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Traffic and Pollution Evaluation For a selected Road Network in Karbala City

A Thesis Submitted to the Department of Civil Engineering, University of Kerbala in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Infrastructure Engineering)

By

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2021

بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ

دَرَجَاتٍ

صدق الله العلي العظيم

(المجادلة: من الآية 11)

Abstract

The holy city of Karbala is one of the most famous cities in the Islamic world because of its religious character. Therefore, the city witnessed an increase in the number of visitors throughout the year, in addition to the economic boom that swept the city. All this led to an increase in the number of daily trips and an increase in the flow of traffic .

This study deals with the evaluation of the traffic performance of selected intersections and urban roads, where the study area consists of five intersections and four urban roads. After defining the study area, traffic data is collected by video imaging technology, and then data is extracted from video films. As for measuring environmental pollution, a device (GasmetDX4040) was used to measure the emission of carbon dioxide and carbon monoxide. After dividing the urban roads into several segments, the travel time for all segments was calculated and the free flow speed was calculated.

The SIDRA INTERSECTION program was used to analyze and evaluate the intersections, the GIS program was used to calculate the number of links and nodes in the network, and the TransCad program was used to represent the network.

As for the analysis stage, it included evaluating the road network using several indications for Karbala city show weak connectivity network according to its indices (Alpha index =0.256 , Beta index = 1.4 , Gamma index = 0.467 , Grid Tree Pattern =0.639) then the roads were classified on the basis of the

average travel speed and the level of service was calculated for them, as well as the calculation of the capacity for all sections and the assessment of the level of service on the basis of (V/C).

After that, a relationship was established between the flow rate and gas emissions to know the effect of increasing traffic congestion on environmental pollution, and finally, the intersections were evaluated using the (Sidra) program. It was found that the intersections suffer from an increase in the volume of traffic, as the level of service for all intersections was (F).

Supervision Certificate

We certify that this thesis entitled "Traffic and Pollution Evaluation For a selected Road Network in Karbala City ", which is submitted by " Narjis Basil Theyab ", is under our supervision at University of Kerbala in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering (Infrastructure Engineering).

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Linguistic Certificate

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Examination Committee Certification

We certify that we have read the thesis entitled "Traffic and pollution evaluation for a selected road network in Karbala city" and as an examining committee, we examined the student "Narjis Basil Theyab" in its content and in what is connected with it, and that in our opinion it is adequate as a thesis for degree of Master of Science in Civil Engineering (Infrastructure Engineering).

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Dedication

To my father, that his body left me, but his soul stay accompanied me in the sky of my life (to your soul peace).

To my mother, which spent all her life to support me mentally and emotionally, to the one who taught me patience and diligence to the light of my eyes.

To my beloved grandmother, who supported me with her prayers.

To my sisters, the writing does not describe how I love you , you were support to me in my life.

To my friends, who were there to listen and support me throughout my study and I would like also thank everyone who supported me, even with a smile.

To all of these I dedicate my scientific thesis …….

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Above all and beyond, I would like to thank almighty allah , who gives me the desire and ability to complete this work in spite of the constraints along the way.

I would like to express my deepest gratitude to my supervisors, Prof. Dr. Hamid Athab Eedan Al-Jameel and Dr. Raid R. A. Almuhanna, whom play a great role in introducing the basis of this research and take over the supervision of this thesis, for their guidance's, advices and encouragements.

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Symbol	Description
AASHTO	American Association of State Highway and Transportation Official
α	Alpha
β	Beta
γ	Gamma
GTP	Grid Tree Pattern
GIS	Gegraphic Information System
HCM	Highway Capacity Manual
LOS	Level of Service
V/C	Volume to Capacity (degree of saturation)

Chapter One
Introduction

1.1 General

The transportation system is the motor of the economic activities in urban societies all over the world.The standard facilities of urban transportation contain roads, railways, airways, and waterways, but the road network is the most important. Logically, most researches and planning studies have concentrated on road systems. In substance, the system of road transportation is a major factor in the economic activities of most urban areas. In current times, a large increase in traffic and transport demand has been seen in many cities, which has thus lead to decay in the capacity and inactive performance of the traffic system **(Chiguma, 2007)**.

Transport activities do not always have a positive impact, but they can also have a negative impact. One of the negative impacts of the transportation activity is a traffic jam downtown . Congestion causes enormous losses, both on the aspect of travel time which takes a long time and gets slow down, financial, health, and environmental aspects as the impacts of air pollution caused by vehicle exhaust emissions **(Adha et al., 2019).**

A primary objective in highway and traffic engineering is to provide highway facilities that operate at levels of service acceptable to the users of those facilities. **(Papacostas, 2008)** Global cities face rising traffic congestion. This situation is getting worse and becoming a major concern of the public. Traffic congestion is a condition of traffic delay because the number of vehicles using a road exceeds the operational capacity of the network to handle **(Boamah, 2010).**

1.2 Problem Statement

The new growth in Karbala traffic congestion has been recognized as a serious problem in the city, which affects the economy, travel time, driver behavior and causes discomfort to drivers and visitors. The number of vehicles in Karbala increases rapidly without a considerable increase in the capacity of the road network, which leads to an increase in delay times and lowers the level of service (LOS).

Locally, these problems keep continue and they may be worsening in the future because of the rapid growth of the number of vehicles owned ship in Karbala city. Sub-standard geometric design and poor road planning of most of the intersections inside the selected network have a significant effect on traffic flow and traffic congestion. Therefore, it is necessary to evaluate the traffic performance for a suitable traffic operation.

1.3 Aim and objectives of the research

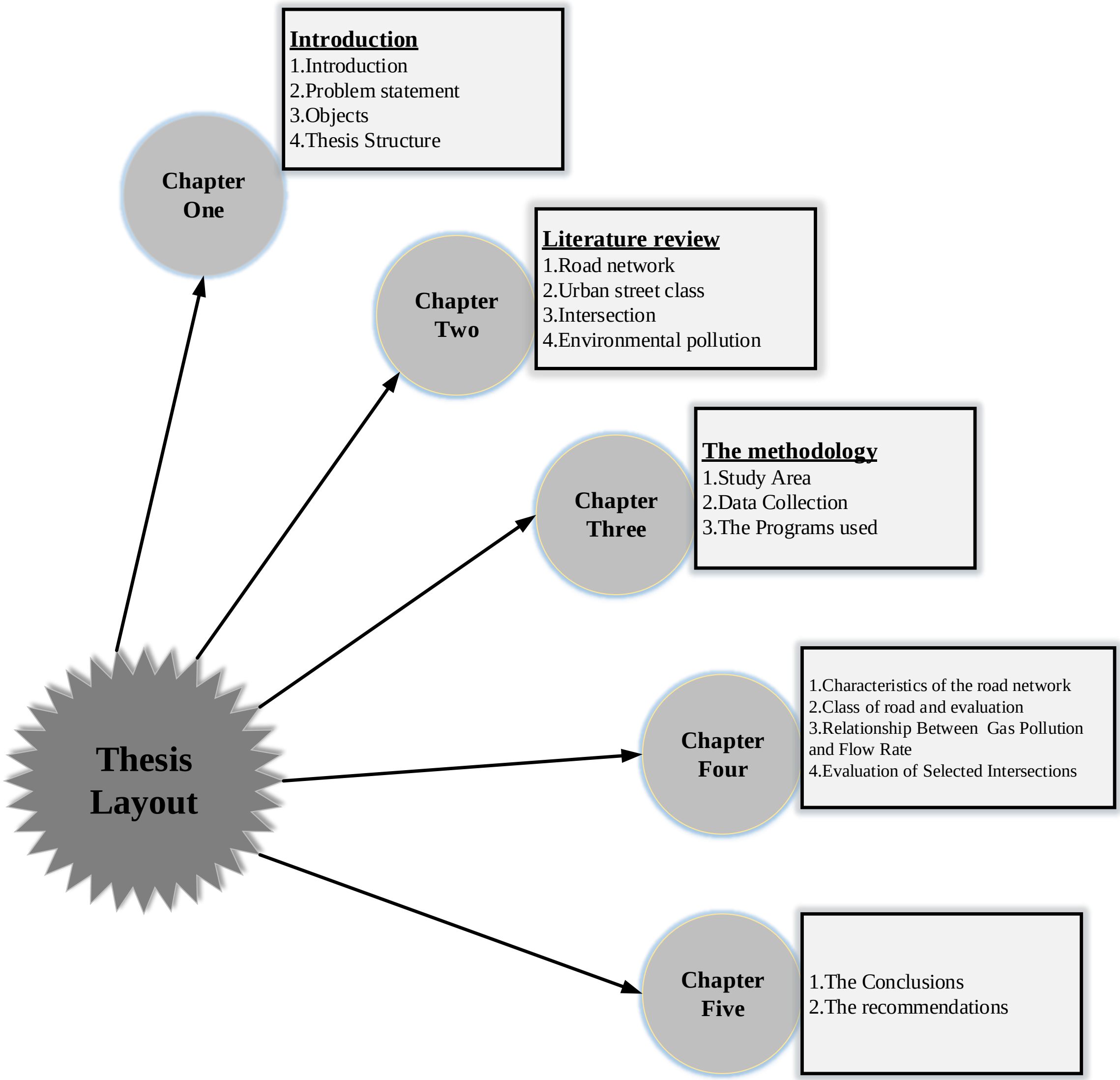
Evaluation of the traffic performance of the intersections and urban streets of the study area .

1. Evaluating the main road network of Karbala in terms of the spatial distribution of the network and the correlation factor using GIS software.
2. Determining the LOS for the intersections for a selected zone in Karbala city by using Sidra software.
3. Find out the classification of each road using Highway Capacity Manual (HCM) 2000 and evaluate the performance of urban streets in the selected network in terms of Level of Service (LOS) according to the HCM 2000.

