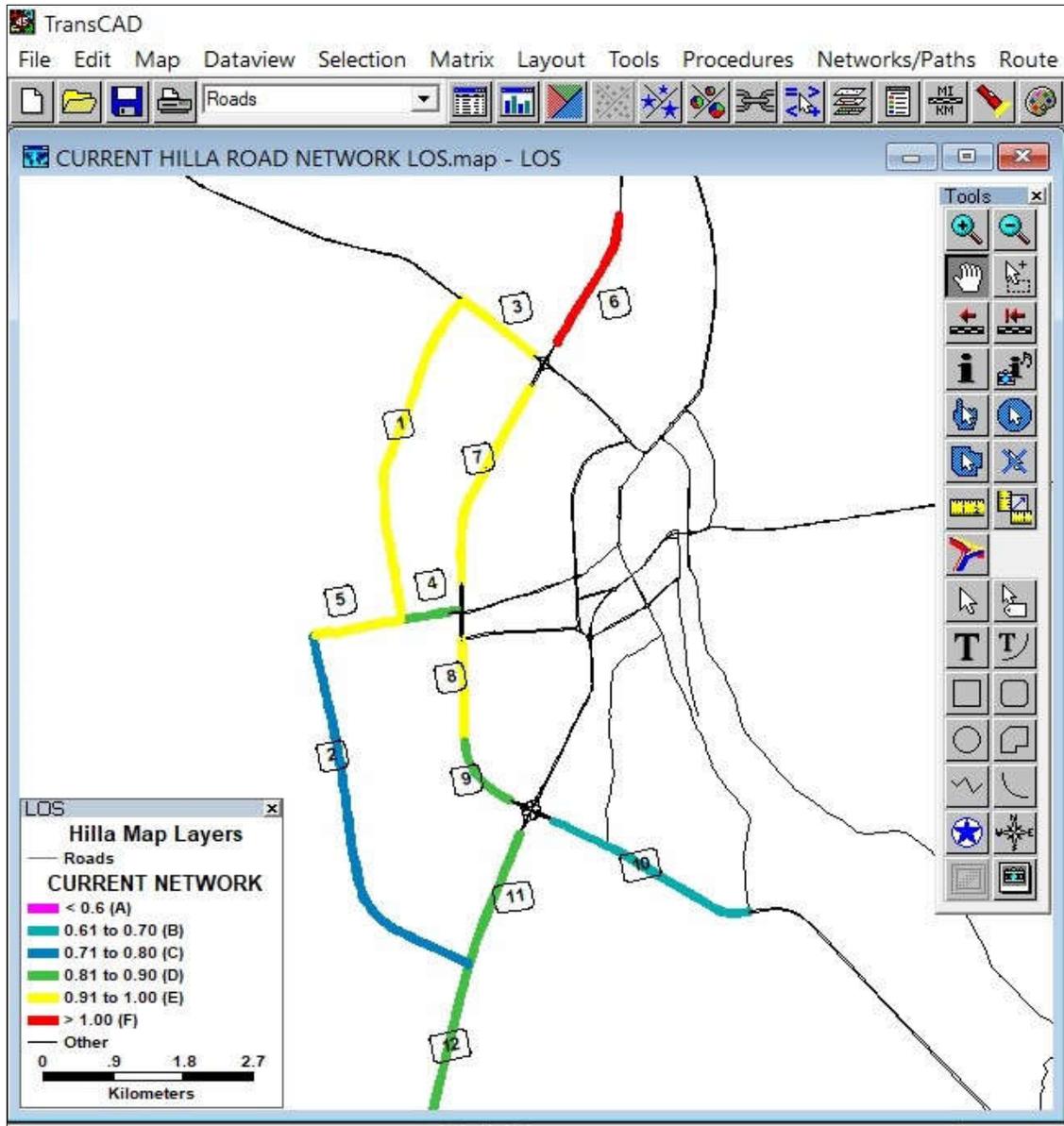


Figure 4.18 The level of service for main roads in the city based on the current network in study year by Trans CAD4.5 program

The result of traffic volume counting, capacity, and LOS for each main road in Hilla city listed in Table 4.11 and Figure 4.18 above, shows that the level of service is unacceptable for (Hilla-Baghdad, Hilla-Karbala, 60 sec1 and sec2, Al-Tohmaziah sec2, and 80 sec1) roads, this is due to several reasons, including the passage of freight vehicles in these roads, which suffer from high traffic volume, in addition to poor services and lack of capacity.

The average level of service for the current freight road network is 0.89 (LOS D) depending on the (V/C) ratio which includes the total percent of freight trucks. But with assuming that the percent of trucks is equal to (0%) the average level of service will be equal to 0.66 (LOS B). These results prove the high negative effect of freight trucks on the performance of the network.

4.6.4 Evaluate the future level of service for the current road network at the target year 2030

To evaluate the main roads network of Hilla city and measure its ability to absorb the yearly increase in the volume of traffics for the target year (2030) under the current conditions of the city's road network, future volumes of traffic are estimated depending on the mean yearly rate of vehicle growth in Hilla city from 2022 to 2030, as the growth rate reached according to the Babil Traffic Directorate is equal to 2.5%

The future total traffic volume for the main road network in 2030 could be determine by using the current total equivalent traffic volume in 2022 after multiplying the values of them by the 2030 rate of growth (2.5%). as demonstrates below (**Khairallah R. and Ali Alwash, 2021**):

$$Future\ volume = Base\ year\ volume (1 + groth\ rate)^{No.of\ years}$$

$$Future\ traffic\ volume = Total\ traffic\ volume\ (2022) * (1 + \frac{2.5}{100})^8$$

The future level of service value was recalculated from the ratio of the future traffic volume to the current capacity for each selected road. Figure (4.19) shown the final level of service outputs for freight network in Hilla city in the target year (2030) represented by a color theme map of Trans CAD 4.5 program.

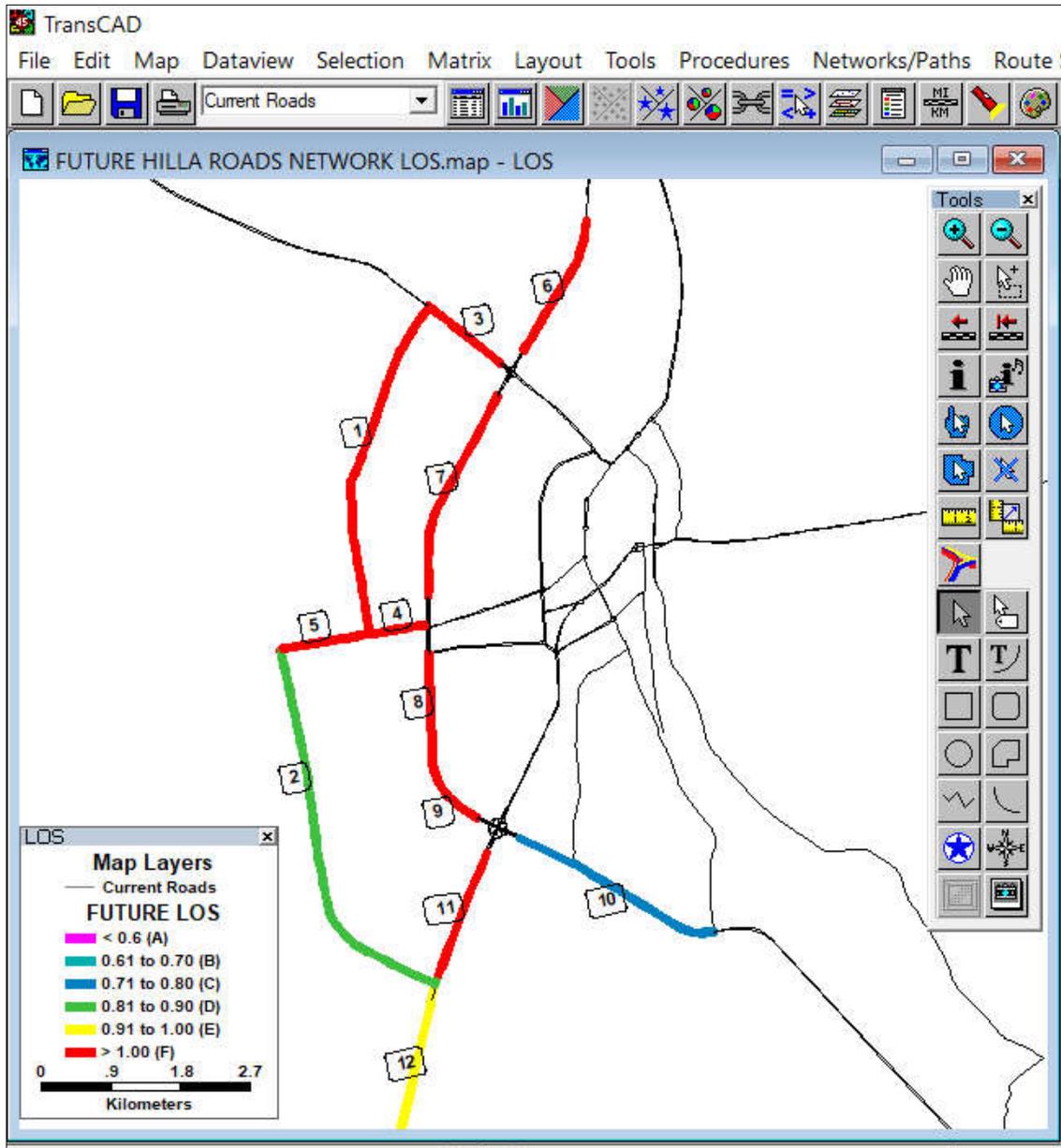


Figure 4.19 The main roads level of service in Hilla based on the current network in the target year 2030 using Trans CAD 4.5.

As shown in Figure 4.19 above, most of the main effective roads in Hilla city (60,80 Section one, Hilla- Baghdad, Hilla-Najaf, Hilla-Karbala, Tohmaziah) in the target year 2030 have the worst operating conditions (level of service F&E) based on the ratio of future traffic volume to current roads capacity (taking into consideration the growth rate and the increase in freight and passenger traffic volume). This means that the Hilla road network needs to be improved and find

solutions to absorb the increasing traffic flow, reduce the proportion of freight trucks on these roads, and improve the level of service.

4.7 The suggestion of new roads as a solution for decreasing the freight traffics volume for (External – External) trip.

To minimize the negative effect of freight vehicles on the main road of the city, which suffer from congestion and poor level of service, as explained previously.

The primary scenario by modifying and developing the current Hilla roads network by adding new roads with special lanes for freight vehicles. The coordination has been made with the municipality directorate and the urban planning directorate about the proposed roads because the planning of the city's road network and the uses of the land are linked to each other and cannot be separated.

The second step is converting the traffic volume of freight vehicles entering the city for transit to the district and neighboring provinces (External – External) trips to these proposed roads to check the effect of this solution on the current road network in Hilla city.

4.7.1 Characteristics of suggested roads

The suggested road took an oval shape surrounding Hilla city, connecting with the existing network in specific locations and consisting of two freeways and three major arterials with a total length of 27.8 km and 20.9 km respectively.

Table 4.16 shows the main characteristics of each suggested road.

Table 4.16 Characteristics of suggested roads

| NO | Location | Type of suggested road | Suggested width* (m) | Suggested speed for freight (Km/hr) | Suggested No. of the lane | Total length (Km) |
|----|---|------------------------|----------------------|-------------------------------------|--|-------------------|
| 1 | It connects Baghdad Road from the north and passes parallel to the eastern border of the city and then ends with its connection to Najaf Road. | freeway | 60 | 80-90 | Three or more lanes in each direction. | 18.8 |
| 2 | It connects Baghdad Road from the north and passes parallel to the Western border of the city and then ends with its connection to Hilla-Karbala Road | freeway | 60 | 80-90 | Three or more lanes in each direction | 9 |
| 3 | It connects Baghdad Road with Hilla-Karbala Road | Major arterial | 60 | 60-80 | three lanes in each direction, | 2.6 |
| 4 | It connects the Hilla - Karbala Road with Tohmaziah road | Major arterial | 60 | 60-80 | three lanes in each direction, | 6.7 |
| 5 | It connects Tohmaziah Road with Hilla-Najaf Road and ends with its connection to the Hilla-Diwaniyah Road | Major arterial | 60 | 60-80 | three lanes in each direction | 11.6 |

* Total width of the road with its right of way

4.7.2 Effect of implementation suggested roads on the current Hilla road network

The rapid and unplanned increase in the number of vehicles in the city of Hilla has caused many problems, including traffic congestion, high rate of delay, and poor level of service, because the current road network was designed in a period when the city's population was less, which in turn is linked to a limited number of vehicles where the road network can accommodate these vehicles. So, the carrying capacity of the roads in the city has become disproportionate to this increase in the number of vehicles which negatively affected the traffic flow in the city.

Therefore, adding a new road to the road network will reflect positively on the existing network by reducing the load on the internal roads of the city, reducing traffic congestion, and improving the level of service for it.

4.7.3 Effect of implementation of the suggested roads on drivers of freight vehicles

Adding the proposed roads and implementing them according to the international specifications and providing them with all the requirements of the controlling traffic signs and lighting will encourage the drivers of freight vehicles to pass through them for many reasons, the most important of which are:

- 1- The speed of freight vehicles on the proposed roads ranges from (60-to 90) Km/hr which is higher than the speed of the inner-city roads, which may reach 40 Km/hr within crowded areas.
- 2- The total traffic volume on the proposed road is less than the inner roads of the city
- 3- The number of intersections, turning areas, and pedestrian crossing areas in the suggested road are less than on inner-city roads.
- 4- The suggested roads are connected to the main roads leading to the entrances and exits of the city without penetrating the city center, which encourages drivers of freight vehicles, especially (External – External) trips, to pass through them.

4.7.4 Effect of implementation suggested roads on freight network analysis

The first step is to draw the suggested roads and link them to the existing road network using Arc GIS 10.4 software and prepare the database. The proposed roads database was taken from Hilla Municipality Directorate. Three basic types of attribute data, the first type is descriptive data that describes the road link, including (length, width, number of lanes, and speed), the second data is cost attributes and includes travel time in minutes, it is extracted depending on

speed, it is very important data in network analysis when finding the best route for vehicles. Finally, the third type of data is called restriction attributes, and it is also important data in network analysis which included the direction of road movement (One way or two-way), Suggested roads, and the current road network of Hilla city shown in the Figure 4.20 below. The full data are tabulated in Appendix B.

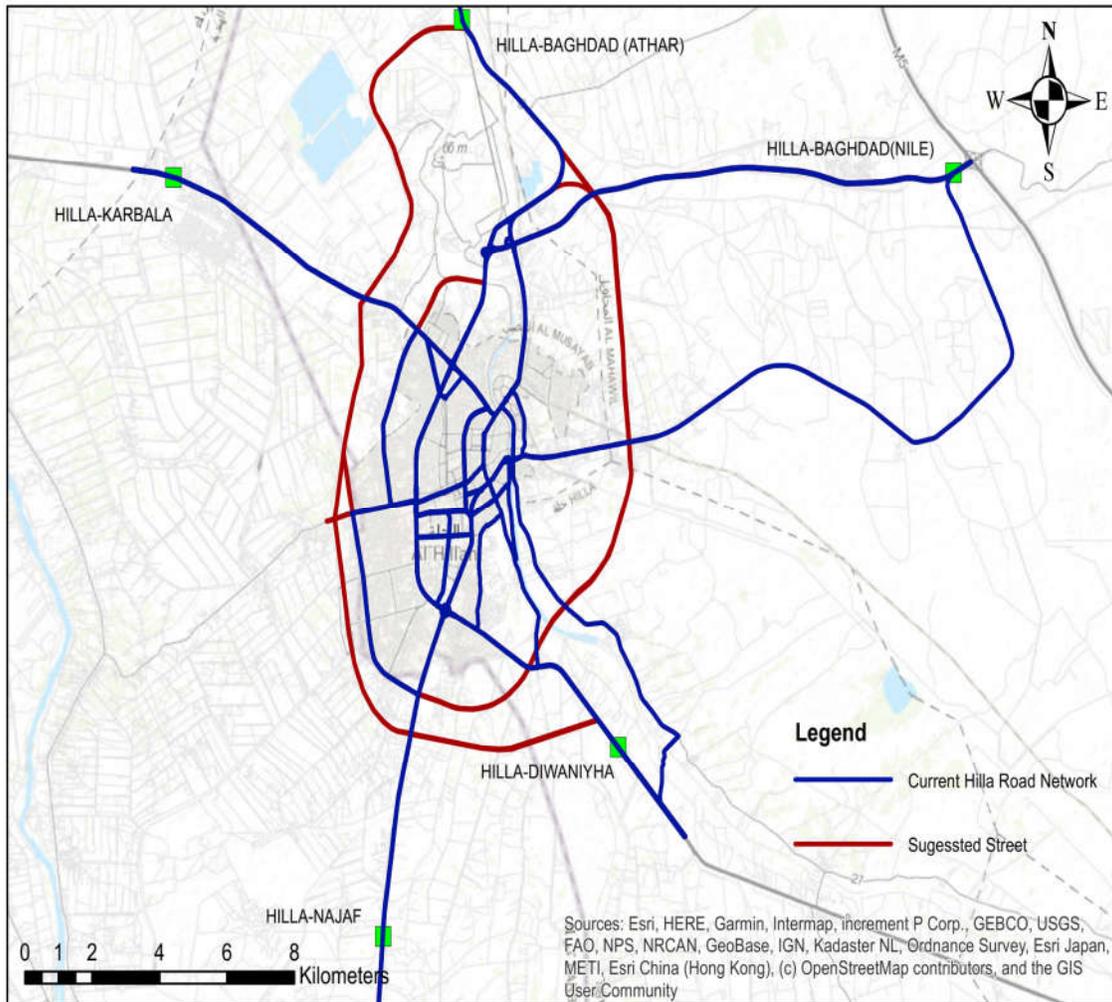


Figure 4.20 Hilla city modified freight road network.