4. Determine air pollution considered as environmental indicators using suitable equipment And to find a relationship between traffic flow and gas emissions.
5. Propose engineering and traffic solutions to reduce the congestion in the specified area.

1.4 Thesis Structure

The structure of the thesis is indicated in Figure (1-1):



Figure(1-1): The thesis structure.

Chapter Two

Literature Review

2.1 Introduction

This chapter reviews road networks and characteristics of the road network and reviews present practices for evaluating the operational criteria of basic urban street segments, and intersections. It also deals with environmental pollutants in terms of gas emissions Finally, previous researches on performance measures of urban street segments and signalized intersections are presented.

2.2 Road networks

A network is a framework of links connected within nodes. Mainly, in the road network, roads are represented by links, and nodes represent intersections. Since 1960, some network-based indicators have been created to assess the transportation network. These indicators are categorized as connectedness, cyclic property, and efficiency measures **(Sreelekha, 2016).**

A road network is regarded as one of the essential factors in its regional growth. The high construction cost of the road network necessitates efficient use, which can only be achieved with adequate connection and direction. However, in many metropolitan areas, the road network grows organically. As a result, the road network's connection design requires special attention. Theoretical study on the urban road network is limited. Only a few industrialized nations have assessed urban road networks. Therefore there is a lot of room for growth and application **(Sreelekha, 2016).**

Road networks in urban areas are essential facilities enabling residents to have mobility and enjoy comfortable lives and are one of the fundamental social infrastructures that form cities **(Ha et al., 2011)**.

In most planning situations, the study's end goal is to determine the number of network elements. Travel lengths and times in various networks must be understood for proper choice modeling. For these objectives, a computerized description of the different networks (auto, bicycle, public transportation) is required, which includes geographic relationships within the network and trip parameters such as speed, journey duration, and so on. As a result, these networks are simplified representations of real networks, with the amount of complexity varying depending on the task at hand. Additionally, networks inside the research region must be represented, including nodes and linkages between nodes. The networks' structure is similar to that of the original real-world network, and zonal centroids are linked to the modeled network's nodes by one or more connections **(Bovy et al., 2006).**

Many research has focused on extracting the primary connection indices, which provide essential information to define a particular network. Only a few researchers have focused on determining the network's geographic layout and identifying its structural characteristics. Connectivity and efficiency are the most crucial factors to consider when evaluating a network.

2.3 Characteristics of the road network

Several indices, such as connectedness, coverage, and spatial pattern, have been presented in prior research to evaluate the road network. These metrics may be used in a variety of ways in both planning and transportation.

2.3.1 Alpha index (α)

This is the ratio of the total number of circuits in the network to the total number of circuits **(Dill, 2003)**. As stated in Equation, it spans from 0 (no circuits) to 1 (fully linked network) (2-1).

$$\alpha = \frac{e-v+p}{2v-5} \qquad \text{(2-1)}$$

Where: p: separate non-connecting sub-graphs number

v: The vertices number in the network.

e: The edges number in the network.

2.3.2 Beta index (β)

It is also identified as the link-node ratio, which measures the "completeness" of a graph. This index defines the connectivity of the transport network **(Buyong, 2007)**. It can be calculated using Equation (2-2):

$$\beta = e/v \qquad \text{(2-2)}$$

Where:

v: Number of vertices in the network.

e: Number of edges in the network.

Its value is zero and three for most route networks; a value of β less one shows a branching like a network, whereas a value of higher than one shows an increasing complexity (a very well connected network). Thus, the β index distinguishes simple topological structures from complicated topological structures.

2.3.3 Gamma index (γ)

This is an important measurement to determine the connectivity degree (Davey, 1971). This index could be calculated according to Equation (2-3):

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

Where:

v: Number of vertices in the network.

e: Number of edges in the network and

It's the ratio of the actual number of edges to the maximum number of edges possible. It ranges from 0 (no connections between nodes) to 1 (maximum number of connections, all nodes connected directly) **(Rodin, Rodina, 2000).**

2.3.4 Grid Tree Pattern (GTP)

This index, which ranges from 0 in tree patterns to 1 in grid patterns, is used to identify the network pattern (Rodin, Rodina, 2000). Zhang et al. (2012) investigated the links between connectivity and pedestrian-bicyclist collisions and found that increased connection is associated with fewer non-motorized road user crashes. With the aid of graph connectivity metrics and road density, Shen (1997) investigated the geographical variance of West Bengal's road network structure. Vinod et al. (2003) used connectedness indices to analyze transportation networks in India using GIS technology. The GTP can be computed using Equation (2- 4).

$$\text{GTP} = e - v + p \div \left(\left(\sqrt{v} \right) - 1 \right)^2 \quad \text{..............} (2\text{-}4)$$

2.3.5 Connectivity

This indicator is used to measure network performance. Any transportation network's fundamental goal is connectivity **(Dill, 2003)** because it connects areas where people wish to travel. To assess the connectedness of the transportation network, the existing network needs to be transformed into a topologically simple network. According to network theory and data, graph theory deals with connections and nodes. The application of network theory to transportation networks has had a considerable impact on the direction of road network analysis. Alpha Index, Beta Index, Gamma Index, Eta Index (Kansky, 1963), and Grid Tree Pattern Index are some of the indices used to analyze the connectedness pattern of road transport networks **(Noda, 1996).**

2.4 Urban Street

The urban street system is a vital component of every city. It serves various purposes, such as traffic, streetscape, free-barrier routes for accessible entrances, and road/street signage, among others. In cities, roadway systems provide an essential ecological and landscape role. Over the last decade, streetscapes, free barrier accessibilities, and street signage have gotten a lot of attention as a viable alternative for building healthy, sustainable urban modernization **(Qi et al., 2011).** An urban street's design and administration should reflect and accommodate these many and competing purposes. The design and operation of roadways may prioritize and improve certain applications for everyone's benefit **(NACTO, 2012).**

Urban streets (including collectors and arterials) are situated between local streets and multi-lane suburban and rural highways in the road transportation hierarchy. Control circumstances, street functions, and the intensity and layout of roadside developments all play a role in these variations **(TRB, 2005).** The degree of mobility given by urban roadways is measured through the traffic stream's travel speed.

2.4.1 Urban Street Class

Urban streets (including arterials and collectors) as these streets which are ranked between local streets and multilane suburban and rural highways. The main factors influencing the difference are street function, control circumstances, and the kind and intensity of roadside development. In addition, more details about the difference between urban streets and other types such as multilane and downtown streets are discussed in detail in (HCM 2000)

This section focuses mainly on the main characteristics mentioned by HCM 2000 to classify urban streets (See Chapter 10- HCM 2000). Four urban street types are listed in the manual. Classes are numbered as Class I, II, III, and IV. This classification for urban streets depends on design category and functional category, as demonstrated in Table 2.1. Two groups are split into the functional portion: arterial principal and arterial minor. The design factor consists of four categories: high-speed, residential, suburban, average, and urban. More details about functional and design classes have been demonstrated in Table 2.2 to determine the precise class for a street in an urban area.

Table (2-1): Urban road division based on functional and design divisions (Adopted by HCM, 2000).

Design Category	Functional Category	
	Principal Arteria	Minor Arterial
High-Speed	I	N/A
Suburban	II	II
Intermediate	II	III or IV
Urban	III or IV	IV

Table (2-2): Functional and design divisions (HCM, 2000).

Criterion	Functional Category: Principal Arterial	Functional Category: Minor Arterial
Mobility function Very	Very important	Important
Access function	Very minor	Substantial
Points connected	Freeways, important activity centers, major traffic generators	traffic generators Principal arterials
Predominant trips served	Relatively long journeys between significant points and through- journeys are entering, leaving, and passing through the city.	Journeys of moderate length within relatively small geographical regions

Design Category

Criterion	High-Speed	Suburban	Intermediate	Urban
Driveway/access density	Very low Density	Low Density	Moderate Density	High Density
Arterial type	Multilane divided; undivided or two-lane with shoulders.	Multilane divided; undivided or two-lane with shoulders.	Multilane divided; undivided one-way two-lane.	Undivided one-way, two-way, two or more lanes
Parking	No	No	Some	Significant
Separate left-turn lanes	Yes	Yes	Usually	Some
Signals/km	0.3–1.2	0.6–3.0	2–6	4–8
Speed limit	75–90 km/h	65–75 km/h	50–65 km/h	40–55 km/h
Pedestrian activity	Very little	Little	Some	Usually
Roadside Development	Low density	Low to medium density	Medium to moderate density	High Density

2.5 Level of Service for Urban street

According to HCM 2000, the level of service (LOS) is a qualitative metric that describes operating circumstances within a traffic stream based on service parameters, including speed and travel time, freedom to maneuver, traffic disruptions, comfort, and convenience.

There have been a lot of methods to determine the LOS for urban streets. One of these methods is the method that depends on criteria by HCM 2000. This manual determines the LOS for each urban street depending firstly on the street class discussed in the previous section and mentioned in HCM 2000 (Chapter 10). Secondly, the classification depends on Free-Flow Speed (FFS). The FFS is the average velocity of the traffic stream. As a result, FFS is normally observed and mid-block parts of the urban street segment (HCM, 2000). Table 2.3 provides urban street class-default FFS for use in the absence of local data (HCM, 2000).

Table (2-3): Default FFS by urban road street division (HCM, 2000).

Urban Road	Class Default (km/h)
I	8 0
II	65
III	55
IV	45

Thirdly, the travel speed is a speed characteristic that captures the effect of traffic control. This speed is calculated by dividing the segment length by the average journey time. The travel time is the total amount of time it takes to travel the length of the roadway section, including any stop-time delays. These criteria could be used to find the suitable LOS as indicated in Table 2.4. The segment could be noticed in the HCM 2000 and as indicated in this Figure 2.1.

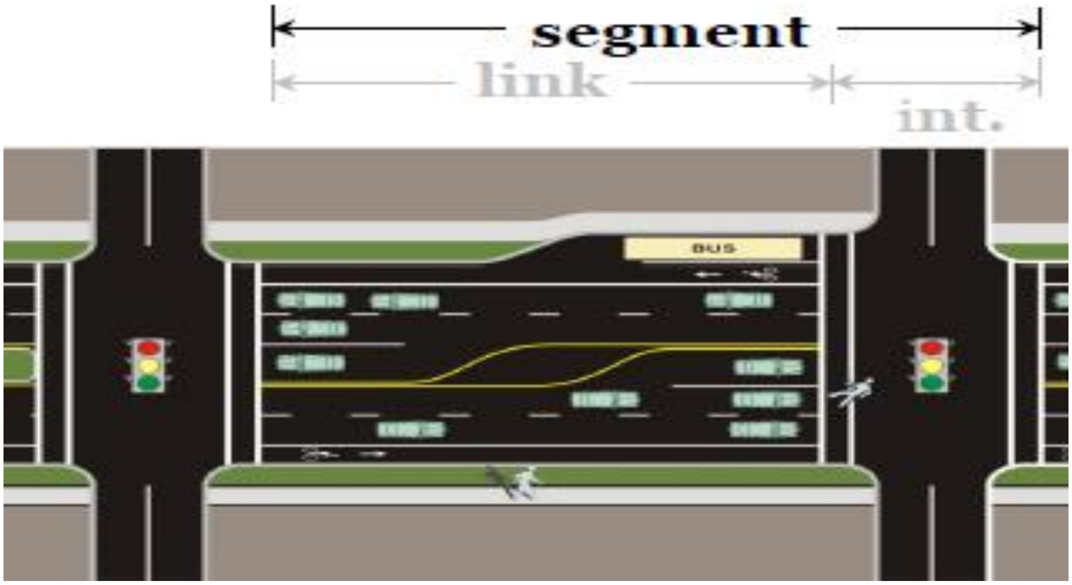


Figure (2-1): Determining segment in the urban streets.

Table (2-4): Urban street LOS by class (HCM, 2000).

Urban Street Class	I	II	III	IV
Range of free-flow speeds (FFS)	90 to 70 km/h	70 to 55 km/h	55 to 50 km/h	55 to 40 km/h
Typical FFS	80 km/h	65 km/h	55 km/h	45 km/h
LOS	Average Travel Speed (km/h)			
A	> 72	> 59	> 50	> 41
B	> 56–72	> 46–59	> 39–50	> 32–41
C	> 40–56	> 33–46	> 28–39	> 23–32
D	> 32–40	> 26–33	> 22–28	> 18–23
E	> 26–32	> 21–26	> 17–22	> 14–18
F	≤ 26	≤ 21	≤ 17	≤ 14

Finally, the v/c ratio is also used to determine the level of service. This could be adopted according to calculate actual flow rate (v) from field observation and determine capacity according to HCM 2000 (Chapter 10) as indicated in Table 2.5

Table (2-5): Services volumes for urban streets (HCM, 2000).

Lanes	Service volumes (veh/h)				
	A	B	C	D	E
Class I					
1	N/A	860	930	1020	1140
2	N/A	1720	1860	2030	2280
3	N/A	2580	2780	3050	3430
4	N/A	3450	3710	4060	4570
Class II					
1	N/A	N/A	670	850	890
2	N/A	N/A	1470	1700	1780
3	N/A	N/A	2280	2550	2670
4	N/A	N/A	3090	3400	3560
Class III					
1	N/A	N/A	480	780	850
2	N/A	N/A	1030	1600	1690
3	N/A	N/A	1560	2410	2540
4	N/A	N/A	2140	3220	3390
Class IV					
1	N/A	N/A	540	780	800
2	N/A	N/A	1200	1570	1620
3	N/A	N/A	1900	2370	2430
4	N/A	N/A	2610	3160	3250

2.6 Intersections

The broad area where two or more highways connect or cross, containing the roadway and roadside amenities for traffic movements within the area, is a junction. Intersections are significant elements of a highway facility since their design influences the facility's efficiency, safety, speed, cost of operation, and capacity**(AASHTO, 2001)**.

The goal that led efficiently to the design of the intersection is to turn the direction of the cars into any different directions to reach the intended destination. Traffic intersection is a complex location because the moving vehicles in different directions are trying to occupy the space at the same time. Besides, the pedestrians try to look at the same area to cross. Therefore, drivers have to make split-second decisions at an intersection by considering the route, intersection geometry, speed and direction of other vehicles, etc. It also has an impact on the road's capacity. As a result, traffic engineers must examine junctions from an accident and capacity standpoint, especially in metropolitan settings **(Tom, 2007)**. Intersections are important in street design in four ways: as a focus of activity, as a conflicting movement, as a traffic management point, and as a capacity point **(MDOT, 2008).**

2.6.1 Signalized Intersection

The signalized junction is the most complicated location in the traffic system and is usually the capacity restriction on any network of roadways. As a result, the study of these sites must take into account a wide range of factors, including intersection geometry, turning motions, relative approach volumes, traffic composition, and intersection signalization features **(Edwards, 1992).**

Signalized intersections could be defined are the basic elements in the system of urban transportation and carry the heavy traffic for motorized and non-motorized vehicles and pedestrians, which, create many conflicts between turning and crossing, merging of maneuvers. For a diversity of reasons like economic, auto ownership growth, and population, increasing traffic demand could exceed the capacity of the intersection through the peak hour periods. Consequently, deterioration of traffic conditions and worsen of safety risk. Congestion and dangerous traffic condition lead to increase emissions, accidents, consumption of fuel, and noise, thus the quality of life, resources of world energy, and global atmospheric conditions lead to deteriorating service**(Yu and Sulijoadikusumo, 2012)**

Even when warranted by traffic and highway circumstances, traffic control signals might be poorly constructed, ineffectively located, inadequately operated, or poorly maintained. Improper or unreasonable traffic control signals can cause one or more of the following problems **(FHWA, 2009):**

1. Excessive delay.

2. Excessive disobedience of the signal indications.

3. Increased use of more minor good routes as road users attempt to avoid the traffic control signals.

4. Significant increases in the number of collisions (especially rear-end collisions). Figure (2-2) shows the signalized intersection

Figure (2-2): Signalized intersection details.

2.6.1.1 Signalized Intersection Flow Characteristics

Three signal indications are shown for a particular approach at a signalized intersection: green, yellow, and red. The indication may contain a brief time where all indicators are red, known as an all-red interval, which, along with the yellow sign, constitutes the transition and clearance interval between two green phases **(HCM, 2000)**.

2.7 Major Parameters for Evaluating Intersection Operations

Because the concepts of capacity, level of service, and delay are essential to the analysis of junctions, as they are to the study of all sorts of facilities, both capacity and level of service must be fully addressed when evaluating the overall traffic operation of the intersections**.**

2.7.1 Capacity

Simply said, capacity refers to the maximum amount of traffic that a road can handle. Within the concept of a level of service analysis, a consistent and relatively exact determining capacity must be created because the capacity of a roadway segment is easily demonstrated to be a function of parameters such as roadway type (e.g., freeway, multilane highway without complete access control, or rural road), free-flow speed, number of lanes, and lane and shoulder lengths **(Khisty and Lall, 1998)**

The maximum range of flow for the subject lane groups can pass through the junctions under prevailing traffic circumstances signalized conditions. The roadway is given for each lane group at a signalized intersection. The units of capacity are vehicles per hour (veh/h). However, they are based on the flow during a 15-minute peak **(Garber and Hoel, 2009).**

The factors which affect capacity are **(Al-Azzawi, 2003):**

1-Physical and operation factors: Parking conditions, approach width, one-way or two-way operation, and the number of lanes are all considered.

2-Traffic characteristics: Traffic signalized (cycle duration and green to cycle time ratio for each approach) and approach lane delineation are included.

3-Environmental factors: Include the degree to which an individual method is used, demand variations throughout peak hours, and the intersection's position within the metropolitan region.

4-Control measures: Involve turning movements and vehicles composition Cars, buses, and trucks).

5- Area type: The saturation flow in the central business district (CBD), which has a more limited junction design, pedestrian movement, and roadside friction, is lower than in other locations.

The average flow rate is lower during the initial few seconds (when cars are increasing to normal operating speed) and throughout the amber phase, as shown in Figure (2-3). (as some vehicles decide to stop and others continue to move on). It's easier to replace the green and amber phases with an "effective green" period, in which the flow is supposed to occur at the saturation rate, and a "lost" period, in which no flow occurs. Because capacity is directly related to adequate green time, this is a valuable notion. The capacity of the lane group is **(HCM,2000):**

$$c = s * \frac{g}{c} \quad \text{……………………………………… (2-5)}$$

where:

c: capacity of lane group (vph),

s: saturation flow for lane group (vph),

g: adequate green time for lane group,

C: cycle length.