4.7.5 The best route analysis for (External – External) trip after adding suggested roads to the network

After completing the process of adding proposed roads database and linking them with the road network, network analysis was reconducting for the modified

network by ArcGIS network analysis tool to check the impact of developing the current network by adding new roads in the process of network analysis, and selecting the best routes for freight movement concerning with (external-external) trips.

1- Best route from Nile entrance to another exit of Hilla city

The routes of Nile entrance to other exit destinations and their main properties for the modified road network by ArcGIS network analysis tool are shown in Table 4.17 and Figure 4.21 respectively.

Table 4.17 Properties of Nile entrance- Ex. destination points routes for modified network

| Destinations (modified network) | Nile entrances | | The difference with the current network (%) = [1-(Modified / Current)] *100 | |
|---------------------------------------|------------------|-----------|---|-------|
| | Distance (Km) | Time(min) | Distance | Time |
| Nile Ex. | - | - | - | - |
| Athar Ex. | 16.50 | 12 | 25 | 40 |
| Karbala Ex. | 25.90 | 20 | 4.07 | 23.07 |
| Najaf Ex. | 31.09 | 26 | 2.84 | 23.53 |
| Diwaniyah Ex. | 26.40 | 22 | 8.97 | 26.67 |

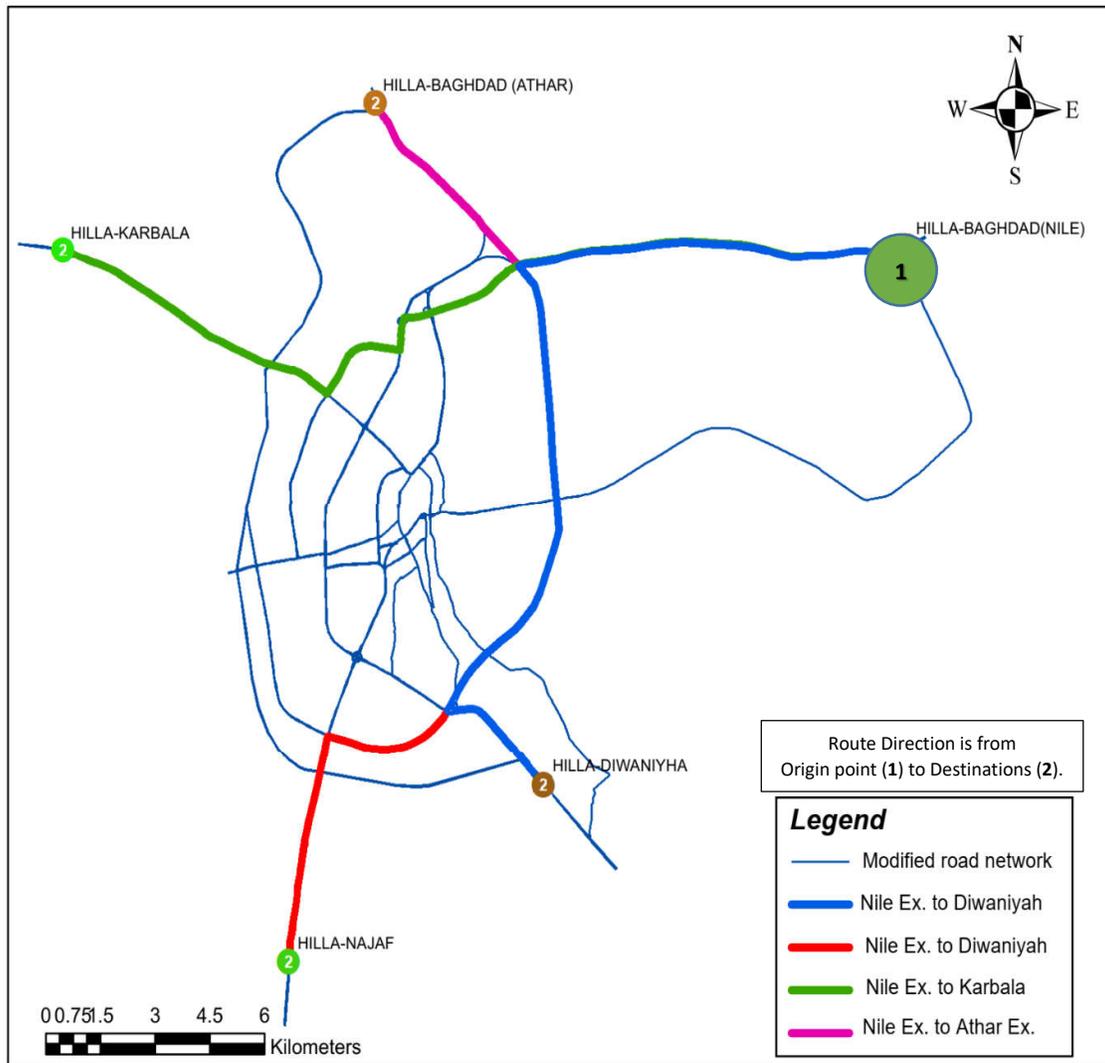


Figure 4.21 Best route from Nile entrance to exterior destination points for the modified road network.

The total sum of the lengths for the proposed route in the modified network, which starts from the Nile entrance toward the other four destinations is equal to 99.89 km while the total time is 80min, these values are lower than those calculated from the current network by 9.19%,27.28% respectively.

2- Best Rout from Athar entrance to another exit of Hilla city

The routes of Athar entrance to other exit destinations and their main properties for the modified road network by ArcGIS network analysis tool are shown the Figure 4.22 and Table 4.18 respectively.

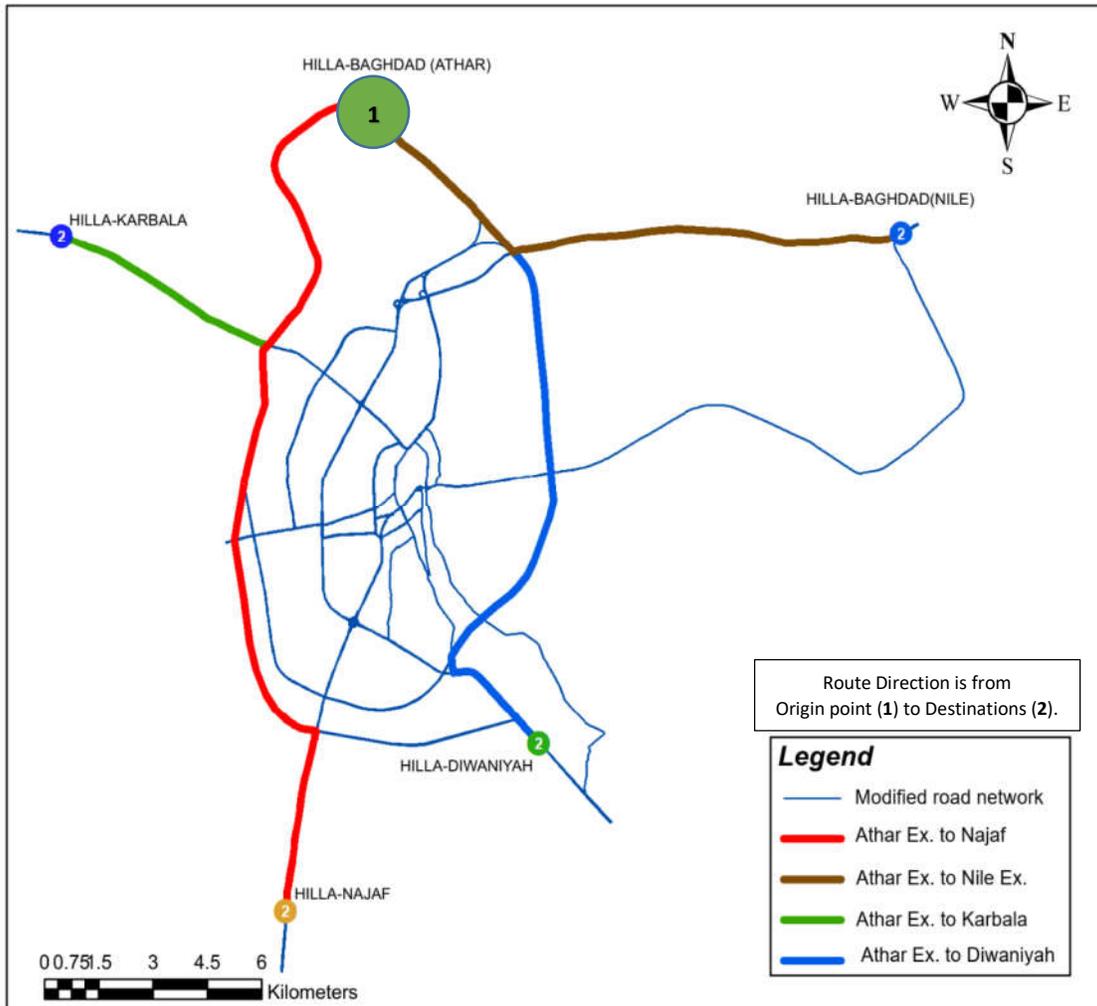


Figure 4.22 Best route from Athar entrance to exterior destination points for the modified road network.

Table 4.18 properties of Athar entrance -Ex. destination point route for modified network

| Destinations (modified network) | Athar entrances | | The difference with the current network (%) = [1-(Modified / Current)] *100 | |
|---------------------------------|-----------------|-----------|--|-------|
| | Distance (Km) | Time(min) | Distance | Time |
| Nile Ex. | 16.56 | 13 | 21.15 | 35 |
| Athar Ex. | - | - | - | - |
| Karbala Ex. | 15.70 | 12 | 21.52 | 36.84 |
| Najaf Ex. | 24.91 | 21 | 0.36 | 25 |
| Diwaniyah Ex. | 21.29 | 18 | 3.23 | 21.74 |

The total sum of the lengths for the proposed route in the modified network, which starts from the Athar entrance toward the other four destinations is equal to 78.46 km while the total time is 64 min, these values are lower than those calculated from the current network by 10.84%,28.89% respectively.

3- Best Rout from Najaf entrance to another exit of Hilla city

The routes of Najaf entrance to other exit destinations and their main properties for the modified road network by ArcGIS network analysis tool are shown in the Figure 4.23 and Table 4.19 respectively.

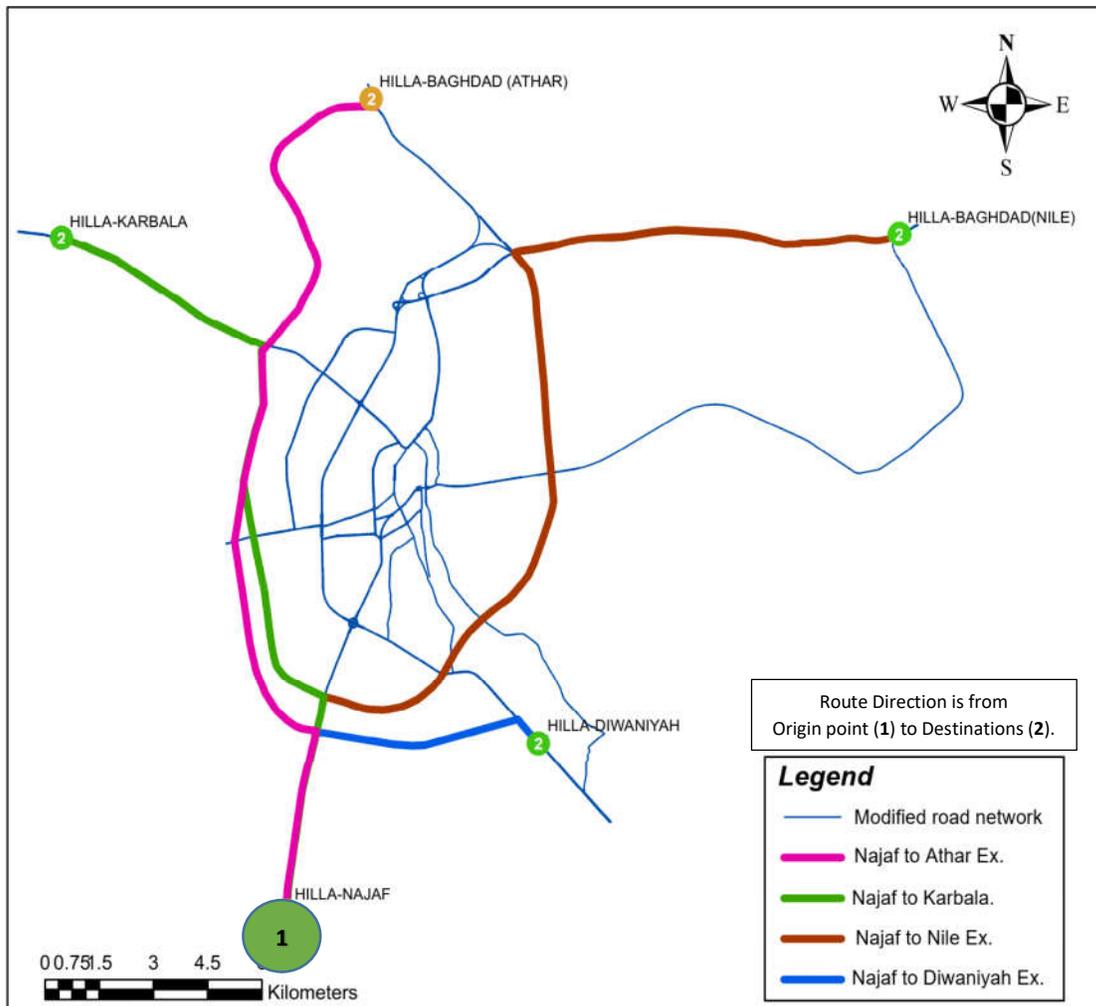


Figure 4.23 Best route from Najaf entrance to exterior destination points for the modified road network.

Table 4.19 Properties of Najaf entrance- Ex. destination points routes for modified network

| Destinations (modified network) | Najaf entrances | | The difference with the current network (%) = [1-(Modified / Current)] *100 | |
|------------------------------------|------------------|-----------|---|-------|
| | Distance (Km) | Time(min) | Distance | Time |
| Nile Ex. | 31.10 | 25 | -7.24 | 16.67 |
| Athar Ex. | 24.91 | 21 | 0.36 | 25 |
| Karbala Ex. | 22.52 | 19 | 9.93 | 29.63 |
| Najaf Ex. | - | - | - | - |
| Diwaniyah Ex. | 11.41 | 10 | 12.23 | 33.33 |

The total sum of the lengths for the proposed route in the modified network, which starts from the Najaf entrance toward the other four destinations is equal to 89.94km while the total time is 75min, these values are lower than those calculated from the current network by 2.24%,25% respectively.

The value of the difference in route distance for the modified network with the current network (-7.24) because the length of the route from Najaf to the Nile exit which resulted from the network analysis before adding the suggested roads passing through the inner-city road where the traveled distance is shorter but at a slower speed due to traffic congestion in the city road.

4-Best Rout from Karbala entrance to another exit of Hilla city

The routes of Karbala entrance to other exit destinations and their main properties for the modified road network by ArcGIS network analysis tool are shown the Figure 4.24 and Table 4.20 respectively.

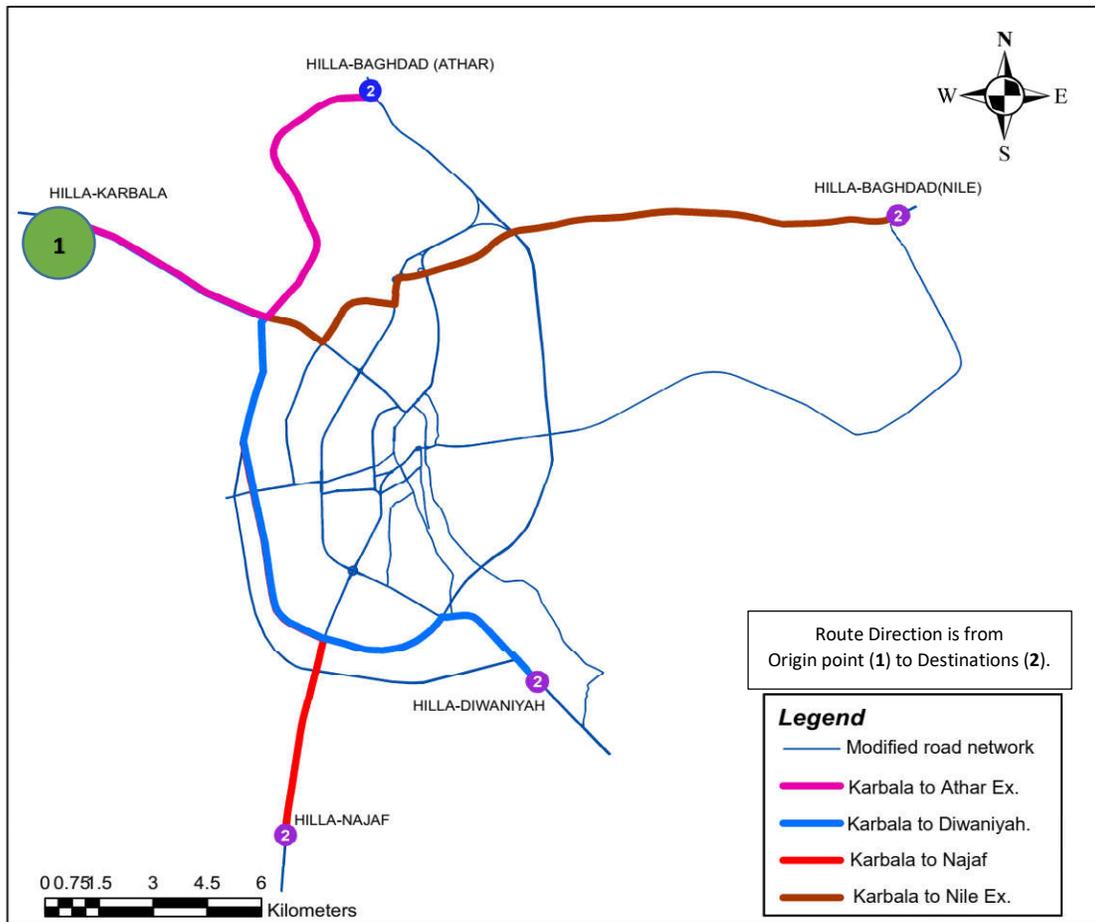


Figure 4.24 Best route from Karbala entrance to exterior destination points for the modified road network.

Table 4.20 Properties of Karbala entrance- Ex. destination points routes for modified network

| Destinations (modified network) | Karbala entrances | | The difference with the current network (%) = $[1 - (\text{Modified} / \text{Current})] * 100$ | |
|---------------------------------|-------------------|-----------|---|-------|
| | Distance (Km) | Time(min) | Distance | Time |
| Nile Ex. | 25.90 | 20 | 4.06 | 23.08 |
| Athar Ex. | 15.70 | 12 | 21.52 | 36.84 |
| Karbala Ex. | - | - | - | - |
| Najaf Ex. | 22.52 | 19 | 9.93 | 29.63 |
| Diwaniyah Ex. | 20.91 | 18 | 9.08 | 28 |

The total sum of the lengths for the proposed route in the modified network, which starts from the Karbala entrance toward the other four destinations is equal

to 85.03km while the total time is 69min, these values are lower than those calculated from the current network by 10.50%,28.87% respectively

5-Best Rout from Diwaniyah entrance to another exit of Hilla city

The routes of Diwaniyah entrance to other exit destinations and their main properties for the modified road network by ArcGIS network analysis tool are shown the Figure 4.25 and Table 4.21 respectively.

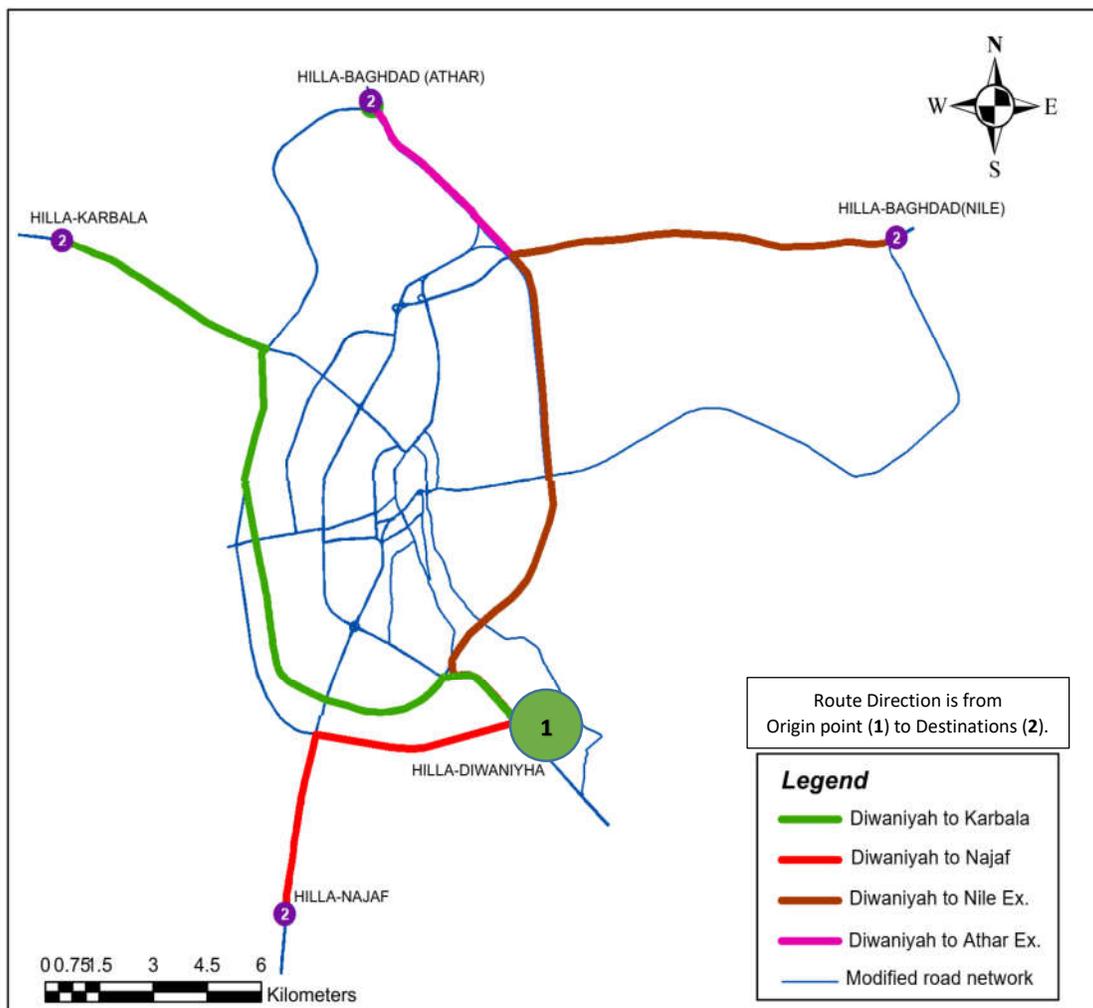


Figure 4.25 Best route from Diwaniyah entrance to exterior destination points for the modified road network.

Table 4.21 Properties of Diwaniyah entrance- Ex. destination points routes for modified network

| Destinations (modified network) | Diwaniyah Entrances | | The difference with the current network (%) = [1-(Modified / Current)] *100 | |
|------------------------------------|---------------------|-----------|---|-------|
| | Distance (Km) | Time(min) | Distance | Time |
| Nile Ex. | 26.43 | 22 | 17.40 | 35.29 |
| Athar Ex. | 21.29 | 18 | 3.23 | 21.74 |
| Karbala Ex. | 20.91 | 18 | 9.08 | 28 |
| Najaf Ex. | 11.41 | 10 | 13.53 | 33.33 |
| Diwaniyah Ex. | - | - | - | - |

The total sum of the lengths for the proposed route in the modified network, which starts from the Diwaniyah entrance toward the other four destinations is equal to 80.04 km while the total time is 68min, these values are lower than those calculated from the current network by 11.26%,29.89% respectively

4.7.6 Summary of network analysis

When comparing the proposed routes for the movement of freight vehicles from each entrance (point of origin) towards other city exits (destination points) before and after adding the suggested roads, find the following:

1-All the proposed routes for freight vehicles passing through the suggested roads without passing through the city center and inner-city roads.

2-The distance traveled by freight vehicles during their movement from each entrance towards the other exits by the modified roads network is less than the distance traveled by vehicles on the current roads network for the same entrance and all paths except the length of the route started from Najaf entrance and end in Nile exit which passes through inner-city roads before adding the suggested roads this led to the shorter route but longer travel time due to congestion in the city center.

3-The travel time taken for freight vehicles to reach the city exits from each entrance after adding the suggested roads is less than the travel time taken before adding the proposed roads to the same entrance for all paths.

4.7.7 Effect of implementation of the suggested roads on LOS. for the main road in Hilla city.

After conducting field surveys on the main effective roads in the city (Hilla-Baghdad, Hilla- Karbala, Hilla -Diwaniyah, Al-Tahmazyah,60 Street, and 80Street) and calculating the traffic volumes and level of service for each road as shown in the Table 4.15 the level of service for most of these roads was unacceptable for many reasons, including the volume of freight traffic in these roads.

After suggesting new roads for the current road network to deal with freight traffic in Hilla city, specifically (External – External) freight trips, it is important to study the impact of converting the traffic volumes of these vehicles to the roads suggested for future implementation in improving the level of service for the main roads in the city.

Because the proportion of freight vehicles that represent (external – external) trips from the total number of freight vehicles that pass on each road is unknown, the results of the questionnaire performed with freight vehicle drivers at city entrances will be relied on, which shows that the percentage of (External – External) trip ranges between (59-68) percent of total freight volume in the city entrances, as shown in Table 3.5.

As a result, will assume that the percentage of the (External – Externa) trip is approximately (50 percent) of the total volume of freight vehicles on each road, after reducing the volume of freight vehicles according to this ratio, the level of service for each road will be recalculated based on the modified traffic volumes, as shown in Table 4.22 and Figure 4.26 by Trans CAD program below.

Table 4.22 The accounts of traffic volume, capacity, and level of service for the main road in Hilla city after adding suggested roads

| Link No. | Direction | Road Name | Effective width (m) | Capacity (PC/hr/Lane) | Volume details | | Equivalent total volume (PCU) | Volume capacity ratio | LOS. | Avg. LOS. |
|----------|-----------|-------------------------------|---------------------|-----------------------|-------------------------|--------------------|-------------------------------|-----------------------|------|-----------|
| | | | | | Total volume (Veh / hr) | Truck percentage % | | | | |
| 1 | ↑ | 80 ROAD (SECTION 1) | 7.35 | 2940 | 2056 | 6.2 | 2328 | 0.79 | C | D |
| | ↓ | 80 ROAD (SECTION 1) | 7.35 | 2940 | 2140 | 5.4 | 2404 | 0.81 | D | |
| 2 | ↓ | 80 ROAD (SECTION 2) | 7.35 | 2940 | 1710 | 6.2 | 1938 | 0.65 | B | B |
| | ↑ | 80 ROAD (SECTION 2) | 7.35 | 2940 | 1642 | 5.5 | 1838 | 0.62 | B | |
| 3 | ← | HILLA-KARBALLA ROAD | 9 | 3600 | 2524 | 5.9 | 2852 | 0.79 | C | D |
| | → | KARBALLA-HILLA ROAD | 9 | 3600 | 3052 | 5.4 | 3404 | 0.94 | E | |
| 4 | ← | TOHMAZIA ROAD (section 1) | 7.35 | 2940 | 1962 | 5.6 | 2186 | 0.74 | C | C |
| | → | TOHMAZIA ROAD (section 1) | 7.35 | 2940 | 1999 | 5.5 | 2217 | 0.75 | C | |
| 5 | → | TOHMAZIA ROAD (section 2) | 7.35 | 2940 | 2192 | 6.2 | 2480 | 0.84 | D | D |
| | ← | TOHMAZIA ROAD (section 2) | 7.35 | 2940 | 2196 | 5.8 | 2452 | 0.83 | D | |
| 6 | ↓ | HILLA-BAGHDAD ROAD | 7 | 2800 | 2424 | 6.4 | 2768 | 0.98 | E | E |
| | ↑ | HILLA-BAGHDAD ROAD | 7 | 2800 | 2385 | 7.3 | 2755 | 0.98 | E | |
| 7 | ↓ | 60 ROAD (SECTION 1) | 7.35 | 2940 | 2168 | 7.2 | 2512 | 0.85 | D | D |
| | ↑ | 60 ROAD (SECTION 1) | 7.35 | 2940 | 2178 | 6.5 | 2494 | 0.84 | D | |
| 8 | ↓ | 60 ROAD (SECTION 2) | 7.35 | 2940 | 2210 | 6.1 | 2518 | 0.85 | D | D |
| | ↑ | 60 ROAD (SECTION 2) | 7.35 | 2940 | 2366 | 6.2 | 2674 | 0.9 | E | |
| 9 | ↓ | 60 ROAD (SECTION 3) | 7.35 | 2940 | 1914 | 6.5 | 2166 | 0.73 | C | C |
| | ↑ | 60 ROAD (SECTION 3) | 7.35 | 2940 | 1917 | 5.9 | 2149 | 0.73 | C | |
| 10 | → | HILLA- DIWANIYAH ROAD | 9 | 3600 | 1868 | 5.4 | 2092 | 0.58 | A | A |
| | ← | HILLA- DIWANIYAH ROAD | 9 | 3600 | 1718 | 4.1 | 1874 | 0.52 | A | |
| 11 | ↓ | HILLA- NAJAF ROAD (SECTION 1) | 12.75 | 5100 | 3706 | 3.8 | 4062 | 0.79 | C | C |
| | ↑ | HILLA- NAJAF ROAD (SECTION 1) | 12.75 | 5100 | 3662 | 4.2 | 4074 | 0.79 | C | |
| 12 | ↓ | HILLA- NAJAF ROAD (SECTION 2) | 12.75 | 5100 | 3273 | 5.1 | 3639 | 0.71 | C | C |
| | ↑ | HILLA- NAJAF ROAD (SECTION 2) | 12.75 | 5100 | 3311 | 5.3 | 3713 | 0.72 | C | |

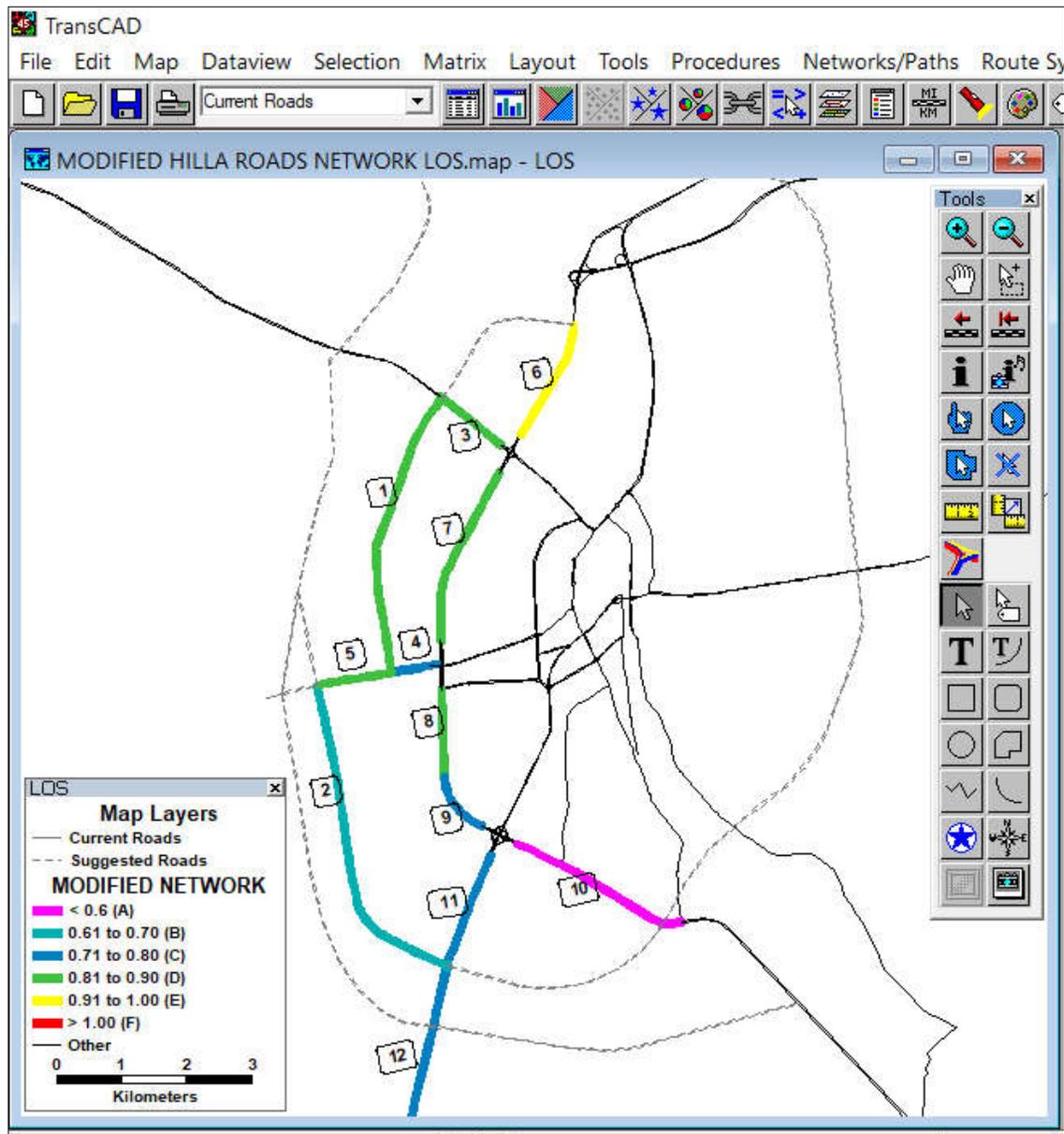


Figure 4.26 The level of service for main roads in the city based on the modified network in the study year using Trans CAD 4.5 program

Figure 4.26 above shows the improvement in the level of service for the main roads in the city. After adopting the proposed developments to the current network, including adding new roads, which leads to reducing the proportion of freight vehicles on the current main roads to 50%.