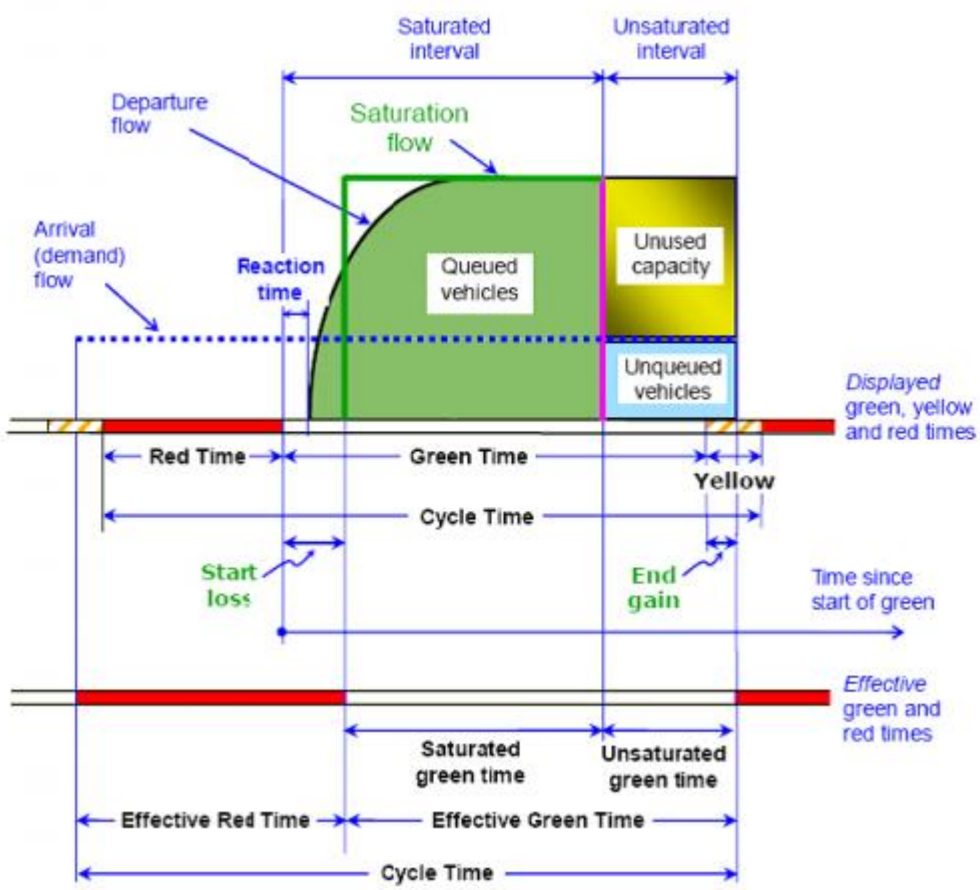


Figure (2-3): Saturation flow and the related signal timing parameters **(Akcelik, 2009).**

2.7.2 Control Delay

Control delay is utilized to describe the degree of service at signalized junctions since it reflects the amount of lost travel time and fuel consumption and indicates the level of annoyance and pain experienced by motorists. The degree of service at a signalized junction is defined by the control or signal delay, which is the fraction of total delay that can be ascribed to the control facility. This covers the time spent decelerating, moving up the queue, final acceleration, and stopping. Even when the (v/c) ratio is as high as 0.9, reasonable levels of service can be attained for short cycle durations. When the effect of signal coordination varies, various levels of service may also be obtained for the same (v/c) ratio **(Garber and Hoel, 2009).**

One of the significant characteristics used in the optimization of traffic signal timings is delay. A delay is also an essential factor in determining the degree of service offered to vehicles at signalized junctions. However, because it comprises the delay involved with decelerating to a halt, the stopped delay, and the delay connected with accelerating from a stop, the delay is a challenging metric to estimate **(Youn, 2000).**

Delay may be measured in a variety of ways. Stopped time delay, approach delay, and travel time delay are the most common types. The numbers can vary slightly depending on the circumstances at a signalized junction. Fig.(2.4) depicts the variations in stopped time, approach, and travel time delays for a vehicle passing a signalised junction. Its necessary course and the true sequential of a vehicle include a halt at a red light **(Youn, 2000).**

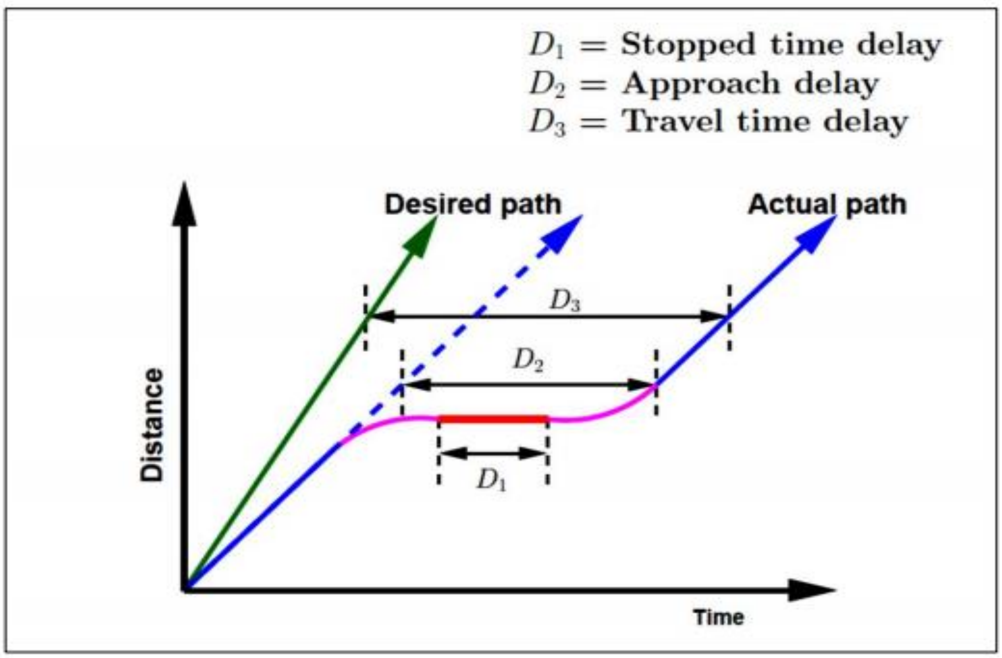


Figure (2-4): Illustration of Delay Measures **(McShane, 2004).**

2.7.3 LOS

LOS is a metric used by transportation planners to assess the quality of service provided by transportation devices or infrastructure. LOS range from A to F, with A being the best when drivers are unaffected by other vehicles and F being the worst. LOS for signalized intersections is calculated using the average stopped delay time per vehicle, as shown in Table (2-6) **(HCM, 2000)**

Table (2-6): Level of Services Criteria (HCM, 2000).

Level of Service (LOS)	Average Delay (Sec.)
A	<10.0
B	>10.0-20.0
C	>20.0-35.0
D	>35.0-55.0
E	>55.0-80.0
F	>80.0

2.8 Roundabout

A roundabout is an unsignalized crossroads with one-way traffic flowing around a central island. In most cases, circulating vehicles prioritize mobility, and all entering cars must reject or accept open gaps while waiting to enter. There are five primary reasons for the popularity of roundabout junctions in nations where they are widespread: (**Polus, 2003)**

1. They frequently offer the necessary entrance capacity from a minor road to the main route, particularly in suburban regions where traffic levels do not approach saturation.
2. When properly built, roundabouts may effectively regulate traffic flow without the need for electrical control signal systems.
3. They offer convenience and uniformity in operation: All cars must turn to enter the junction.
4. They are safer than unsignalized traditional crossings because fewer conflict spots and cars travel at slower speeds around the middle island.
5. The middle island of a roundabout is often utilized to beautify the junction area.

Roundabouts have two distinct benefits over junctions in terms of safety and mobility. In nations where traffic is driven on the right, roundabouts generate slower and smooth traffic flows with minimal pauses and no left turns in front of oncoming vehicles. Because left turns are not allowed, roundabouts have a higher capacity than give-way intersections and signalized junctions **(Elvik and Vaa, 2004).**

At grade, modern roundabouts have near-circular junctions. They're a good junction type since they have fewer conflict spots and lower speeds, making decisions easier than other types. They are also less expensive to maintain than traffic lights. Well-designed roundabouts have been shown to minimize accidents (particularly fatal and serious injury incidents), traffic delays, fuel consumption, and pollution. They also have a traffic-calming impact since they use a geometric design rather than depending simply on traffic control equipment to reduce vehicle speeds **(WISDOT, 2008).**

2.8.1 Capacity of Roundabout

The total of all entering approach capabilities is the roundabout capacity. The highest pace at which cars may reasonably be expected to enter the roundabout from an approach over a particular period under current traffic and roadway (geometric) conditions is the capacity of each entrance **(Aty and Hosni, 2001).**

2.8.2 Roundabout Delay

Control delay may be defined as the total amount of time lost owing to all delays encountered while passing through an intersection at approach and departure cruising speeds (including all acceleration and deceleration delays, delay due to cruise at a slower speed, and stopped delay). In the absence of any other cars, the geometric delay is the time it takes for a vehicle to pass through (negotiate) a junction **(Akcelik, 2009 b].**

2.8.3 LOS of Roundabout

The LOS of a junction has a big impact on the overall performance of the intersection. Automobiles, trucks, bicycles, pedestrians, and buses are all forms of transportation that utilize highways, and LOS represents the quality of service as evaluated by a scale of user satisfaction. When a transportation facility is supporting a variety of traffic volumes, LOS is defined as a word that represents a range of operational circumstances that occur on the facility(**HCM, 2010).**

LOS is a qualitative measure that describes operational conditions within a traffic stream and how motorists and/or passengers perceive them. The level of service criteria simplifies traffic flow parameters like delay, speed, travel time, comfort, safety, and maneuverability into a simple A to F scale, where A indicates ideal conditions based on the traveler's perspective **(Taylor, 2012).**

2.9 Environmental pollution

2.9.1 Traffic Gas Emissions

Traffic congestion not only adds to travel time and energy consumption but also pollutes the environment, reduces productivity, and costs society money. Vehicles spend more time on the road during traffic congestion, idling or crawling, and undergoing numerous acceleration and deceleration events, which may increase emissions**(Smit et al., 2008).**

For traffic engineers, air pollution caused by automobile traffic has become a significant issue. Traffic, road and vehicle features, atmospheric conditions, and driving behavior are all vehicular influence emissions. In terms of air quality, intersections are essential components of road networks, and their control type and geometric layout can significantly influence vehicular emissions. Vehicles slow down and frequently halt at junctions, disrupting traffic flow in a variety of patterns **(Gastaldi et al ., 2014)**