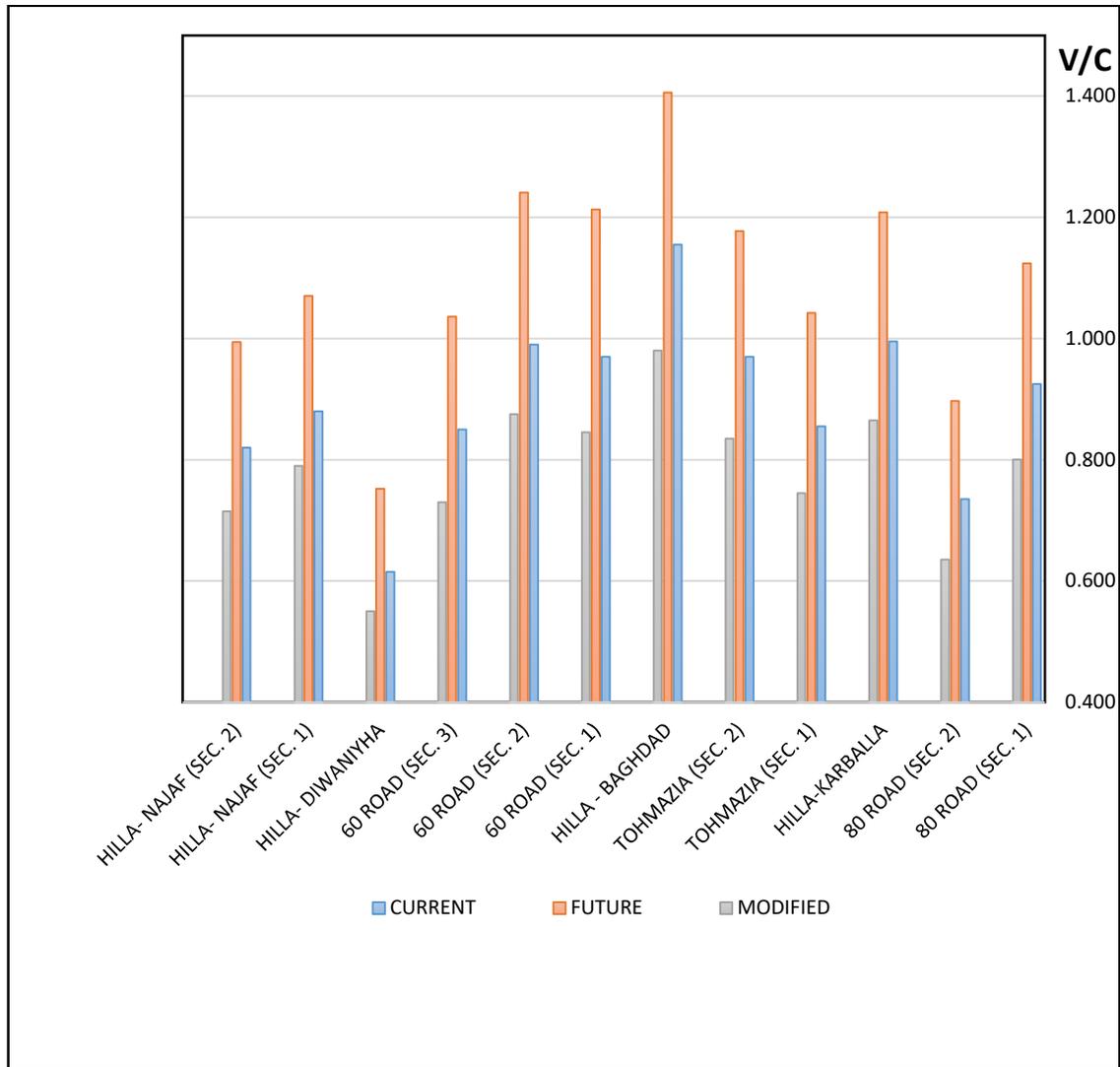


Figure 4.27 V/C Comparison between the study year 2022 (current and modified network) and the target year 2030

Figure 4.27 shows a comparison between the level of service (LOS) for the main freight road network in Hilla city depending on the average (V/C ratio) between the study year 2022 (based on a current and modified network) and the target year 2030 (based on current network capacity taking into account the growth rate in the traffic volume).

The results show that the average volume to the capacity ratio for the year 2022 is 0.89 (LOS D) while for the target year 2030 it will be 1.09 (LOS F). The adoption of the proposed developments in the current network reduces the

proportion of freight vehicles on main roads in the city, lowering the V/C ratio to 0.78 and improving the level of service in the study year to (C).

4.8 Suggested scenarios to reduce the impact of (External – Internal) trips on Hilla road network.

The transportation of goods in urban areas has several negative effects. therefore, careful planning and management are important to minimize its large impact, especially on large trucks that have a higher impact than other freight vehicles, thus they require special care. Vehicles that deliver or pick up big amounts of goods at specified locations across the city appear to be an example of this sort of vehicle.

Freight vehicles that enter from the main entrances of Hilla city to unload their cargo at different destinations in the city center reflect negative effects on the city roads and the flow of traffic in it. Although the percentage of these vehicles does not exceed (41%) of the total volume of freight vehicles entering the city, according to the results of the survey conducted with the drivers of freight vehicles at the entrances of the city.

Two scenarios are proposed to solve this problem as shown below:

4.8.1 First scenario: Inner-city night delivery

Night delivery is the process of delivering goods to commercial centers located in the inner areas of cities at night when the city is quiet and traffic is inactive. Standard periods are between 10:00 p.m. and 7:00 a.m. (**Gnap J. et al., 2017**).

This is one of the scenarios that can be applied in Hilla city to deal with the problem of transporting and unloading goods within the city center through the roads of the city that suffers from traffic congestion during the day.

The concept of night deliveries in the city treats the following issues (**Fu J. and Erik J., 2018**):

- Night delivery enables drivers to complete the delivery process faster due to less traffic in the city during the night and thus reduces the negative effect on cities.
- Allowance for heavier vehicles to access the city center, which is normally prohibited during the day.

The following basic requirements are required to put these concepts into action.:

- Political will in the city: The establishment of night delivery services is depending on supporting of political will in the city.
- The main stakeholder: It is necessary to cooperate between freight carriers and traders for the success of night deliveries as they are the main stakeholders in this sector.
- Local legal strategy: A strategy that encourages the reduction of active noise in the city and regulates entry into the city at night is very useful for a realistic implementation plan in the legal framework.

4.8.1.1 Benefits of inner-city night delivery

Inner-city deliveries at night have a variety of possible benefits, (**Forkert S. and Eichhorn C., 2008**):

- Reducing traffic congestion by using the road network at night.
- Shorter travel times.
- Optimization of vehicle and manpower operation.
- Lowering of emissions.
- Consolidation and gathering of shipments.
- Support the safety on road positively.

The main benefits for **transport companies** are the use of larger vehicles to transport products and the reduction of journey time.

The advantages to **society**, especially residents, include reduced travel times for all vehicles during the day (decrease of time lost due to heavy traffic) and

reduced goods vehicles driving in the city center. Additionally, the reduction of travel times leads to less pollution and energy consumption.

4.8.2 Second scenario: Freight consolidation centers (FCC)

Freight Consolidation Centers (FCC) is a logistics center that is located relatively near to the geographical area it serves (For example, a center of the city, the whole city, or specific city sites such as retail malls), this logistic facility provides many logistical services in organizing the delivery of goods within cities by the implementation of consolidated deliveries for goods within the areas it serves.

It offers freight transport companies the chance to deliver goods destined for urban areas to a specialist center for final delivery rather than having to make the delivery to the final customer in a busy part of the city. Freight consolidation facilities have a high ability to improve delivery reliability and use of goods vehicles (Quak H., 2008).

An FCC can also be theoretically illustrated as shown in Figure 4.28

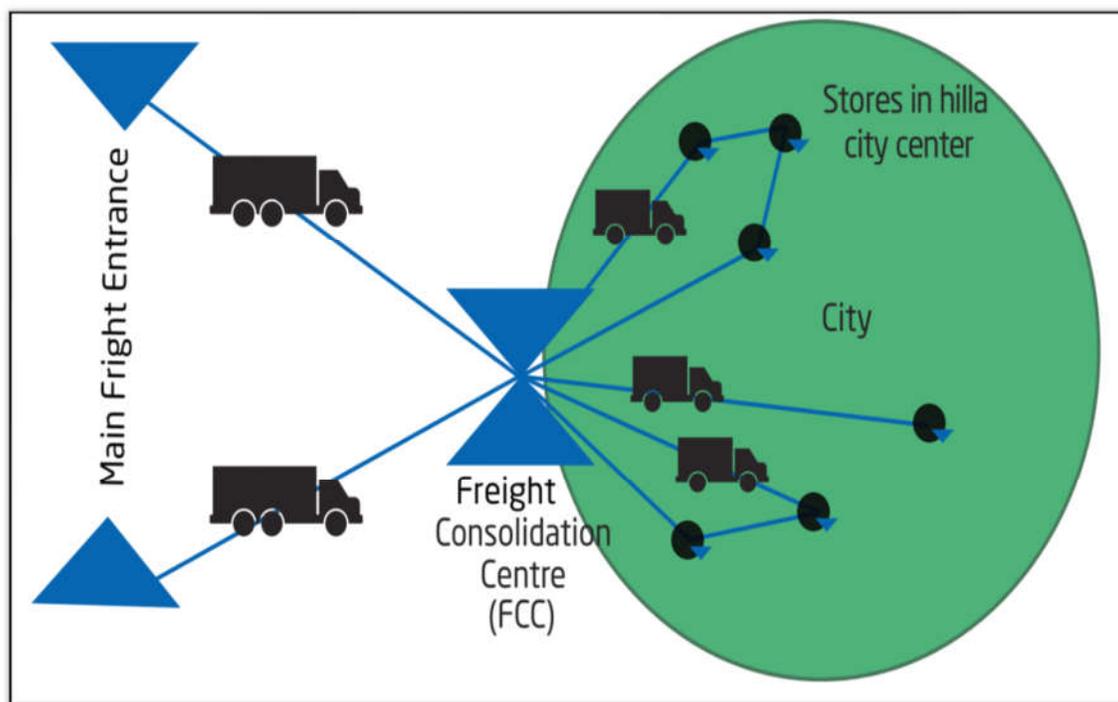


Figure 4.28 Concept of freight consolidation centers FCC (Quak H., 2008)

4.8.2.1 Objectives of freight consolidation centers

A consolidation center frequently has many goals, and the most common are related to decreasing congestion, traffic disturbance, and emission levels within the urban region that the consolidating center covers. Among the various goals are the following (**Allen J. et al., 2007**):

- Minimize traffic congestion by reducing the number of delivery trucks needed.
- Help in the improvement of air quality.
- Reduce vehicle accidents in unloading zones and delivery bays.
- Decrease conflicts between delivery trucks and also other road users, such as pedestrians.
- Improve the shipping service offered to traders.
- More efficient and sustainable movement of freight within the city.
- Optimize product line and stock availability.
- Protect and/or decrease stock theft.

4.8.2.2 Operation of freight consolidation centers

Freight consolidation centers have the same operating principles to some extent, regardless of the type of sector they serve. These principles can be summarized as follows (**Shigute S. and Araz N., 2015**):

- 1- Traders and contractors agree with their suppliers about the materials and goods to be supplied, with condition that the delivery must be made to the consolidation center not directly to the final destination's sites.
- 2- Following that, the traders and contractors submit a request to the freight consolidation center for carrying out the final delivery of the goods and materials that had previously been requested from their suppliers. The freight consolidation center combines the shipments and then delivers them to the required places. In most situations, the consolidation center converts shipments from large trucks to smaller freight vehicles for ease of delivery

inside congested areas and to finish the loading and unloading operation with greater flexibility and speed than large trucks.

Figure 4.29 shows how the distribution system is typically arranged.

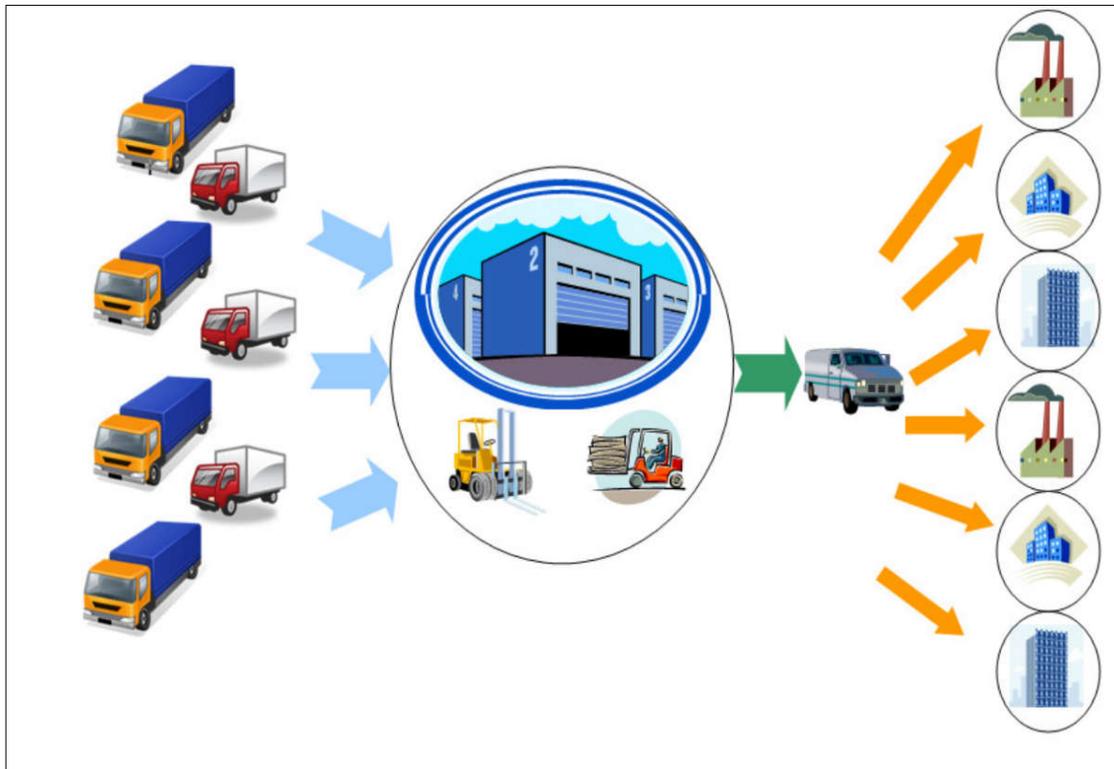


Figure 4.29 Consolidation Center Basic Operations (Shigute S. and Araz N., 2015)

4.8.2.3 Preferred Site Location of FCC in Hilla city

The most suitable locations for establishment a freight consolidation center to improve and organize the process of transporting goods in city centers are located in zones with affordable industrial land with excellent accessibility to major roads and goods receivers (Aljohani K. and Russell G., 2020)

Find the appropriate locations for the construction of (FCC) in the city of Hilla have been chosen by cooperating with the Directorate of the Municipality of Hilla and the Directorate of Urban Planning according to special requirements of land use to be compatible with the basic design map of Hilla city and make this research recommendation applicable in the future.

Two locations are available, one on the north side of the city with an area of (87) hectares and the other on the south side of the city with an area of (134) hectares as shown in Figure 4.30, while Table 4.23 and Table 4.24 listed the coordinates of their locations.

Table 4.23 The coordinates of the Site Location of FCC in Hilla city (Southside location)

| Point No. | Feature Type | X coordinate | Y coordinate |
|----------------------------|-----------------------|--------------|--------------|
| South side location | | | |
| 1 | Circumferential Point | 447481.488 | 3588138.129 |
| 2 | Circumferential Point | 447492.534 | 3588003.971 |
| 3 | Circumferential Point | 447035.161 | 3586863.325 |
| 4 | Circumferential Point | 445664.327 | 3587013.3315 |
| 5 | Circumferential Point | 445908.376 | 3587718.736 |
| 6 | Circumferential Point | 446645.401 | 3587757.021 |
| 7 | Centroid Point | 446492.737 | 3587362.201 |

Table 4.24 The coordinates of the Site Location of FCC in Hilla city (Northside location)

| Point No. | Feature Type | X coordinate | Y coordinate |
|---------------------------|-----------------------|--------------|--------------|
| Northside location | | | |
| 1 | Circumferential Point | 449908.3625 | 3599883.2814 |
| 2 | Circumferential Point | 450679.3495 | 3600004.8721 |
| 3 | Circumferential Point | 451582.0812 | 3600180.6064 |
| 4 | Circumferential Point | 451057.1585 | 3599515.2114 |
| 5 | Circumferential Point | 450499.278 | 3598878.9539 |
| 6 | Circumferential Point | 450322.1956 | 3599422.406 |
| 7 | Centroid Point | 450656.66 | 3599633.1695 |

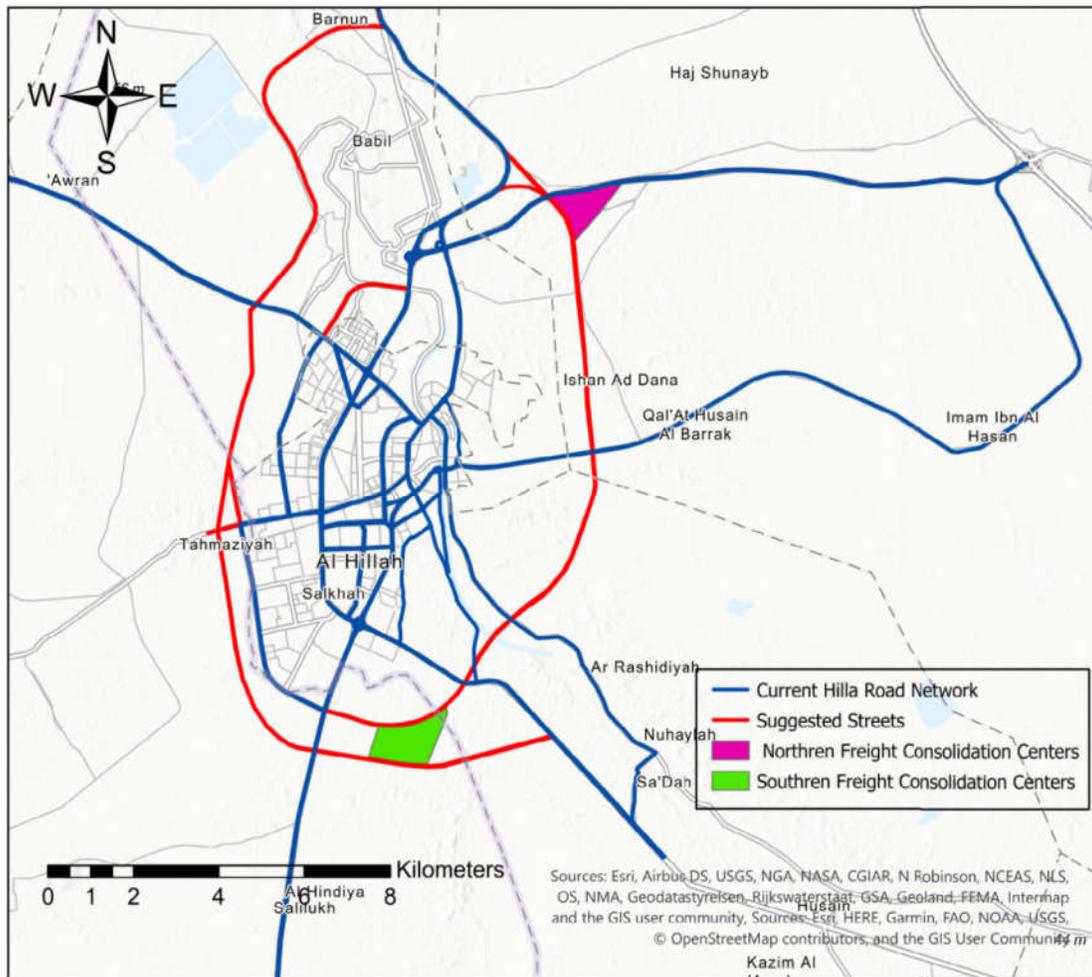


Figure 4.30 Northern and southern consolidation center locations

4.8.2.4 Analysis of available location for FCC

After locating the proposed locations for construction (FCC) on the map of the current and proposed road network using the (ArcGIS10.4) program, the locations are analyzed to determine their suitability, according to the conditions below:

The proposed locations are located within the areas of future development for industrial use and warehouses, in addition to their location near the proposed external roads linking (Baghdad, Hilla- Karbala, Hilla - Najaf, Hilla - Diwaniyah, Hillah Kish) Roads which are the main ports of entry for goods in Hilla city. It provides easy access for freight vehicles that enter from neighboring provinces to unload goods at (the North and South FCC site) without needs to pass through

the inner streets of Hilla city, which often suffer from traffic congestion. On the other hand, the two proposed locations for the establishment of a freight consolidation center in the northern and southern parts of the city are relatively close to the city center and thus provide easy access for small freight vehicles to reach the city center and distribute the goods to their final destinations.

Chapter 5

Conclusions and Recommendations

5.1 General

By using the freight data collected for Hilla city, and by using Arc GIS 10.4 software, the conclusions and the recommendation are obtained and contained in this chapter, as well as the future studies proposals that contribute to developing this work.

5.2 Conclusions

- 1- Hilla city freight transportation system consists of five main entrances linking external and internal traffic; the Nile entrance is the most important, accounting for 27% of total freight volume entering Hilla city.
- 2- Freight trucks is one of the factors causing traffic congestion on the road network in Hilla city, although the percentage of trucks measured on most of the city's main roads was not exceed 14%, due to the general inefficiency of Hilla road network as shown below:
 - After calculating the density of the road network using the ArcGIS10.4 software, it was found that the network density was (364km) per 100,000 people, which is considered a low density when compared to the global standards of (496 km) per 100,000 people.
 - Road capacity is insufficient for the high volume of freight and passenger traffic, as well as a deficiency of enough parking spaces and public transportation in the city.
- 3- The analysis of the freight vehicles flows over current Hilla road network using the network analysis tool of the ArcGIS 10.4 software, found that the largest proportion of freight traffic pass through the main effective roads in the city.

- 4- All the proposed routes by Arc GIS 10.4 network analysis for (external-external) freight trips on the modified network pass through the new suggested roads to the network without passing through the city center and inner roads.
- 5- The total (travel time and distance) for the same origin and destination points will be reduced by 9% and 30% from the current distance and travel time respectively when freight vehicles pass through suggested roads on the modified network.
- 6- The overall evaluation level of service for the road freight network in Hilla city depends on the results of (V/C) ratio by the Trans CAD 4.5 program. Shown that the LOS for current network in the study year 2022 is (LOS D), and for the target year, 2030 is (LOS F). The adoption of the proposed developments in the network will improve the level of service for modified network in the study year to (LOS C).
- 7- The suggestion of establishing a freight consolidation center in the northern part of Hilla city and another in the southern part of it will minimize the number of heavy freight vehicles on the city's internal roads, particularly during peak periods, improving traffic flow and reducing congestion.
- 8- The suggestion for night delivery of goods starting from 10:00 PM until 7:00 AM. to their destinations in Hilla city's center that experience traffic congestion during the day will reduce the movement of freight trucks during the day, improving traffic flow and the comfort of other road users.

5.3 Recommendations

- 1- Setting special times for entering (external - external) freight trips to Hilla city at night to reduce their impact on city traffic flow during the day.
- 2- Providing special lanes for transporting goods on the main roads that witness a high traffic volume of freight vehicles in Hilla city (Hilla-

Baghdad, Hilla-Karbala, Hilla-Najaf, 60 street, 80 street, Al-Tohmaziah street).

- 3- Expansion of the road network with comprehensive rehabilitation and treatment of all defects identified in this research about the road network in the city of Hilla to improve the transportation of goods and passengers together based on the modified road network from this study.

5.4 Recommendations for future studies

- 1- Highlighting the importance of railway freight transportation to reduce the burden on the road network by analyzing the railway line in Hilla and surrounding provinces using the Arc GIS technique. Rail transport has fewer fuel costs than road transport, particularly when delivering a high volume of freight. Shipping by rail is better for the environment. Trucks use more fuel per ton-mile than trains.
- 2- Study freight river transportation and its importance in reducing congestion on-road transportation.
- 3- The city must establish a modern public transportation system based on collaboration with the city's General Directorates of Traffic to identify new paths of movement to reduce traffic congestion, travel time, and costs, as well as study the possibility of implementing a tram system in the city.

References

- Akgün, E.Z., Monios, J., Rye, T. and Fonzone, A., 2019. Influences on urban freight transport policy choice by local authorities. *Transport Policy*, 75, pp.88-98.
- Aljohani, K. and Thompson, R.G., 2020. A multi-criteria spatial evaluation framework to optimise the siting of freight consolidation facilities in inner-city areas. *Transportation Research Part A: Policy and Practice*, 138, pp.51-69.
- Allen, J., Browne, M., Piotrowska, M. and Woodburn, A.G., 2010. Freight Quality Partnerships in the UK: an analysis of their work and achievements. Green Logistics Report, University of Westminster.
- Allen, Julian, G. Thorne, and Michael Browne. "Good practice guide on urban freight transport." *Bestufs Administration Centre 84* (2007): 1-85.
- Alterkawi, Mezyad. "Application of GIS in transportation planning: the case of Riyadh, the Kingdom of Saudi Arabia." *GBER Journal* 1, no. 2 (2001): 38-46.
- Anderson, Stephen, Julian Allen, and Michael Browne. "Urban logistics—how can it meet policy makers' sustainability objectives." *Journal of transport geography* 13, no. 1 (2005): 71-81.
- Banister, D., 2000. Sustainable urban development and transport—a Eurovision for 2020. *Transport reviews*, 20(1), pp.113-130.
- Björklund, Maria, and Sara Gustafsson. "Toward sustainability with the coordinated freight distribution of municipal goods." *Journal of Cleaner Production* 98 (2015): 194-204.
- Boylaud, O. and Nicoletti, G., 2001. Regulatory reform in road freight. *OECD Economic studies*, 2001(1), pp.229-251.
- Browne, Michael, and Julian Allen. "Enhancing the sustainability of urban freight transport and logistics." *Transport and communications bulletin for Asia and the Pacific* 80 (2011): 1-19.

Browne, Michael, Michael Sweet, Allan Woodburn, and Julian Allen. "Urban freight consolidation centres final report." Transport Studies Group, University of Westminster 10 (2005).

Chankaew, N., Sumalee, A., Treerapot, S., Threepak, T., Ho, H.W. and Lam, W.H., 2018. Freight traffic analytics from national truck GPS data in Thailand. *Transportation research procedia*, 34, pp.123-130.

Coffin, Alisa W. "From roadkill to road ecology: a review of the ecological effects of roads." *Journal of transport Geography* 15, no. 5 (2007): 396-406.

Curtin, K.M., 2007. Network analysis in geographic information science: Review, assessment, and projections. *Cartography and geographic information science*, 34(2), pp.103-111.

Daniel, C.B., Saravanan, S. and Mathew, S., 2020. Gis based road connectivity evaluation using graph theory. In *Transportation Research* (pp. 213-226). Springer, Singapore.

Deng, Jin S., Ke Wang, Yang Hong, and Jia G. Qi. "Spatio-temporal dynamics and evolution of land use change and landscape pattern in response to rapid urbanization." *Landscape and urban planning* 92, no. 3-4 (2009): 187-198.

Dhanani, Ashley. "Suburban built form and street network development in London, 1880–2013: An application of quantitative historical methods." *Historical Methods: A Journal of Quantitative and Interdisciplinary History* 49, no. 4 (2016): 230-243.

Easa, Said, and Yupo Chan. "Urban planning and development applications of GIS." Asce, 2000. American Society of Civil Engineers, Reston, VA. Book.

El Khayat, Mustapha. "Transport infrastructure and logistics: the strategic levers of trade and competitiveness." In *mediterranean 2014 (english)*, pp. 107-124. Presses de Sciences Po, 2014.

Escobar, F., Hunter, G., Bishop, I. and Zerger, A., 2008. Introduction to GIS. Department of Geomatics, The University of Melbourne, Available online at: <http://www.sli.unimelb.edu.au/gisweb/> (Accessed 02 April 2008).

Liu, X., Wang, X., Wright, G., Cheng, J.C., Li, X. and Liu, R., 2017. A state-of-the-art review on the integration of Building Information Modeling (BIM) and Geographic Information System (GIS). *ISPRS International Journal of Geo-Information*, 6(2), p.53.

Ezquerro, S., Romero, J.P., Moura, J.L., Benavente, J. and Ibeas, Á., 2018. Minimizing the impact of large freight vehicles in the city: a multicriteria vision for route planning and type of vehicles. *Journal of Advanced Transportation*, 2018.

Falih, K., 2016. The Utilization of Geomatics Techniques for Analysis of Urban Areas Transportation Network (Doctoral dissertation, University of Technology, Iraq).

Falzarano, Aaron, Sai Ketha, and J. Scott Hawker. "Development of an intermodal network for freight transportation analysis." Rochester Institute of Technology (2007). ESRI 2007 User Conference Paper 1488

Forkert, S. and Eichhorn, C., 2008. Innovative Approaches in City Logistics: Inner-City Night Delivery. Niches. (Accessed 05.11. 08), the project websites: (www.niches-transport.org). (www.osmose-os.org).

Frank, W.C., Thill, J.C. and Batta, R., 2000. Spatial decision support system for hazardous material truck routing. *Transportation Research Part C: Emerging Technologies*, 8(1-6), pp.337-359.

Fu, J. and Jenelius, E., 2018. Transport efficiency of off-peak urban goods deliveries: A Stockholm pilot study. *Case Studies on Transport Policy*, 6(1), pp.156-166.

Garth Thorne, Allen, Julian, and Michael Browne. "BESTUFS good practice guide on urban freight transport." (2007). Web address (URL)http://www.bestufs.net/download/Bestufs_II/good_practice/English_Bestufs_Guide.pdf report.

Gatta, Valerio, Edoardo Marcucci, Paolo Delle Site, Michela Le Pira, and Céline Sacha Carrocci. "Planning with stakeholders: Analysing alternative off-hour delivery solutions via an interactive multi-criteria approach." *Research in Transportation Economics* 73 (2019): 53-62.

Gnap, J., Beňová, D., Slávik, R. and Dydkowski, G., 2017. Changes in night-time distribution of goods to the city centres as a tool to meet the requirements of the EU white paper on transport (347.0Kb). Collections Transport and Communications - Volume 5.; Issue 2/2017 [11].

Gupta, P., Jain, N., Sikdar, P.K. and Kumar, K., 2009. Geographical Information System in Transportation Planning, Geospatial World report. Central Road Research Institute. New Delhi, India, 110020.

Holguín-Veras, J., Polimeni, J., Cruz, B., Xu, N., List, G., Nordstrom, J. and Haddock, J., 2005. Off-peak freight deliveries: Challenges and stakeholders' perceptions. *Transportation Research Record*, 1906(1), pp.42-48.

Holguín-Veras, José, and Miguel Jaller. "Comprehensive freight demand data collection framework for large urban areas." In *Sustainable urban logistics: Concepts, methods and information systems*, pp. 91-112. Springer, Berlin, Heidelberg, 2014.

Johannes Schneider, Ebersbach, Anja, Ingo Morgenstern, and Rainer Hammwöhner. "The Influence of Trucks on Traffic Flow—An Investigation on The Nagel–Schreckenberg-Model." *International Journal of Modern Physics C* 11, no. 04 (2000): 837-842.

Johnston, K., Ver Hoef, J.M., Krivoruchko, K. and Lucas, N., 2001. *Using ArcGIS geostatistical analyst* (Vol. 380). Redlands: Esri (Book).

Kaszubowski, Daniel, Alicja Pawłowska, and Karolina Marszałkowska. "Adapting new tools of urban freight management based on Gdynia's dedicated delivery bays example—an analysis of the process." *Transportation Research Procedia* 30 (2018): 265-274.

Khairallah R. and Ali Alwash, "Development of Travel Demand Models for Al-Salaam Sector within Hilla City." Msc. Thesis Babylon University (2021).

Kong, D. and Guo, X., 2016. Analysis of vehicle headway distribution on multi-lane freeway considering car–truck interaction. *Advances in Mechanical Engineering*, 8(4), p.1687814016646673.

Kumar, Parveen, and Dinesh Kumar. "Network analysis using GIS techniques: A case of Chandigarh city." *International Journal of Science and Research* 5, no. 2 (2016): 409-411.

Lewis, A., M. Fell, and D. Palmer. "Freight consolidation center study." London (2010). Report Prepared for Department for Transport by transport and travel research, Project Number N_10_507. Version 1.0 14th July 2010.

Liang Ding, Shi, Ge, Jie Shan, Peng Ye, Yang Li, and Nan Jiang. "Urban road network expansion and its driving variables: a case study of Nanjing City." *International journal of environmental research and public health* 16, no. 13 (2019): 2318.

Macharis, C., Kin, B., Balm, S. and Ploos van Amstel, W., 2016. Multiactor participatory decision making in urban construction logistics. *Transportation Research Record*, 2547(1), pp.83-90.

Matthew C. Camden, Alejandra Medina-Flintsch, Jeffrey S. Hickman, Andrew M. Miller, and Richard J. Hanowski., September 2017. "Leveraging Large-Truck Technology and Engineering to Realize Safety Gains: Air Disc Brakes" Technical Report, Virginia Tech Transportation Institute, Blacksburg, Virginia

Marcotullio, P.J., 2009. Urban sustainability and the regional city system in the Asia Pacific. *Human Settlement Development-Volume I*, p.66.

Marcucci, E. and Danielis, R., 2008. The potential demand for a urban freight consolidation centre. *Transportation*, 35(2), pp.269-284.

Maurits H.M. van der Donk., 2015 "Critical design variables of a freight consolidation centre" Faculty of TPM, Delft University of Technology, Netherlands. Student Number: 1374397

Michael Sweet, Browne, Michael, Allan Woodburn, and Julian Allen. "Urban freight consolidation centers final report." *Transport Studies Group*, University of Westminster 10 (2005).

Nguyen, H.O. and Tongzon, J., 2010. Causal nexus between the transport and logistics sector and trade: The case of Australia. *Transport policy*, 17(3), pp.135-146.