It is well known that Carbon monoxide (CO) is considered an extremely unhealthy gas. CO results from the incomplete combustion fuel. CO could be produced by car equipment operated by internal combustion engines, and its concentration measured in parts per million or ppm **(Chen et al.,2012)**

Vehicles are one of the most major energy-consuming sources. Automobiles emit around one-fifth of the CO2 released into the atmosphere due to human activity, one-third of CFCs, and almost half of nitrogen oxides. As a result of these three significant gasses, climate change becomes a significant contributor. CO emissions from heavy-duty cars, buses, and trucks (diesel fuel) are only 1/11 of those from small vehicles due to traffic, highway and automotive characteristics, weather conditions, and driver behavior (Pratama et al., 2013). (benzene) **(Shuhaili et al., 2019).**

Traffic-generated air pollution is of great concern to the general public. Motor vehicles emit nitrogen oxides (NOx), carbon monoxide (CO), volatile organic compounds (VOC), and particulate matter (PM), which constitute a major source of air pollution in large cities Traffic generated air pollutants, such as NO2 and PM, are of health concern; and traffic generated greenhouse gases, such as carbon dioxide (CO2), may contribute to global warming. As motor vehicles are the major contributor to urban air pollution, control strategies need to be developed that minimize the environmental impacts but maximize the efficiency of motorized transport **(Xia and Shao, 2005)**

2.10 Previous Studies

Al-Haydari (2018) analyzed the traffic performance of the road network around the old city of Karbala from the southern side, at Al-Tarbia Street and Fatima Al-Zahraa Street, using junctions as a metric. Following that, several improvement recommendations are offered, ranging from altering the timing plan to making geometric improvements to replacing the junction type. The research area consists of seven junctions, three of which have four signalized legs and the other four roundabouts. The traffic data for 27 approaches is collected using video capturing technology. These data are extracted from video clips using the EVENT software and processed using EXCEL sheets produced. At the same time, the pavement marking approach is used to collect spot speed data for each connection in the network. SYNCHRO software was utilized to assess and analyze signalized crossings and the optimum timing plan and coordination proposal. Both signalized junctions and roundabouts were evaluated and analyzed using SIDRA INTERSECTION software. For the target year, the best suggestion was also considered.

Qasim (2018) evaluated the transportation network in Nasiriyah city using TransCad, GPS, and GIS programs to evaluate the flow of the current traffic network patterns so collecting different types of data, such as (Traffic volumes and free-flow speed) using a device (MSSS), field surveys are done for the work of large-scale map road network. As shown in the analysis map, the majority of the city's roads have a LOSB, as the network revealed LOSF where the vehicle relative to the road capacity (v/c) is higher than one in the city center, such as Habboubi Street, Nasir Bridge, Sumer Street, and so on. On this basis, it was suggested that new roads be built to modify external - external journeys and new bridges to alleviate the congestion developed in the city center.

Al-Thawra signalized crossroads in Al-Hilla city, which is a four-legged major roadway, was examined by Al-Ubaidy (2010). The primary goal of this research was to analyze the performance of the traffic operation at the specified junction and determine the current LOS and provide the best proposed geometrical design for the study area to achieve a correct LOS in the present and future. The junction was determined to be operating at LOS F with an average delay of 263.7 sec/veh, according to the HCS, 2000 program. The study found that building an overpass from the north-south direction (Baghdad – 60th) is the best approach for increasing junction capacity. LOS will attain level C with (22.8 sec/veh.) and a cycle time of 58 seconds using the proposed geometrical design.

Irtema (2015) used SIDRA software version 4.0 to enhance the LOS at four junctions in Kuala Lumpur and Petaling Jaya: two with four legs and two with three legs, as well as two roundabouts. Furthermore, the study intends to compare the findings between each peak hour in terms of the percentage change in the variables and the time delay. When comparing delays in morning and evening peak hours, the concept of geometric delay should also be taken into account. The results demonstrate that the morning period is superior to the evening period in delay, queue, trip duration, and speed, as determined by actual measurements in the research region. The average decrease in delay in the study region before and after SIDRA software improvement is 3489 sec to 1571 sec in the morning and 5093 sec to 1663 sec in the evening. The decrease percentages were around 45 percent and 33 percent, respectively. And the observations made in the scope of study regions throughout this research are as follows:

1. The LOS in the morning period was better than the evening period, which means that the volume of traffic flows in the evening more than in the morning period.
2. The capacity of an intersection and roundabout was unable to absorb the considerable volume of traffic flow at rush hours.

3. Some intersections and roundabouts need new lanes to be added to reduce the congestion and improve system speed.
4. Some intersections couldn't have new lanes added to them. Therefore, alternative routes must be opened to reduce traffic jams at these intersections.

Awad (2008) attempted to improve traffic capacity for the congested square in Baghdad City using the SIDRA program. Increased traffic volumes at junctions were the subject of the study, which are regarded as one of the major issues that cause traffic operation management and movement challenges, resulting in traffic congestion at these facilities. Capacity and degree of service are essential factors and control points when analyzing junctions and evaluating how well they work. This paper evaluates the capacity and level of service at Al-Mat'haf Square in Baghdad City. It proposes various improvement methods to address traffic operation difficulties and provide the best plan to increase performance from a capacity standpoint. The traffic volumes data collection and geometric layout for Al-Mat'haf square necessary for the traffic and geometrical analysis were obtained manually to fulfill these objectives, while the SIDRA traffic software was utilized for the traffic analysis process needs. The most significant plan for improving the capacity and traffic operation ability of Al-Mat'haf square has been determined to be a flyover linking the direction arriving from Al-Tajneed crossroads towards Damascus square.

Masllam (2016) assessed traffic flow and traffic network management in Jordan, using Highway Capacity Software HCS2000 and updated Synchro-8 programs software to evaluate traffic conditions at each intersection between 2012 and 2022. Traffic network management aims to reduce traffic congestion, delay, fuel consumption, and air and noise pollution. In addition, the level of service (LOS) of urban roadways and junctions should be improved. It took place on a network of two significant thoroughfares with eight signalized intersections. Al Kindi Street, Prince Shaker Bin Zaid Street, and Al-Sharif Naser Bin Jamel Street are the names of the streets. The data was gathered from government records at numerous departments in the Amman Municipality and the Directorate of Public Security. The analysis revealed that the junctions function at LOS F, with a significant wait time and saturation flow. To improve traffic conditions, two options were employed. The first is to optimize the present traffic signal timing schedule; nevertheless, this resulted in few traffic conditions. The second option is to adjust the geometric circumstances by altering and optimizing the signalized crossings' timing plans. It indicated a significant improvement in traffic conditions and reduced delay time and fuel usage in current and future situations. The junctions' Level of Service LOSs were enhanced from LOS F to LOS C, D, and E. It also revealed that the average total reduction in vehicle delay is around 87.75 percent and that the saturation flow at all junctions is reduced to less than one. The amount of gasoline consumed is also decreased by roughly 93%.

Aboud (2019) used the SIDRA program to study how to improve current traffic operations at Baghdad's Al-Turkman Roundabout. The roundabout is one of the most significant in the city, connecting the suburbs east of Baghdad to the city center in the Bab Al-Moatham neighborhood. High traffic volumes (congestion) define this location, especially during peak hours, resulting in a poor level of service (LOS) with higher travel time delays, expenditures, and CO_2 emissions. To analyze these factors, the researchers used the SIDRA program to collect traffic volumes in the area. The study suggested a set of planning processes that are separated into sequential periods. These planning methods are intended to solve the area's traffic congestion and jams, enhance service, and minimize travel time, cost, and CO_2 emissions. According to the findings, implementing the planning suggestions in the study region increased service levels from E and F to C, decreased travel time by 16 percent, cut expenditures by 25%, and reduced CO_2 emissions by 29%.

Table (2-7): A literature review of previous researches.

Researcher	Year	Topic title	Software Used
Al-Haydari	2018	Improvement of traffic performance at intersections in Karbala city	SYNCHRO and SIDRA INTERSECTION
Qasim	2018	TransCad analysis and GIS techniques to evaluate transportation network in Nasiriyah city	TransCad, GPS, and GIS
Al-Ubaidy	2010	Evaluation The Performance of Al-Thawra At-Grade Intersection Using The HCS2000 Computer Package	HCS2000
Irtema	2015	Evaluating the Performance of Traffic Flow in Four Intersections and Two Roundabouts in Petaling Jaya and Kuala Lumpur	SIDRA
Awad	2008	Improving traffic capacity for the congested square in Baghdad City	SIDRA
Masllam	2016	Evaluated traffic flow and traffic network management system in Jordan	HCS2000 and Synchro-8
Aboud	2019	A Case Study on Roundabout under Congestion: Proposal to Improve Current Traffic Operation	SIDRA

Chapter Three
Methodology and Data Collection

3.1 Introduction

This chapter indicates a general description of the study area and the methodology which includes defining the intersections and streets chosen for the city of Karbala and defining the segment for each street. Then, the stage of data collection, the methods used for data collection, abstraction, and processing were explained. In addition, the primary input data required for the selected software programs are identified.

3.2 Location of study area

Karbala City is one of the remarkable cities in the Islamic world. It is famous because of its religious history. The old city, or city center, holds shrines of Imam Hussain and his brother Abbas. It lies between (41°, 10`) to (44°, 20`) longitude and (32°) to (31°) latitude and it's around 36 meters above average sea level, departed at about 110 km southwest of Baghdad. It is surrounded by Al-Anbar province to the north and west, Al-Najaf city from the south, and Babylon city from the east **(ICTR, 2007)**.

3.3 Boundary of the study area

The selected study area has one roundabout and four intersections with the different urban streets. Traffic congestion in this area was increased with increasing traffic demand due to the presence of many centers of activity such as schools, governmental buildings, shopping centers, and religious places. The study area is shown in Figure (3-1) .The intersections names, codes, and the type of traffic control are shown in Table (3-1). The main roads in this part of the network are classified into four roads, as shown in Table (3-2).