- Patarasuk, R., 2013. Road network connectivity and land-cover dynamics in Lop Buri province, Thailand. *Journal of Transport Geography*, 28, pp.111-123.
- Qasim, Zaynab, Abdul-Razzak Ziboon, and Khaldoon Falih. "TransCad analysis and GIS techniques to evaluate transportation network in Nasiriyah city." In *MATEC Web of Conferences*, vol. 162, p. 03029. EDP Sciences, 2018.
- Quak, H.J. (2008, March 20). Sustainability of Urban Freight Transport: Retail Distribution and Local Regulations in Cities (No. EPS-2008-124-LIS). ERIM Ph.D. Series Research in Management. Erasmus Research Institute of Management. Retrieved from <http://hdl.handle.net/1765/11990>. Book
- Rabab Hadi, Abdul Razzak T. Ziboon, Salah A. Salih "evaluation of holly karbala city roads network using GIS (network analyst)", January 2013, <https://www.researchgate.net>, DOI: 10.13140/RG.2.2.31831.93602.
- Reddy, P.S., 2021. Implication Of GIS on Sustainable Urban Planning and Management in Uganda. *International Journal of Technology and Systems*, 6(1), pp.15-27.
- Rui, Yikang, and Yifang Ban. "Exploring the relationship between street centrality and land use in Stockholm." *International Journal of Geographical Information Science* 28, no. 7 (2014): 1425-1438.
- Russo, Francesco, and Antonio Comi. "Measures for sustainable freight transportation at urban scale: expected goals and tested results in Europe." *Journal of Urban Planning and Development* 137, no. 2 (2011): 142-152.
- Sánchez-Díaz, I., Georén, P. and Brolinson, M., 2017. "Shifting urban freight deliveries to the off-peak hours: a review of theory and practice. *Transport reviews*", 37(4), pp.521-543.
- Sarvi, Majid. "Heavy commercial vehicles-following behavior and interactions with different vehicle classes." *Journal of advanced transportation* 47, no. 6 (2013): 572-580.
- Satoh, I., 2011, November. Selection of Truck Route for Cooperative Logistics. In *2011 International Conference on Technologies and Applications of Artificial Intelligence* (pp. 82-87). Publisher IEEE.

Shigute, Sefera Ali, and Araz Nasirian. "The Future of Construction Logistics Consolidation Centers in Construction Logistics." (Master's thesis). Master of Science Thesis in the Master's Programme Department of Civil and Environmental Engineering Division of construction management. Chalmers University of Technology Göteborg, Sweden, 2015.

Sola Olusesan, Ogunleye, "Spatial Structure of Road Infrastructure in Ekiti State, Nigeria: Options for Transformation." *Advances in Natural Science* 4, no. 2 (2011): 138-142.

Strano, Emanuele, Vincenzo Nicosia, Vito Latora, Sergio Porta, and Marc Barthélemy. "Elementary processes governing the evolution of road networks." *Scientific reports* 2, no. 1 (2012): 1-8.

Subramani, T., and P. K. Kumaresan. "Traffic study on road network and identify transport improvement projects required in salem." *International Journal of Managment, IT and Engineering* 2, no. 7 (2012): 190-200.

Teodorovic, D. and Janic, M., 2016. *Transportation engineering: Theory, practice and modeling*. Butterworth-Heinemann (Book).

Van Duin JH, Quak HJ. "City logistics: a chaos between research and policy making? A review". *WIT Transactions on the Built Environment*. 2007 Jul 25;96.

Van Maarseveen, Martin, Javier Martinez, and Johannes Flacke. "GIS in sustainable urban planning and management": a global perspective. Publisher Taylor & Francis, 2019. Pages 364(Book).

Watkiss, P., Allen, J., Anderson, S., Beevers, S., Browne, M., Carslaw, D., Emerson, P., Fairclough, P., Franciscs, J., Freeman, D. and Haydock, H., 2003. *London low emission zone feasibility study phase II: Project report, final report to the London low emission zone steering group*.

Wazer, Zainab A., and Noor M. Asmael. "Analysis Travel Pattern of Freight Demand Using GIS Techniques." In *IOP Conference Series: Materials Science and Engineering*, vol. 1090, no. 1, p. 012091. IOP Publishing, 2021.

Yannis, G., Golias, J. and Antoniou, C., 2006. Effects of urban delivery restrictions on traffic movements. *Transportation Planning and Technology*, 29(4), pp.295-311.

Zhao, G., Zheng, X., Yuan, Z. and Zhang, L., 2017. Spatial and temporal characteristics of road networks and urban expansion. *Land*, 6(2), p.30.

Ziboon, Abdul-Razzak T., Zaynab I. Qasim, and Khaldoon T. Falih. "Gis application to evaluate transportations network in nasiriyah city." *J. Eng. Sustain. Dev* 21 (2017): 75-87.

عزيز الظاهر، محمد الخزامي، عجيل تركي. (٢٠٠٣). التحليل المكاني لشبكة النقل الحضري في مدينة الكويت. *مجلة جامعة دمشق للآداب والعلوم الإنسانية*، مج ١٩، ع ٣٤، ١٧٣ - ٢٢٢. مسترجع من <http://search.mandumah.com/Record/158493>

أحمد رفعت مصطفى "تحليل خصائص شبكة الطرق في مدينة الخليل باستخدام نظم المعلومات الجغرافية." *مجلة البحوث الجغرافية* ٢٥/١٢/٢٠١٧ العدد الخامس بحث رقم ٢٥

Ahmed Ra'fat Mustafa, Ghodieh, "Analyze the characteristics of AL-Khalil city road network using geographic information systems" 25, Dec,2017

Volume 5; No.25

Appendix A

Roadside Interview Survey Questionnaire Form

استمارة استبيان لرحلات الشاحنات الداخلة الى مدينة الحلة

- نوع الشاحنة:

| | |
|--------------------------------|-------------------------------|
| <input type="checkbox"/> حكومي | <input type="checkbox"/> اهلي |
|--------------------------------|-------------------------------|

- نوع البضاعة المنقولة:

| | | | |
|---------------------------------|----------------------------------|--|---|
| <input type="checkbox"/> غذائية | <input type="checkbox"/> انشائية | <input type="checkbox"/> منتوجات نفطية | <input type="checkbox"/> أجهزة كهربائية |
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> سلع اخرى |

- وجهة الرحلة:

(نقطة الانطلاق) ----- الى نقطة التفريغ او التسليم-----

- نوع الرحلة:

| | |
|--|--|
| <input type="checkbox"/> داخلي - داخلي | <input type="checkbox"/> خارجي - خارجي |
|--|--|

- سرعة الشاحنة

معدل سرعة المركبة للوصول الى نقطة التفريغ ----- كم/ساعة

- عدد محاور المركبة:

| | |
|---------------------------------|-------------------------------------|
| <input type="checkbox"/> محورين | <input type="checkbox"/> ثلاث محاور |
| <input type="checkbox"/> | <input type="checkbox"/> |
| <input type="checkbox"/> | <input type="checkbox"/> اكثر |

- وزن الحمولة

الوزن التقريبي للحمولة ----- طن

- مدة الرحلة:

الفترة الزمنية المستغرقة من منطقة الدخول في مدينة الحلة الى منطقة التفريغ ----- ساعة-----

- فتره دخول الشاحنات من الساعة ----- الى الساعة-----

- المشاكل التي يعاني منها السائق عند مداخل او داخل مدينة الحلة

Figure A-1 Interview survey questionnaire form.

Appendix B

Network Attributes for Hilla Freight Roads Network

Network attributes are properties of the network elements that control travers ability over the network. Examples of attributes include the time to travel a given length of road, which streets are restricted for which vehicles, the speeds along a given road, and which streets are one-way.

Network attributes have five basic properties: name, usage type, units, data type, and use by default. Additionally, they have a set of assignments defining the values for the elements:

- The usage type specifies how the attribute will be used during analysis, which is identified as either a cost, descriptor, restriction, or hierarchy.
- Units of a cost attribute are either distance or time units (for example, centimeters, meters, miles, minutes, and seconds).
- Hierarchies, and restrictions have unknown units.
- Data types can be either Boolean, integer, float, or double.
- Cost attributes cannot be a Boolean data type. Restrictions are always Boolean, whereas a hierarchy is always an integer.

Table B-1 shows the attribute information for current Hilla freight roads network, which contains 677 links, these data are very useful for future study that deal with Hilla main road network analysis. Table B-2 shows the attribute information for the suggested roads which contains 24 link those used for improving Hilla freight roads network.

Table B-1 The attribute table for current Hilla freight roads network

| Object ID | Shape | Road Type | One-way | Bridge | Shape Length (Meter) | Time (Minute) | Speed (Km/hr) |
|-----------|----------|----------------|---------|--------|----------------------|---------------|---------------|
| 1 | Polyline | minor arterial | 1 | 0 | 185.218329 | 0.277772 | 40 |
| 2 | Polyline | major arterial | 1 | 0 | 2382.333435 | 2.381857 | 60 |
| 3 | Polyline | major arterial | 1 | 0 | 1390.861652 | 1.042938 | 80 |
| 5 | Polyline | | 1 | 1 | 199.380272 | 0.19934 | 60 |
| 6 | Polyline | minor arterial | 1 | 0 | 2040.033213 | 3.060049 | 40 |
| 7 | Polyline | major arterial | 1 | 1 | 7211.868258 | 5.40782 | 80 |
| 10 | Polyline | minor arterial | 1 | 0 | 52.743521 | 0.079099 | 40 |
| 11 | Polyline | minor arterial | 1 | 0 | 217.553145 | 0.326264 | 40 |
| 12 | Polyline | minor arterial | 0 | 0 | 167.577563 | 0.251316 | 40 |
| 13 | Polyline | minor arterial | 1 | 0 | 214.294642 | 0.321378 | 40 |
| 14 | Polyline | minor arterial | 1 | 0 | 150.829215 | 0.226199 | 40 |
| 15 | Polyline | minor arterial | 1 | 0 | 330.484396 | 0.660837 | 30 |
| 16 | Polyline | minor arterial | 1 | 0 | 152.90092 | 0.229306 | 40 |
| 17 | Polyline | minor arterial | 1 | 0 | 153.772799 | 0.230613 | 40 |
| 18 | Polyline | minor arterial | 0 | 0 | 113.924036 | 0.170852 | 40 |
| 19 | Polyline | minor arterial | 1 | 0 | 213.153225 | 0.319666 | 40 |
| 20 | Polyline | major arterial | 1 | 1 | 86.664171 | 0.064985 | 80 |
| 21 | Polyline | major arterial | 1 | 1 | 58.325411 | 0.043735 | 80 |
| 22 | Polyline | major arterial | 1 | 0 | 10697.661237 | 8.021642 | 80 |
| 23 | Polyline | major arterial | 1 | 0 | 329.684901 | 0.250785 | 80 |
| 24 | Polyline | major arterial | 1 | 0 | 267.147973 | 0.200321 | 80 |
| 25 | Polyline | minor arterial | 1 | 0 | 461.679664 | 0.923175 | 30 |
| 26 | Polyline | minor arterial | 1 | 0 | 422.814908 | 0.856214 | 30 |
| 27 | Polyline | major arterial | 1 | 0 | 504.63249 | 0.378399 | 80 |
| 28 | Polyline | major arterial | 1 | 1 | 83.658336 | 0.062731 | 80 |
| 29 | Polyline | minor arterial | 1 | 0 | 394.441979 | 0.788726 | 30 |
| 30 | Polyline | minor arterial | 1 | 0 | 366.978213 | 0.73381 | 30 |

| Object ID | Shape | Road Type | One-way | Bridge | Shape Length (Meter) | Time (Minute) | Speed (Km/hr) |
|-----------|----------|----------------|---------|--------|----------------------|---------------|---------------|
| 31 | Polyline | major arterial | 1 | 1 | 88.220977 | 0.066153 | 80 |
| 32 | Polyline | minor arterial | 1 | 0 | 113.783674 | 0.170641 | 40 |
| 33 | Polyline | | 1 | 1 | 65.049874 | 0.097555 | 40 |
| 34 | Polyline | minor arterial | 1 | 0 | 51.77014 | 0.07764 | 40 |
| 35 | Polyline | minor arterial | 1 | 0 | 54.635377 | 0.081937 | 40 |
| 37 | Polyline | major arterial | 1 | 0 | 1921.74843 | 1.921373 | 60 |
| 38 | Polyline | minor arterial | 1 | 0 | 198.109854 | 0.297105 | 40 |
| 39 | Polyline | minor arterial | 0 | 0 | 97.89799 | 0.195757 | 30 |
| 40 | Polyline | major arterial | 1 | 0 | 2422.796233 | 3.633468 | 40 |
| 41 | Polyline | minor arterial | 1 | 0 | 342.775634 | 0.514061 | 40 |
| 42 | Polyline | minor arterial | 1 | 0 | 2443.638036 | 3.664724 | 40 |
| 43 | Polyline | minor arterial | 1 | 0 | 2337.578142 | 3.505666 | 40 |
| 44 | Polyline | minor arterial | 1 | 0 | 80.465267 | 0.160898 | 30 |
| 45 | Polyline | major arterial | 1 | 0 | 8710.971284 | 6.531922 | 80 |
| 46 | Polyline | minor arterial | 0 | 0 | 172.025042 | 0.057859 | 30 |
| 47 | Polyline | minor arterial | 1 | 0 | 2246.883398 | 3.369651 | 40 |
| 48 | Polyline | minor arterial | 1 | 0 | 80.491915 | 0.160952 | 30 |
| 49 | Polyline | minor arterial | 1 | 0 | 79.839065 | 0.159646 | 30 |
| 50 | Polyline | major arterial | 1 | 0 | 8719.014574 | 6.537953 | 80 |
| 53 | Polyline | major arterial | 1 | 0 | 1342.622386 | 1.342354 | 60 |
| 54 | Polyline | minor arterial | 0 | 0 | 8314.39029 | 12.471585 | 40 |
| 56 | Polyline | minor arterial | 1 | 0 | 746.103615 | 1.119155 | 40 |
| 57 | Polyline | minor arterial | 1 | 0 | 1216.575709 | 1.824863 | 40 |
| 59 | Polyline | minor arterial | 0 | 0 | 157.856926 | 0.086572 | 30 |
| 60 | Polyline | minor arterial | 1 | 0 | 484.571143 | 0.726711 | 40 |
| 62 | Polyline | major arterial | 1 | 0 | 491.895981 | 0.737696 | 40 |
| 63 | Polyline | minor arterial | 0 | 0 | 89.999199 | 0.539995 | 10 |
| 64 | Polyline | minor arterial | 0 | 0 | 12.081787 | 0.024163 | 30 |

| Object ID | Shape | Road Type | One-way | Bridge | Shape Length (Meter) | Time (Minute) | Speed (Km/hr) |
|-----------|----------|----------------|---------|--------|----------------------|---------------|---------------|
| 65 | Polyline | minor arterial | 0 | 1 | 288.346671 | 0.576578 | 30 |
| 72 | Polyline | minor arterial | 1 | 0 | 2177.550952 | 3.266326 | 40 |
| 73 | Polyline | minor arterial | 0 | 0 | 1758.912869 | 2.637842 | 40 |
| 74 | Polyline | minor arterial | 1 | 0 | 19.924711 | 0.039841 | 30 |
| 75 | Polyline | minor arterial | 1 | 0 | 22.467397 | 0.044926 | 30 |
| 76 | Polyline | minor arterial | 1 | 0 | 24.216332 | 0.048423 | 30 |
| 77 | Polyline | minor arterial | 1 | 0 | 16.450837 | 0.032895 | 30 |
| 78 | Polyline | minor arterial | 1 | 0 | 768.554848 | 1.152602 | 40 |
| 79 | Polyline | minor arterial | 1 | 0 | 797.146219 | 1.19548 | 40 |
| 80 | Polyline | minor arterial | 1 | 0 | 104.422106 | 0.208802 | 30 |
| 81 | Polyline | minor arterial | 1 | 0 | 97.137509 | 0.194236 | 30 |
| 97 | Polyline | minor arterial | 1 | 0 | 389.403249 | 0.778651 | 30 |
| 120 | Polyline | minor arterial | 1 | 1 | 65.574717 | 0.098342 | 40 |
| 124 | Polyline | minor arterial | 1 | 0 | 150.399741 | 0.30131 | 30 |
| 125 | Polyline | minor arterial | 1 | 0 | 140.44777 | 0.280839 | 30 |
| 126 | Polyline | minor arterial | 0 | 0 | 1561.839627 | 2.342291 | 40 |
| 127 | Polyline | minor arterial | 1 | 0 | 200.503051 | 0.400926 | 30 |
| 128 | Polyline | minor arterial | 1 | 0 | 57.082995 | 0.114143 | 30 |
| 129 | Polyline | minor arterial | 1 | 0 | 53.637068 | 0.107253 | 30 |
| 130 | Polyline | minor arterial | 1 | 0 | 195.424807 | 0.390771 | 30 |
| 135 | Polyline | minor arterial | 1 | 0 | 263.665601 | 0.395419 | 40 |
| 136 | Polyline | minor arterial | 1 | 0 | 1019.84418 | 1.52946 | 40 |
| 147 | Polyline | minor arterial | 1 | 0 | 485.315153 | 0.727827 | 40 |
| 149 | Polyline | minor arterial | 1 | 0 | 326.883726 | 0.490228 | 40 |
| 150 | Polyline | minor arterial | 1 | 0 | 327.748537 | 0.491525 | 40 |
| 153 | Polyline | minor arterial | 0 | 0 | 122.651349 | 0.245254 | 30 |
| 154 | Polyline | minor arterial | 0 | 0 | 151.291186 | 0.302522 | 30 |
| 155 | Polyline | minor arterial | 0 | 0 | 558.515558 | 0.837606 | 40 |