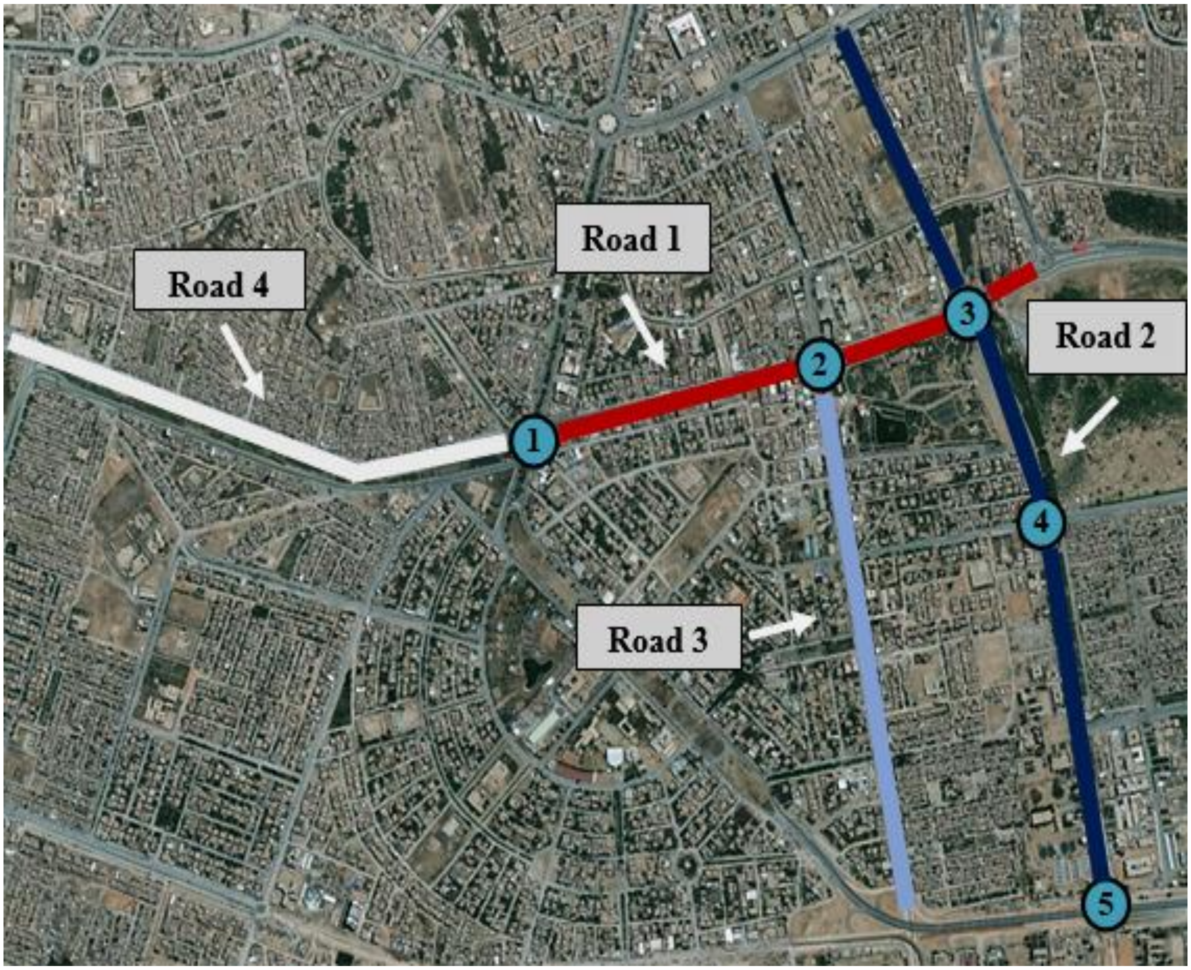


Figure (3-1) :The Study Area in Karbala City.

Table (3-1): Intersections Names, Codes, and Traffic Control Types.

Intersection code	Intersection name	Control type
1	Al-Dhareeba	Signalized intersection
2	Al-Safeena	Roundabout
3	Al- Sayed Jawda	Signalized intersection
4	Police Central Al-Hussein Neighborhood	Signalized intersection
5	Saif Saad intersection	Signalized intersection

Table (3-2): Roads details in the study area

Road No.	Local name	Lanes/ dir.	Divided/Undivided
1	Fatima Al-Zahraa Street	3	Divided
2	Al-Abbas Street	3	Divided
3	Al-Iskan Street	3	Divided
4	Ramadan Street	3	Divided

3.4 Data collection methodology

The data collection phase aims at assembling all data required to evaluate the traffic flow condition at the study area. The required data are collected in January, February/2021 at morning and evening peaks. All required traffic data are collected during good weather, because adverse weather conditions may cause variation in the normal traffic flow pattern. Figure (3-2) demonstrates the procedure for traffic data collection.

3.5 Peak hour periods

Several personal observations and pilot surveys were conducted in the study area, as well as personal interviews with relevant parties such as traffic officers in the area and other road users, to forecast the most crowded period for traffic data collecting. For typical weekdays, these observations revealed that the research area is characterized by (A.M.) peak periods of (8:30- 10:30) and (P.M.) peak periods of (4:00-6:00). The period in which the data was collected was the Corona period, where the working hours of employees, university students and schools were not continuous, so the peak period started from 8:30 (A.M).

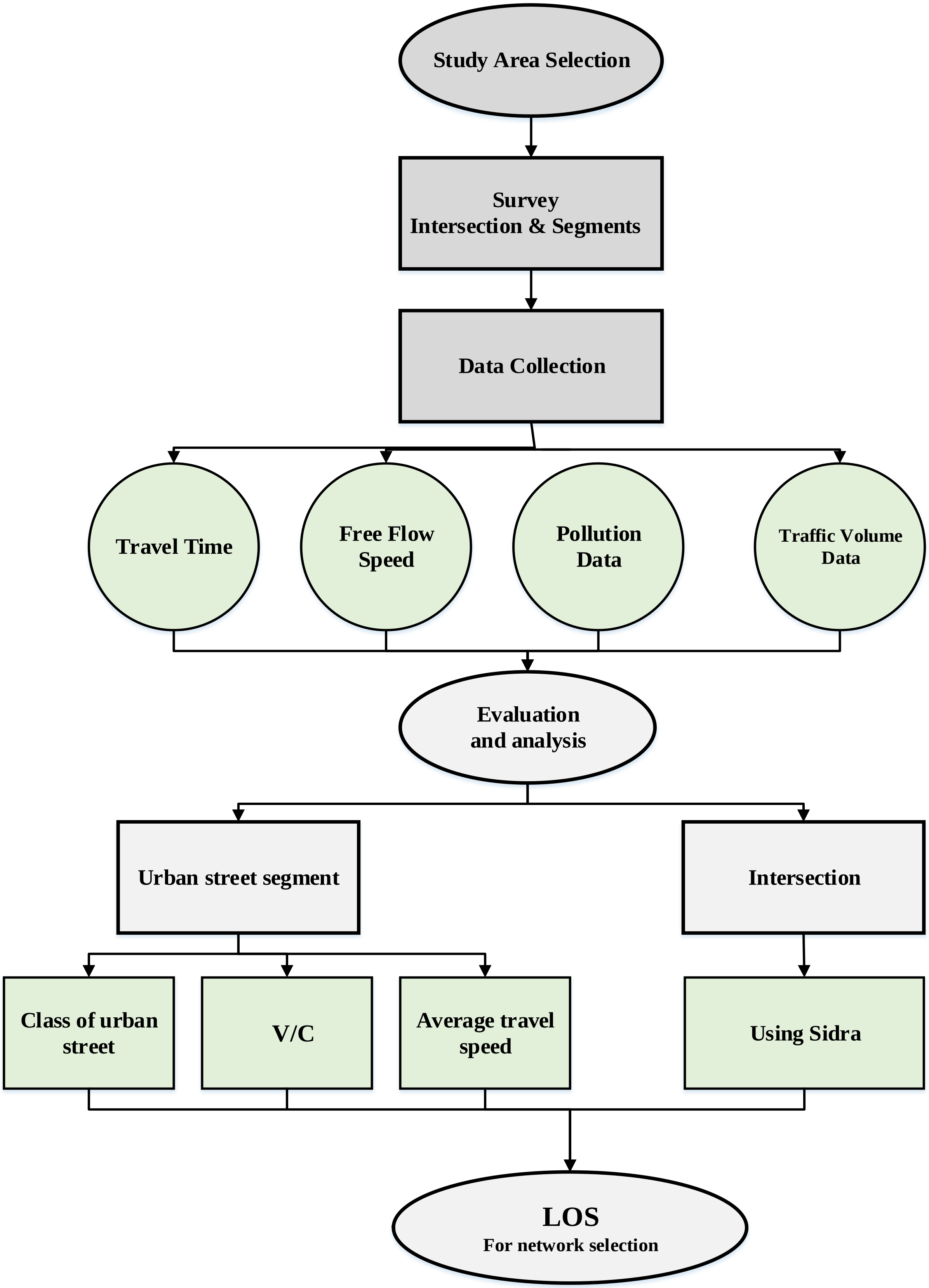


Figure (3-2): Methodology of the current study.

3.6 Data collection method

1. The traffic flow data have been collected from the field using the video camera, videotaping method is preferable for many reasons including:

- The ease of collecting data.
- A large number of situations can be recorded clearly.
- The collected data can be revised and analyzed in more detailed at any time.
- Data including traffic flow, capacity, and all the maneuvers can be extracted visually from the videotapes.

The camera used has the following specifications:

- 2 Megapixel high-performance
- Analog HD output with up to 1080p resolution
- Day/Night switch

The survey was made to choose the suitable vantage point to implement the video recording on the overhead bridge carrying the traffic signals and this is to ensure the optimum possible coverage for each intersection approaches as indicated in Figure(3-3). Many considerations should be taken into account while recording such as good weather and good visibility condition.