| Object ID | Shape | Road Type | One-way | Bridge | Shape Length (Meter) | Time (Minute) | Speed (Km/hr) |
|-----------|----------|----------------|---------|--------|----------------------|---------------|---------------|
| 156 | Polyline | minor arterial | 1 | 0 | 109.751304 | 0.164594 | 40 |
| 157 | Polyline | major arterial | 1 | 0 | 102.589275 | 0.153853 | 40 |
| 158 | Polyline | minor arterial | 0 | 0 | 323.07193 | 0.484511 | 40 |
| 159 | Polyline | minor arterial | 0 | 0 | 400.913091 | 0.601249 | 40 |
| 160 | Polyline | minor arterial | 0 | 0 | 120.264752 | 0.240481 | 30 |
| 170 | Polyline | major arterial | 1 | 0 | 612.991333 | 2.828625 | 60 |
| 171 | Polyline | major arterial | 1 | 0 | 566.402749 | 0.566402 | 60 |
| 172 | Polyline | minor arterial | 0 | 0 | 636.17335 | 0.954260 | 40 |
| 173 | Polyline | major arterial | 1 | 0 | 2814.341095 | 2.813778 | 60 |
| 174 | Polyline | minor arterial | 1 | 0 | 246.246181 | 0.369295 | 40 |
| 175 | Polyline | minor arterial | 1 | 0 | 453.776398 | 0.680528 | 40 |
| 176 | Polyline | major arterial | 1 | 0 | 410.887496 | 0.616208 | 40 |
| 177 | Polyline | minor arterial | 0 | 0 | 3083.808891 | 4.624788 | 40 |
| 179 | Polyline | minor arterial | 1 | 0 | 244.336821 | 0.488576 | 30 |
| 180 | Polyline | minor arterial | 1 | 0 | 214.991916 | 0.429898 | 30 |
| 181 | Polyline | minor arterial | 1 | 0 | 225.99583 | 0.451636 | 30 |
| 182 | Polyline | minor arterial | 1 | 0 | 190.043701 | 0.399275 | 30 |
| 190 | Polyline | major arterial | 1 | 0 | 3421.545519 | 3.420861 | 60 |
| 200 | Polyline | minor arterial | 0 | 0 | 16971.878023 | 25.457817 | 40 |
| 211 | Polyline | major arterial | 1 | 0 | 1513.492877 | 1.134893 | 80 |
| 221 | Polyline | major arterial | 1 | 0 | 949.64632 | 0.949456 | 60 |
| 225 | Polyline | major arterial | 1 | 0 | 107.07173 | 0.10705 | 60 |
| 226 | Polyline | minor arterial | 1 | 0 | 179.251983 | 0.358432 | 30 |
| 227 | Polyline | major arterial | 1 | 0 | 200.961344 | 0.200921 | 60 |
| 228 | Polyline | minor arterial | 1 | 0 | 184.340783 | 0.368608 | 30 |
| 229 | Polyline | minor arterial | 1 | 0 | 195.099779 | 0.390122 | 30 |
| 230 | Polyline | minor arterial | 1 | 0 | 400.038435 | 0.799917 | 30 |
| 231 | Polyline | minor arterial | 1 | 0 | 375.549572 | 0.750949 | 30 |

| Object ID | Shape | Road Type | One-way | Bridge | Shape Length (Meter) | Time (Minute) | Speed (Km/hr) |
|-----------|----------|----------------|---------|--------|----------------------|---------------|---------------|
| 232 | Polyline | minor arterial | 1 | 0 | 390.326811 | 0.780498 | 30 |
| 233 | Polyline | minor arterial | 1 | 0 | 301.068907 | 0.602017 | 30 |
| 234 | Polyline | minor arterial | 1 | 0 | 201.57986 | 0.403079 | 30 |
| 235 | Polyline | major arterial | 1 | 0 | 7187.749604 | 7.186312 | 60 |
| 236 | Polyline | major arterial | 1 | 0 | 6854.244835 | 6.852874 | 60 |
| 237 | Polyline | | 1 | 1 | 233.766612 | 0.23372 | 60 |
| 238 | Polyline | | 1 | 1 | 92.10966 | 0.092091 | 60 |
| 239 | Polyline | minor arterial | 1 | 0 | 21.968344 | 0.131784 | 10 |
| 240 | Polyline | major arterial | 1 | 0 | 1847.532525 | 1.847163 | 60 |
| 242 | Polyline | major arterial | 0 | 0 | 16.345426 | 0.098053 | 10 |
| 243 | Polyline | major arterial | 1 | 0 | 5050.647913 | 5.049638 | 60 |
| 244 | Polyline | major arterial | 1 | 0 | 5074.554653 | 5.07354 | 60 |
| 248 | Polyline | major arterial | 1 | 0 | 323.095993 | 0.242274 | 80 |
| 252 | Polyline | minor arterial | 1 | 0 | 360.612513 | 0.540811 | 40 |
| 253 | Polyline | minor arterial | 1 | 0 | 63.203858 | 0.379223 | 10 |
| 254 | Polyline | minor arterial | 1 | 0 | 61.040203 | 0.366241 | 10 |
| 257 | Polyline | minor arterial | 1 | 0 | 52.118879 | 0.312713 | 10 |
| 258 | Polyline | minor arterial | 1 | 0 | 43.679411 | 0.262076 | 10 |
| 259 | Polyline | minor arterial | 1 | 0 | 50.681828 | 0.304090 | 10 |
| 260 | Polyline | minor arterial | 1 | 0 | 32.332361 | 0.064664 | 30 |
| 264 | Polyline | major arterial | 1 | 1 | 11057.839648 | 8.291721 | 80 |
| 275 | Polyline | minor arterial | 1 | 0 | 453.528631 | 0.680157 | 40 |
| 276 | Polyline | minor arterial | 0 | 0 | 20.753117 | 0.124494 | 10 |
| 277 | Polyline | minor arterial | 0 | 0 | 22.541422 | 0.135221 | 10 |
| 281 | Polyline | minor arterial | 1 | 0 | 403.53335 | 0.605179 | 40 |
| 282 | Polyline | minor arterial | 1 | 0 | 404.568381 | 0.606631 | 40 |
| 284 | Polyline | minor arterial | 0 | 0 | 26.76845 | 0.040145 | 40 |
| 286 | Polyline | minor arterial | 1 | 0 | 1018.203513 | 1.527 | 40 |

| Object ID | Shape | Road Type | One-way | Bridge | Shape Length (Meter) | Time (Minute) | Speed (Km/hr) |
|-----------|----------|----------------|---------|--------|----------------------|---------------|---------------|
| 287 | Polyline | minor arterial | 1 | 0 | 0.954260 | 0.005725 | 10 |
| 292 | Polyline | major arterial | 1 | 0 | 956.470435 | 0.956279 | 60 |
| 293 | Polyline | major arterial | 1 | 0 | 597.426163 | 0.597307 | 60 |
| 295 | Polyline | minor arterial | 1 | 0 | 359.744759 | 0.719346 | 30 |
| 298 | Polyline | major arterial | 1 | 0 | 721.287816 | 0.721144 | 60 |
| 299 | Polyline | | 1 | 1 | 558.649181 | 0.837806 | 40 |
| 300 | Polyline | minor arterial | 1 | 0 | 708.831654 | 0.103893 | 40 |
| 301 | Polyline | minor arterial | 1 | 0 | 1219.569601 | 1.828989 | 40 |
| 302 | Polyline | major arterial | 1 | 0 | 78.881366 | 0.118298 | 40 |
| 303 | Polyline | minor arterial | 1 | 0 | 367.713059 | 0.735279 | 30 |
| 306 | Polyline | minor arterial | 1 | 0 | 463.381509 | 0.926578 | 30 |
| 307 | Polyline | minor arterial | 1 | 0 | 329.262142 | 0.658393 | 30 |
| 308 | Polyline | major arterial | 1 | 0 | 1305.179721 | 1.304919 | 60 |
| 309 | Polyline | minor arterial | 1 | 0 | 81.805814 | 0.122684 | 40 |
| 310 | Polyline | major arterial | 1 | 0 | 2301.130754 | 2.300671 | 60 |
| 318 | Polyline | major arterial | 1 | 0 | 3435.029653 | 3.434343 | 60 |
| 319 | Polyline | major arterial | 1 | 0 | 561.367382 | 0.561255 | 60 |
| 320 | Polyline | major arterial | 1 | 0 | 395.498157 | 0.395419 | 60 |
| 321 | Polyline | minor arterial | 1 | 0 | 20.300954 | 0.121781 | 10 |
| 322 | Polyline | minor arterial | 0 | 0 | 18.305144 | 0.109809 | 10 |
| 330 | Polyline | major arterial | 0 | 0 | 16.054838 | 0.09631 | 10 |
| 340 | Polyline | minor arterial | 1 | 0 | 13.119398 | 0.078701 | 10 |
| 341 | Polyline | minor arterial | 1 | 0 | 1282.173509 | 1.922876 | 40 |
| 342 | Polyline | minor arterial | 1 | 0 | 279.010504 | 0.418432 | 40 |
| 345 | Polyline | minor arterial | 1 | 0 | 16.24184 | 0.097432 | 30 |
| 349 | Polyline | minor arterial | 1 | 0 | 13.091252 | 0.078532 | 10 |
| 351 | Polyline | minor arterial | 1 | 0 | 21.721954 | 0.130306 | 10 |
| 377 | Polyline | minor arterial | 0 | 0 | 13.000705 | 0.077989 | 10 |

| Object ID | Shape | Road Type | One-way | Bridge | Shape Length (Meter) | Time (Minute) | Speed (Km/hr) |
|-----------|----------|----------------|---------|--------|----------------------|---------------|---------------|
| 378 | Polyline | minor arterial | 0 | 0 | 13.976384 | 0.083842 | 10 |
| 379 | Polyline | minor arterial | 0 | 0 | 15.896849 | 0.095362 | 10 |
| 384 | Polyline | major arterial | 1 | 0 | 1299.154039 | 1.298894 | 60 |
| 385 | Polyline | minor arterial | 0 | 0 | 17.8078 | 0.106825 | 10 |
| 389 | Polyline | minor aerial | 1 | 0 | 412.697004 | 0.618922 | 40 |
| 390 | Polyline | minor arterial | 0 | 0 | 16.144693 | 0.096849 | 10 |
| 400 | Polyline | major arterial | 1 | 0 | 76.933447 | 0.115377 | 40 |
| 401 | Polyline | minor arterial | 1 | 0 | 72.417816 | 0.144807 | 30 |
| 402 | Polyline | minor arterial | 0 | 0 | 520.23392 | 0.780195 | 40 |
| 410 | Polyline | minor arterial | 0 | 0 | 1339.807639 | 2.00931 | 40 |
| 411 | Polyline | minor arterial | 0 | 0 | 2554.808036 | 3.831446 | 40 |
| 413 | Polyline | major arterial | 1 | 0 | 39.930725 | 0.039923 | 60 |
| 414 | Polyline | major arterial | 1 | 0 | 72.577217 | 0.072527 | 60 |
| 415 | Polyline | | 1 | 1 | 553.158403 | 0.553048 | 60 |
| 416 | Polyline | major arterial | 1 | 0 | 71.177089 | 0.071163 | 60 |
| 417 | Polyline | major arterial | 1 | 0 | 42.199807 | 0.042191 | 60 |
| 418 | Polyline | major arterial | 1 | 1 | 550.793674 | 0.55041 | 60 |
| 419 | Polyline | minor arterial | 0 | 0 | 17.939827 | 0.107617 | 10 |
| 435 | Polyline | minor arterial | 0 | 0 | 13.707509 | 0.082245 | 10 |
| 436 | Polyline | minor arterial | 0 | 0 | 22.260378 | 0.133562 | 10 |
| 438 | Polyline | minor arterial | 0 | 0 | 19.883685 | 0.119278 | 10 |
| 439 | Polyline | minor arterial | 0 | 0 | 17.484582 | 0.104887 | 10 |
| 440 | Polyline | minor arterial | 0 | 0 | 15.417305 | 0.092485 | 10 |
| 441 | Polyline | minor arterial | 0 | 0 | 15.891351 | 0.095329 | 10 |
| 444 | Polyline | minor arterial | 0 | 0 | 14.821208 | 0.088909 | 10 |
| 445 | Polyline | minor arterial | 0 | 0 | 15.045702 | 0.090256 | 10 |
| 446 | Polyline | minor arterial | 0 | 0 | 13.354801 | 0.080113 | 10 |
| 447 | Polyline | major arterial | 0 | 0 | 23.357345 | 0.140116 | 10 |

| Object ID | Shape | Road Type | One-way | Bridge | Shape Length (Meter) | Time (Minute) | Speed (Km/hr) |
|-----------|----------|----------------|---------|--------|----------------------|---------------|---------------|
| 448 | Polyline | minor arterial | 0 | 0 | 31.516124 | 0.189096 | 10 |
| 449 | Polyline | minor arterial | 1 | 0 | 48.615085 | 0.097211 | 30 |
| 450 | Polyline | minor arterial | 1 | 0 | 40.7758 | 0.244654 | 10 |
| 451 | Polyline | minor arterial | 0 | 0 | 14.997267 | 0.089966 | 10 |
| 454 | Polyline | minor arterial | 1 | 0 | 24.677929 | 0.037009 | 40 |
| 455 | Polyline | minor arterial | 1 | 0 | 46.910606 | 0.070352 | 40 |
| 456 | Polyline | minor arterial | 1 | 0 | 28.425008 | 0.042629 | 40 |
| 457 | Polyline | minor arterial | 1 | 0 | 20.550368 | 0.030819 | 40 |
| 459 | Polyline | minor arterial | 1 | 0 | 20.423648 | 0.122517 | 10 |
| 467 | Polyline | minor arterial | 0 | 0 | 18.584549 | 0.111485 | 10 |
| 468 | Polyline | minor arterial | 0 | 0 | 17.374746 | 0.104228 | 10 |
| 474 | Polyline | minor arterial | 1 | 0 | 18.159403 | 0.119143 | 10 |
| 475 | Polyline | minor arterial | 1 | 0 | 17.024585 | 0.112498 | 10 |
| 476 | Polyline | minor arterial | 0 | 0 | 20.721922 | 0.124307 | 10 |
| 477 | Polyline | minor arterial | 1 | 0 | 17.326444 | 0.103938 | 10 |
| 478 | Polyline | minor arterial | 1 | 0 | 17.017017 | 0.102082 | 10 |
| 479 | Polyline | major arterial | 1 | 0 | 6086.718 | 6.086718 | 60 |
| 481 | Polyline | major arterial | 1 | 1 | 2041.626237 | 1.530913 | 80 |
| 482 | Polyline | major arterial | 1 | 0 | 5028.125319 | 5.028125 | 60 |
| 484 | Polyline | minor arterial | 1 | 0 | 21.593018 | 0.129532 | 10 |
| 489 | Polyline | major arterial | 1 | 0 | 63.848284 | 0.063836 | 60 |
| 494 | Polyline | major arterial | 1 | 0 | 204.81163 | 0.204771 | 60 |
| 495 | Polyline | major arterial | 1 | 0 | 213.472435 | 0.21343 | 60 |
| 520 | Polyline | minor arterial | 0 | 0 | 22.799095 | 0.136767 | 10 |
| 523 | Polyline | minor arterial | 0 | 0 | 20.102417 | 0.12059 | 10 |
| 524 | Polyline | minor arterial | 0 | 0 | 18.303062 | 0.109796 | 10 |
| 525 | Polyline | major arterial | 1 | 0 | 19.39478 | 0.116345 | 10 |
| 526 | Polyline | minor arterial | 1 | 0 | 22.114566 | 0.132661 | 10 |

| Object ID | Shape | Road Type | One-way | Bridge | Shape Length (Meter) | Time (Minute) | Speed (Km/hr) |
|-----------|----------|----------------|---------|--------|----------------------|---------------|---------------|
| 527 | Polyline | minor arterial | 1 | 0 | 21.77661 | 0.043545 | 30 |
| 528 | Polyline | minor arterial | 1 | 0 | 20.95017 | 0.041892 | 30 |
| 529 | Polyline | minor arterial | 1 | 0 | 18.149894 | 0.036293 | 30 |
| 530 | Polyline | minor arterial | 0 | 0 | 15.475152 | 0.092832 | 10 |
| 531 | Polyline | minor arterial | 0 | 0 | 21.232071 | 0.11219 | 10 |
| 532 | Polyline | minor arterial | 1 | 0 | 861.946104 | 1.292661 | 40 |
| 533 | Polyline | minor arterial | 1 | 0 | 1023.253729 | 1.534574 | 40 |
| 534 | Polyline | minor arterial | 1 | 0 | 681.191973 | 1.021584 | 40 |
| 535 | Polyline | minor arterial | 1 | 0 | 686.134782 | 1.028996 | 40 |
| 546 | Polyline | minor arterial | 1 | 0 | 9.178664 | 0.059406 | 10 |
| 547 | Polyline | minor arterial | 1 | 0 | 9.314635 | 0.060235 | 10 |
| 548 | Polyline | minor arterial | 0 | 0 | 8.592138 | 0.056288 | 10 |
| 549 | Polyline | minor arterial | 1 | 0 | 8.563003 | 0.056077 | 10 |
| 550 | Polyline | minor arterial | 1 | 0 | 8.817445 | 0.057605 | 10 |
| 551 | Polyline | minor arterial | 1 | 0 | 8.80385 | 0.05752 | 10 |
| 562 | Polyline | major arterial | 1 | 0 | 5268.253057 | 3.9504 | 80 |
| 564 | Polyline | minor arterial | 0 | 0 | 2202.15417 | 3.303231 | 40 |
| 568 | Polyline | minor arterial | 0 | 0 | 34.277281 | 0.205623 | 10 |
| 570 | Polyline | major arterial | 1 | 0 | 454.724893 | 0.454634 | 60 |
| 571 | Polyline | major arterial | 1 | 0 | 380.571473 | 0.380495 | 60 |
| 572 | Polyline | major arterial | 1 | 0 | 1493.548467 | 1.49325 | 60 |
| 573 | Polyline | major arterial | 1 | 0 | 36.095415 | 0.036088 | 60 |
| 574 | Polyline | major arterial | 1 | 0 | 1815.774532 | 1.813512 | 60 |
| 575 | Polyline | major arterial | 1 | 0 | 653.032897 | 0.652902 | 60 |
| 579 | Polyline | minor arterial | 1 | 0 | 1572.57997 | 2.358398 | 40 |
| 580 | Polyline | major arterial | 1 | 0 | 330.087189 | 0.330021 | 60 |
| 581 | Polyline | major arterial | 1 | 0 | 1137.293766 | 1.137066 | 60 |
| 582 | Polyline | major arterial | 1 | 0 | 145.206991 | 0.145178 | 60 |