Figure(3-3): The location of cameras in the study area.

2. The pollution data was gathered using a (GASMET DX4040) instrument. The Gasmet DX4040 FTIR gas analyzer can detect up to 25 gases at once and provide verified findings in only 25 seconds. FTIR (Fourier Transform Infrared Spectroscopy) allows for accurate measurements with low detection limits and real multi-compound analysis. The user can change the library of measured gases through an easy-to-use interface, giving the DX4040 exceptional flexibility and the ability to respond to any measurement requirement in the field. The sample gas is drawn into the analyzer with a built-in pump through a handheld particle filter and Tygon tubing. The analyzer operates in continuous mode, taking time-weighted averages of user-defined lengths ranging from 1 second to 5 minutes; the instrument is seen in Figure (3-4).

Figure(3-4): GasmetDX4040 devices.

3.7 Geometric data

GIS tools in map measurements were used to calculate the geometric data like intersection spacing, right of way depending on the available satellite photographs for Karbala city with the accuracy of 0.6m, updated to 2016. Other geometric data such as no. of lines per approach, lane width, median width, splitter island width were calculated by field measurement by using measuring tape. In addition, some of the geometric features for roundabouts, which were difficult to be measured at the field like entry and exit radius, island diameter, circulating width, and so on, were taken from the Municipality department of Karbala city. The field survey was used to obtain the geometric features that could not be drawn from satellite images due to the unavailability of an updated one. Also, most of the intersections' geometric layouts were unavailable in Karbala municipality.

3.8 Traffic data

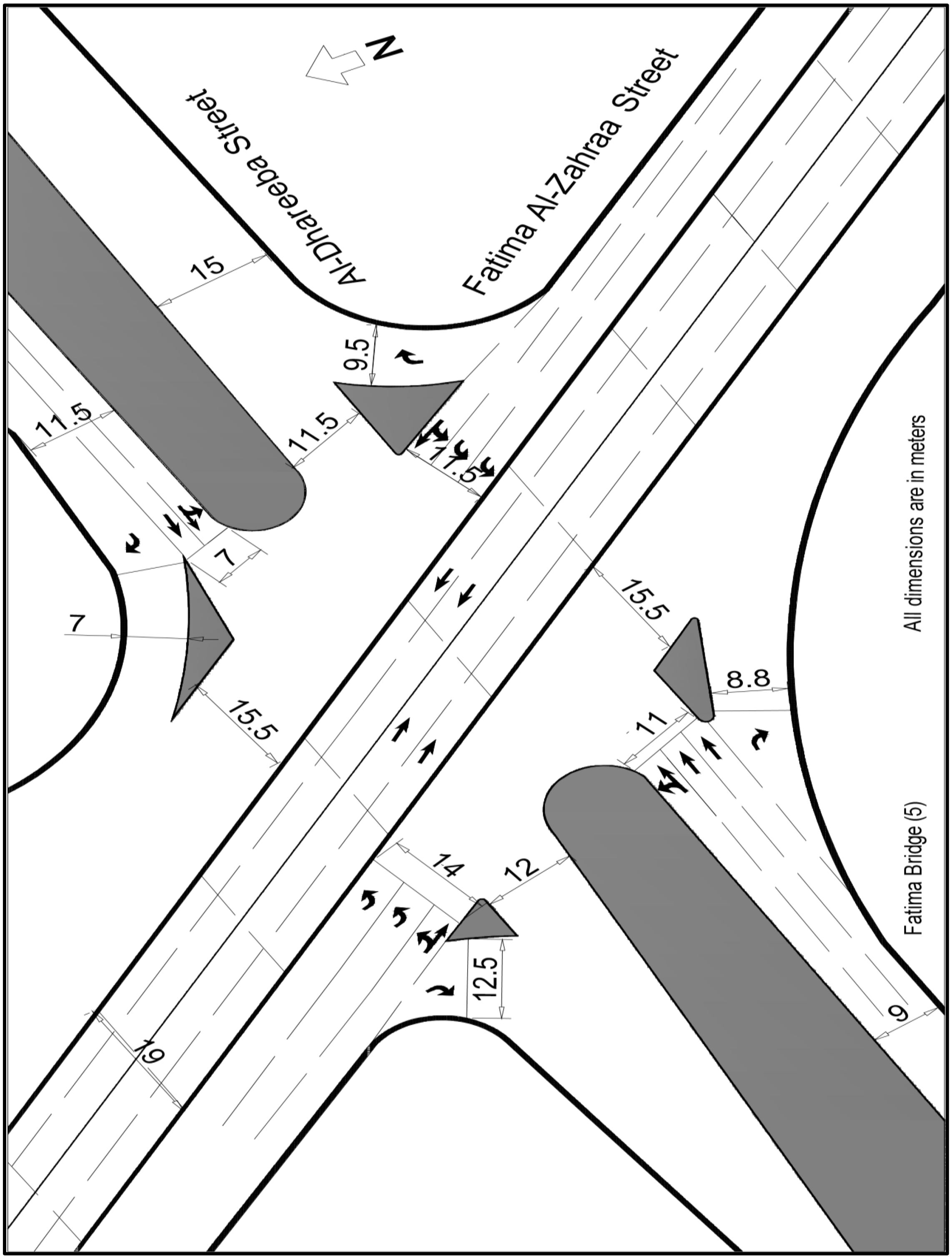
The traffic data that have been collected are as follows:

3.8.1 Traffic volume data

These data include counting the traffic volumes abstracted from video recording for each approach at the intersections in the selected network, also, traffic volume studies are conducted to determine the number, movements, and classifications of roadway vehicles at a given location. These data can help identify critical flow periods, determine the influence of large vehicles on vehicular traffic flow.

3.8.1.1 Al- Dhareeba Intersection

It is a four legs-signalized-intersection and is considered one of the most important intersections located in the center of Karbala city, the north direction leads to the center of this area, while the west direction leads to the University of Kerbala, it contains a bridge of (432) m length, was constructed in the direction of Fatima Al-Zahraa Street, it was constructed to mitigate the traffic interference at the intersection especially the conflicting with heavy left turns, this intersection as indicated in Figure(3-5). The traffic data was collected on Thursday (28-1- 2021), the 4 cameras have been installed on the overhead bridge carrying the traffic signals. As the video recording started from (8:30 to 10:30) for the morning peak and from (4:00 to 6:00) for the evening peak, the traffic Flow rate for period morning and period evening has been calculated as shown in Tables (3-3) and (3-4), respectively.



Figure(3-5) : AL-Dhareeba intersection.

Table(3-3): Traffic Flow rate for each approach for AL-Dhareeba intersection (morning period)

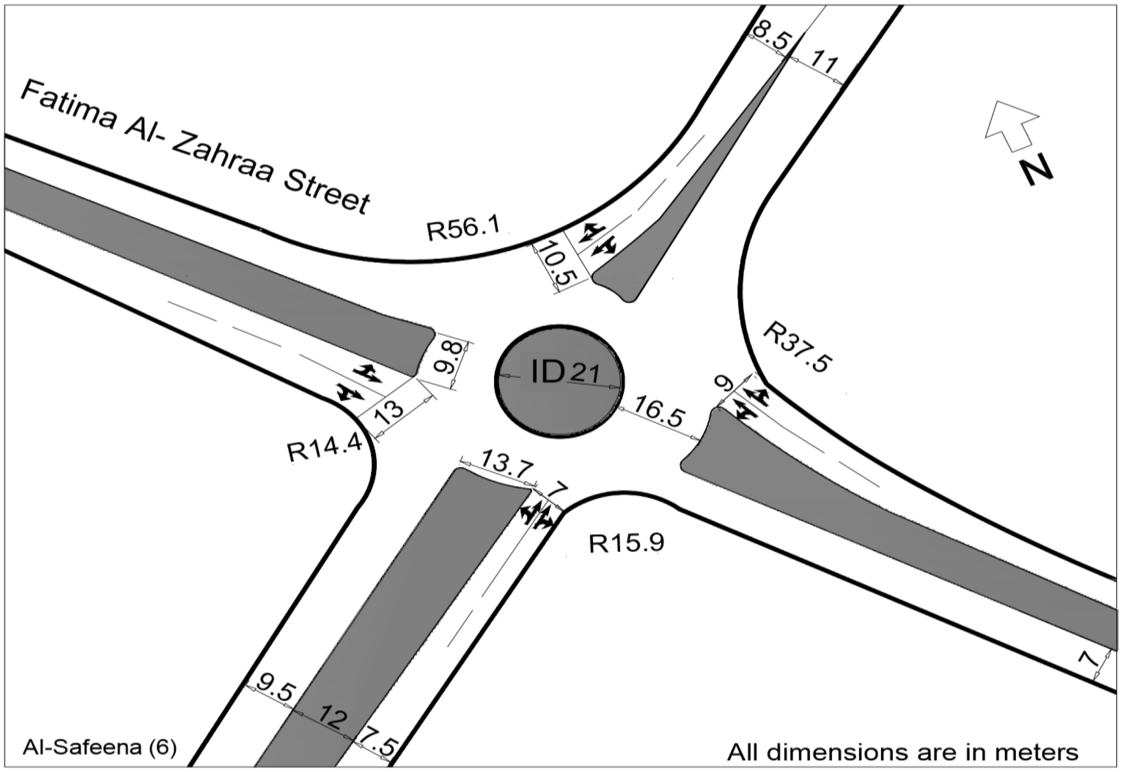
Time	North	South	East	West	Flow rate(veh/hr)
8:30 - 8:45	1220	1336	400	1052	4008
8:45 - 9:00	1276	1260	416	976	3928
9:00 - 9:15	1424	1320	428	1092	4264
9:15 - 9:30	1184	1548	460	868	4060
9:30 - 9:45	1452	1536	500	976	4464
9:45 - 10:00	1348	1616	460	896	4320
10:00 - 10:15	1568	1716	532	1216	5032
10:15 - 10:30	1584	1800	736	1140	5260

Table(3-4): Traffic Flow rate for each approach for AL-Dhareeba intersection (evening period)

Time	North	South	East	West	Flow rate(veh/hr)
4:00-4:15	2272	2504	920	1484	7180
4:15-4:30	2264	2588	1020	1536	7408
4:30-4:45	2340	2388	1144	1460	7332
4:45-5:00	2284	2476	1120	1532	7412
5:00-5:15	2352	2692	1152	1892	8088
5:15-5:30	2388	2468	1220	1664	7740
5:30-5:45	2264	2620	1280	1688	7852
5:45-6:00	2732	2616	1488	1864	8700

3.8.1.2 Al-Safeena Roundabout

It is a four-leg roundabout intersection. This roundabout suffered from congestion due to the connection between two major streets, Fatima Al-Zahraa Street with Al-Iskan street, all approaches consist of three lanes. It suffers from congestion, especially in the evening peak this could be due to a lot of centers of activities (Shopping centers and doctors' clinics) and other facilities, Figure(3-6) illustrates Al-Safeena Roundabout.