| Object ID | Shape | Road Type | One-way | Bridge | Shape Length (Meter) | Time (Minute) | Speed (Km/hr) |
|-----------|----------|----------------|---------|--------|----------------------|---------------|---------------|
| 584 | Polyline | major arterial | 1 | 0 | 347.402106 | 0.347333 | 60 |
| 586 | Polyline | minor arterial | 1 | 0 | 20.819465 | 0.124892 | 10 |
| 587 | Polyline | major arterial | 1 | 0 | 835.689031 | 0.835522 | 60 |
| 588 | Polyline | major arterial | 1 | 0 | 1311.778233 | 1.311516 | 60 |
| 589 | Polyline | major arterial | 1 | 0 | 237.926769 | 0.237879 | 60 |
| 590 | Polyline | major arterial | 1 | 0 | 104.811304 | 0.10479 | 60 |
| 591 | Polyline | major arterial | 1 | 0 | 149.625459 | 0.149596 | 60 |
| 592 | Polyline | major arterial | 1 | 0 | 164.158017 | 0.164125 | 60 |
| 593 | Polyline | major arterial | 1 | 0 | 97.688092 | 0.097669 | 60 |
| 594 | Polyline | major arterial | 1 | 0 | 92.352838 | 0.092334 | 60 |
| 596 | Polyline | major arterial | 1 | 0 | 1493.533925 | 1.493235 | 60 |
| 597 | Polyline | major arterial | 1 | 0 | 439.19633 | 0.439109 | 60 |
| 598 | Polyline | major arterial | 1 | 0 | 101.480954 | 0.101461 | 60 |
| 600 | Polyline | major arterial | 1 | 0 | 1041.087636 | 1.040879 | 60 |
| 601 | Polyline | major arterial | 1 | 0 | 187.28743 | 0.150388 | 60 |
| 603 | Polyline | minor arterial | 1 | 0 | 2040.616516 | 3.060924 | 40 |
| 604 | Polyline | major arterial | 1 | 0 | 1574.7788 | 1.574464 | 60 |
| 605 | Polyline | major arterial | 1 | 0 | 415.50705 | 0.415424 | 60 |
| 606 | Polyline | major arterial | 1 | 0 | 299.38732 | 0.223642 | 80 |
| 607 | Polyline | major arterial | 1 | 0 | 189.561712 | 0.189524 | 60 |
| 608 | Polyline | major arterial | 1 | 0 | 123.314792 | 0.133097 | 60 |
| 609 | Polyline | major arterial | 1 | 0 | 155.379598 | 0.155349 | 60 |
| 610 | Polyline | major arterial | 1 | 0 | 60.320831 | 0.060309 | 60 |
| 611 | Polyline | major arterial | 1 | 0 | 222.02634 | 0.221982 | 60 |
| 612 | Polyline | major arterial | 1 | 0 | 1550.338313 | 1.550028 | 60 |
| 614 | Polyline | minor arterial | 1 | 0 | 11.871526 | 0.017807 | 40 |
| 615 | Polyline | major arterial | 1 | 0 | 349.172935 | 0.349103 | 60 |
| 616 | Polyline | major arterial | 1 | 0 | 196.1459 | 0.196107 | 60 |

| Object ID | Shape | Road Type | One-way | Bridge | Shape Length (Meter) | Time (Minute) | Speed (Km/hr) |
|-----------|----------|----------------|---------|--------|----------------------|---------------|---------------|
| 617 | Polyline | major arterial | 1 | 0 | 1560.193758 | 1.559882 | 60 |
| 618 | Polyline | major arterial | 1 | 0 | 604.698415 | 0.604577 | 60 |
| 619 | Polyline | major arterial | 1 | 0 | 32.000594 | 0.031994 | 60 |
| 620 | Polyline | major arterial | 1 | 0 | 16.685495 | 0.016682 | 60 |
| 622 | Polyline | minor arterial | 0 | 0 | 35.963216 | 0.053934 | 40 |
| 623 | Polyline | minor arterial | 0 | 0 | 27.029235 | 0.040536 | 40 |
| 624 | Polyline | minor arterial | 0 | 0 | 18.23234 | 0.027343 | 40 |
| 633 | Polyline | minor arterial | 0 | 0 | 98.603901 | 0.147876 | 40 |
| 634 | Polyline | major arterial | 1 | 0 | 19.016114 | 0.028524 | 40 |
| 635 | Polyline | major arterial | 1 | 0 | 119.641759 | 0.119618 | 60 |
| 636 | Polyline | minor arterial | 1 | 0 | 57.238436 | 0.114454 | 30 |
| 637 | Polyline | minor arterial | 1 | 0 | 18.790008 | 0.037573 | 30 |
| 639 | Polyline | minor arterial | 1 | 0 | 20.51057 | 0.03076 | 40 |
| 640 | Polyline | major arterial | 1 | 0 | 548.928598 | 0.548819 | 60 |
| 641 | Polyline | major arterial | 1 | 0 | 560.206325 | 2.585051 | 10 |
| 642 | Polyline | minor arterial | 1 | 0 | 122.354497 | 0.183531 | 40 |
| 643 | Polyline | | 1 | 1 | 89.119102 | 0.089101 | 60 |
| 644 | Polyline | major arterial | 1 | 0 | 179.901121 | 0.179865 | 60 |
| 645 | Polyline | major arterial | 1 | 0 | 33.572811 | 0.033566 | 60 |
| 646 | Polyline | major arterial | 1 | 0 | 460.26723 | 0.460175 | 60 |
| 647 | Polyline | major arterial | 1 | 0 | 219.32589 | 0.219282 | 60 |
| 648 | Polyline | major arterial | 1 | 0 | 38.608731 | 0.038601 | 60 |
| 649 | Polyline | | 1 | 1 | 51.292622 | 0.051282 | 60 |
| 650 | Polyline | major arterial | 1 | 0 | 1002.605871 | 1.002405 | 60 |
| 652 | Polyline | minor arterial | 1 | 0 | 156.695137 | 0.234996 | 40 |
| 653 | Polyline | major arterial | 1 | 0 | 116.477198 | 0.116454 | 60 |
| 654 | Polyline | major arterial | 1 | 0 | 190.718452 | 0.19068 | 60 |
| 655 | Polyline | major arterial | 1 | 0 | 221.748861 | 0.221705 | 60 |

| Object ID | Shape | Road Type | One-way | Bridge | Shape Length (Meter) | Time (Minute) | Speed (Km/hr) |
|------------------|--------------|------------------|----------------|---------------|-----------------------------|----------------------|----------------------|
| 657 | Polyline | major arterial | 1 | 0 | 47.225229 | 0.047216 | 60 |
| 658 | Polyline | minor arterial | 1 | 0 | 57.720661 | 0.086564 | 40 |
| 659 | Polyline | major arterial | 1 | 0 | 59.631685 | 0.05962 | 60 |
| 660 | Polyline | major arterial | 1 | 0 | 208.843046 | 0.162929 | 80 |
| 661 | Polyline | major arterial | 1 | 0 | 190.508233 | 0.142853 | 80 |
| 662 | Polyline | major arterial | 1 | 0 | 457.048505 | 0.469871 | 60 |
| 663 | Polyline | major arterial | 1 | 0 | 1091.334684 | 0.818337 | 80 |
| 664 | Polyline | minor arterial | 1 | 0 | 466.540593 | 0.62193 | 40 |
| 665 | Polyline | major arterial | 1 | 0 | 606.037657 | 0.454437 | 80 |
| 666 | Polyline | major arterial | 1 | 1 | 3026.374571 | 2.269327 | 80 |
| 667 | Polyline | minor arterial | 1 | 0 | 1080.221567 | 1.080006 | 60 |
| 668 | Polyline | major arterial | 1 | 0 | 2787.790621 | 2.090425 | 80 |
| 669 | Polyline | major arterial | 1 | 0 | 1219.659104 | 0.914561 | 80 |
| 670 | Polyline | major arterial | 1 | 0 | 31.798603 | 0.031792 | 60 |
| 671 | Polyline | major arterial | 1 | 0 | 75.185428 | 0.076471 | 60 |
| 672 | Polyline | major arterial | 1 | 0 | 435.989131 | 0.435902 | 60 |
| 673 | Polyline | minor arterial | 0 | 0 | 396.115814 | 0.594055 | 40 |
| 674 | Polyline | minor arterial | 1 | 0 | 35.984515 | 0.053966 | 40 |
| 675 | Polyline | minor arterial | 1 | 0 | 73.711025 | 0.110544 | 40 |
| 677 | Polyline | major arterial | 1 | 0 | 89.76697 | 0.089749 | 60 |

Table B-2 Attribute information for the suggested roads

| Object ID | Shape | Road Type | One-way | Bridge | Time (Minute) | Speed (Km/hr) | Shape Length | Width (m) |
|-----------|----------|----------------|---------|--------|---------------|---------------|--------------|-----------|
| 1 M | Polyline | major arterial | 1 | 0 | 3.284104 | 80 | 4652.480811 | 60 |
| 2 M | Polyline | major arterial | 1 | 0 | 5.448734 | 80 | 7719.039667 | 60 |
| 3 M | Polyline | major arterial | 1 | 0 | 5.208483 | 70 | 6076.563597 | 60 |
| 4 M | Polyline | major arterial | 1 | 0 | 5.224863 | 70 | 6095.672989 | 60 |
| 5 M | Polyline | major arterial | 1 | 0 | 1.242731 | 70 | 1449.852949 | 60 |
| 6 M | Polyline | major arterial | 1 | 0 | 1.223806 | 70 | 1427.773932 | 60 |
| 7 M | Polyline | major arterial | 1 | 0 | 12.462951 | 80 | 17655.84696 | 60 |
| 8 M | Polyline | major arterial | 1 | 0 | 5.314954 | 80 | 7529.518516 | 60 |
| 9 M | Polyline | major arterial | 1 | 0 | 0.874215 | 80 | 1238.470559 | 60 |
| 10 M | Polyline | major arterial | 1 | 0 | 7.08778 | 80 | 10041.02196 | 60 |
| 11 M | Polyline | major arterial | 1 | 0 | 2.238733 | 70 | 2611.855045 | 60 |
| 12 M | Polyline | major arterial | 1 | 0 | 2.222295 | 70 | 2592.67704 | 60 |
| 13 M | Polyline | major arterial | 1 | 0 | 3.268267 | 80 | 4630.044411 | 60 |
| 14 M | Polyline | major arterial | 1 | 0 | 0.757349 | 80 | 1072.910586 | 60 |
| 15 M | Polyline | major arterial | 1 | 0 | 5.440692 | 80 | 7707.64724 | 60 |
| 16 M | Polyline | major arterial | 1 | 0 | 0.936685 | 80 | 1326.969934 | 60 |
| 17 M | Polyline | major arterial | 1 | 0 | 0.929357 | 80 | 1316.589143 | 60 |
| 18 M | Polyline | major arterial | 1 | 0 | 1.389678 | 70 | 1621.291276 | 60 |
| 19 M | Polyline | major arterial | 1 | 0 | 1.401252 | 70 | 1634.794497 | 60 |
| 20 M | Polyline | major arterial | 1 | 0 | 1.829396 | 70 | 2134.295287 | 60 |
| 21 M | Polyline | major arterial | 1 | 0 | 0.020289 | 70 | 23.670606 | 60 |
| 22 M | Polyline | major arterial | 1 | 0 | 1.338836 | 70 | 1561.974785 | 60 |
| 23 M | Polyline | major arterial | 1 | 0 | 3.190042 | 70 | 3721.715709 | 60 |
| 24 M | Polyline | major arterial | 1 | 0 | 4.746247 | 70 | 5537.287701 | 60 |
| 25 M | Polyline | major arterial | 1 | 0 | 4.771298 | 70 | 5566.514624 | 60 |

التحليل الشبكي لحركة الشاحنات عبر الشبكة المطورة يبين أن الطرق المقترحة ستقلل من إجمالي (زمن الرحلة والمسافة) لنفس نقطة الأصل والوجهة بنسبة ٩٪، و ٣٠٪ مقارنةً بالمسافة والوقت للشبكة الحالية على التوالي.

التوصية بتطوير شبكة الطرق الحالية من خلال اقتراحات أخرى لتنظيم تدفقات الشحن وتقليل الآثار السلبية لنقل البضائع في المدينة. تضمنت التسليم الليلي للبضائع إلى الوجهات الواقعة داخل المدينة من الساعة (١٠ مساءً إلى ٧ صباحًا)، وكذلك مقترح إنشاء مركزي لتجميع الشحن FCC في الجزء الشمالي من المدينة وآخر في الجزء الجنوبي منها لتقليل عدد مركبات الشحن داخل المدينة خاصة خلال فترات الذروة.

الخلاصة

نقل البضائع امر بالغ الاهمية لضمان الحيوية الاقتصادية للمدن. مع ذلك تنشأ عوامل خارجية سلبية من تدفقات الشاحنات في المناطق الحضرية أهمها الازدحام المروري. تعاني مدينة الحلة من الازدحام المروري في مواقع عديدة من شبكة الطرق فيها، مما تسبب في السرعات البطيئة وارتفاع معدل التأخير وضعف مستوى الخدمة، ومن المتوقع تفاقم هذه المشاكل مستقبلا مع ارتفاع معدل النمو السكاني وازدياد الحجم المروري للمركبات بشكل عام من ضمنها الشاحنات.

يهدف هذا البحث الى تحليل وتقييم شبكة الطرق وحركة الشاحنات في منطقة الدراسة المتمثلة بمدينة الحلة للوقوف على اهم المعوقات التي تواجه نقل البضائع والمشاكل التي يعكسها على شبكة النقل في المدينة، مع إيجاد الحلول المناسبة لتحسين حركة المرور باستخدام بيانات الشحن المجمعة وتقنيات برنامج ArcGIS10.4.

تم جمع بيانات الشحن بناءً على الاستبيان من سائقي مركبات الشحن والمقالات مع موظفي نقاط التفتيش عند المداخل الخمسة لمدينة الحلة وكذلك المسوحات الحقلية لحساب الحجم المروري عند المداخل وفي الطرق الرئيسية للمدينة (١٢ مقطع من الطرق الشريانية) بالإضافة الى البيانات التي تم الحصول عليها من الدوائر الحكومية ذات العلاقة.

تم إنشاء خريطة رقمية دقيقة لشبكة الطرق الرئيسية في مدينة الحلة، باستخدام تقنية التحليل الشبكي لبرنامج ArcGIS 10.4, تم تحليل حركة الشاحنات عبر الشبكة الحالية في المدينة حيث أظهرت نتائج التحليل ان أكبر زخم مروري للشاحنات يمر عبر الشوارع الشريانية الرئيسية للمدينة.

ولغرض اظهار الاختلاف في مستوى الخدمة لشبكة الطرق في المدينة تم اعداد ثلاث خرائط باستخدام برنامج (Trans CAD4.5) استنادا الى نتائج (الحجم المروري / استيعابية الطرق). الخارطة الأولى لسنة الدراسة ٢٠٢٢ بالاعتماد على بيانات الشبكة الحالية، الخارطة الثانية لسنة الدراسة أيضا مع تبني التطويرات المقترحة للشبكة بتنفيذ طرق جديدة تربط مداخل المدينة بشبكة الطرق الحالية مما يؤدي إلى تقليل نسبة مركبات الشحن التي تمر عبرها إلى ٥٠٪ والخارطة الثالثة هي لسنة الهدف ٢٠٣٠ لنفس استيعابية الشبكة الحالية مع الاخذ بنظر الاعتبار معدل النمو والزيادة في الحجم المروري للمركبات في مدينة الحلة (٢,٥٪).

أظهرت النتائج ان التقييم العام لمستوى الخدمة لشبكة الطرق الحالية في المدينة لسنة الدراسة ٢٠٢٢ هو (D) ولسنة الهدف ٢٠٣٠ (F). ان تبني التطويرات المقترحة للشبكة يحسن مستوى الخدمة في سنة الدراسة للشبكة المطورة إلى (C).



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

تقييم وتطوير شبكة طرق نقل الحمولات في مدينة الحلة

رسالة مقدمة الى

كلية الهندسة/ جامعة بابل كجزء من متطلبات نيل شهادة الماجستير

في الهندسة / الهندسة المدنية / هندسة المواصلات

من قبل

هدى عبد الأمير عباس الطائي

(بكالوريوس في الهندسة المدنية ٢٠٠٧)

بإشراف

أ.د. علي عبد الأمير علوش

أ.م. حيدر عباس عبيد

(٢٠٢٢)

(١٤٤٤)