Figure(3-6): Al-Safeena Roundabout.

Traffic volumes were calculated for the morning and evening periods on Monday (11-1-2021). Traffic volumes were measured for the morning period from (8:30-10:30) AM and evening period (4:00-6:00) PM, this data as shown in Tables (3-5) and (3-6), respectively.

Table (3-5): Traffic Flow rate for each approach for Al-Safeena Roundabout (morning period)

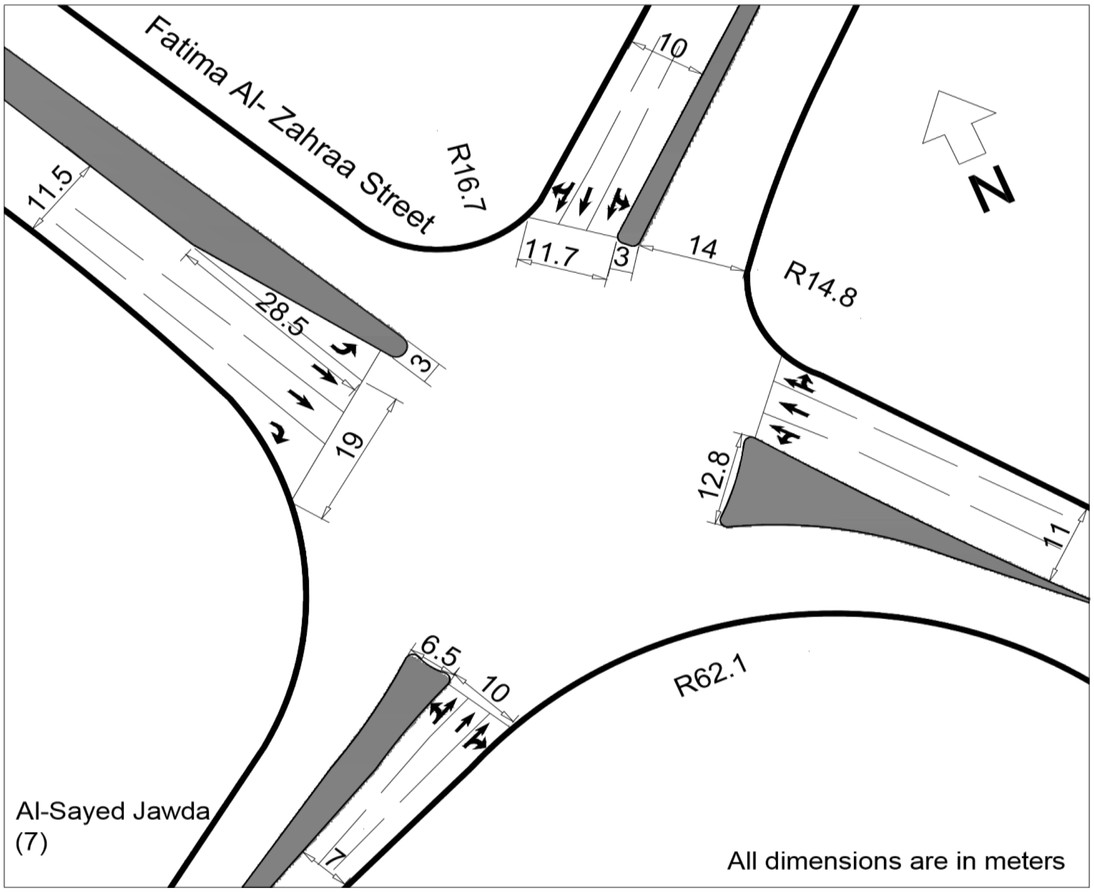
Time	North	South	East	West	Flow rate(veh/hr)
8:30 - 8:45	1208	1556	1200	736	4700
8:45 - 9:00	1308	1332	1476	760	4876
9:00 - 9:15	1244	1276	1320	716	4556
9:15 - 9:30	1276	1240	1260	700	4476
9:30 - 9:45	1600	1576	1860	840	5876
9:45 - 10:00	1572	1400	1580	1008	5560
10:00 - 10:15	1496	1284	1512	972	5264
10:15 - 10:30	1520	1376	1600	1068	5564

Table (3-6): Traffic Flow rate for each approach for Al-Safeena Roundabout (evening period)

Time	North	South	East	West	Flow rate(veh/hr)
4:00-4:15	1720	2092	1520	2124	7456
4:15-4:30	1792	2120	1608	2108	7628
4:30-4:45	1684	2164	1672	2208	7728
4:45-5:00	1800	2288	1748	2236	8072
5:00-5:15	2116	2368	1716	2248	8448
5:15-5:30	1876	2168	1656	2164	7864
5:30-5:45	1812	2192	1796	2184	7984
5:45-6:00	1740	2208	1684	2300	7932

3.8.1.3 Sayed Jawda Intersection

It is a four-leg signalized intersection. It represents one of the main important intersections in Karbala city which suffered from congestion. The north direction leads to the center of this area, while the west direction leads to the Al-Safeena Roundabout Intersection, the south direction leads to the Police Central Al-Hussein Neighborhood intersection , this intersection as indicated in Figure(3-7). The survey was conducted to calculate traffic volumes on Wednesday (13-1-2021) in the morning and evening, using four cameras. The cameras have been installed on the overhead bridge carrying the traffic signals . Traffic Flow rate data for all vehicle classification shown as Tables(3-7) and (3-8).



Figure(3-7): Sayed Jawda Intersection.

Table(3-7): Traffic Flow rate for each approach for Sayed Jawda Intersection (morning period)

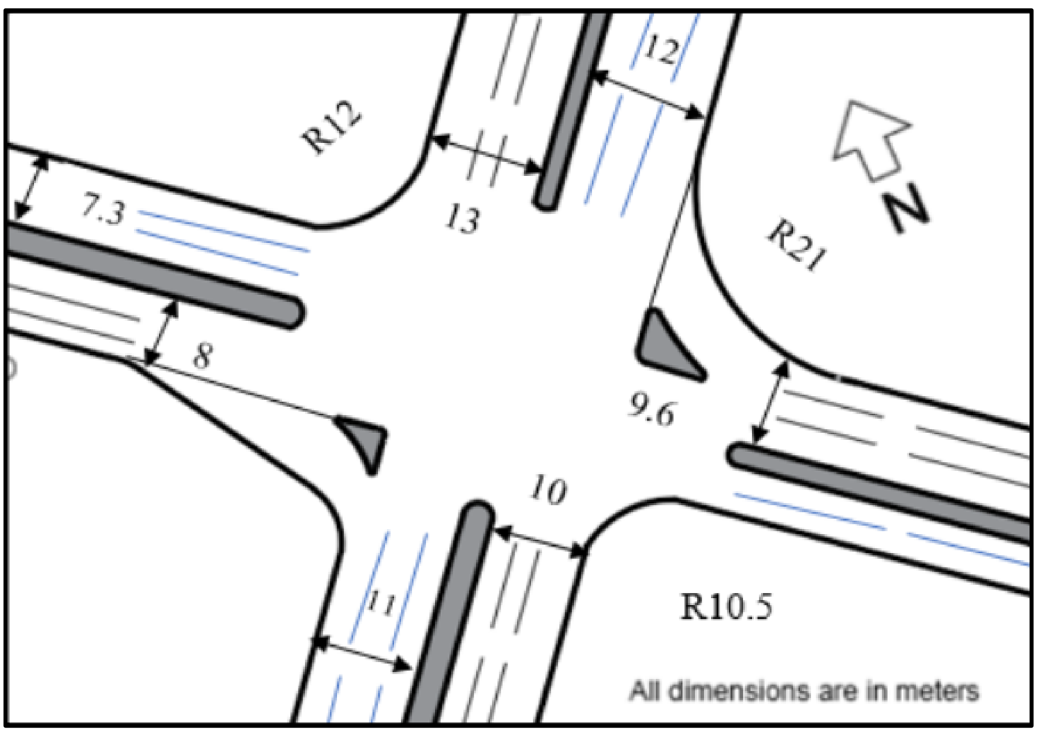
Time	North	South	East	West	Flow rate(veh/hr)
8:30 - 8:45	1288	2188	1676	2004	7156
8:45 - 9:00	1244	2108	1600	2104	7056
9:00 - 9:15	1304	2156	1636	2084	7180
9:15 - 9:30	1356	2400	1716	2192	7664
9:30 - 9:45	1400	2472	2092	2296	8260
9:45 - 10:00	1384	2388	1824	2160	7756
10:00 - 10:15	1548	2548	1872	2048	8016
10:15 - 10:30	1588	2688	2068	2128	8472

Table(3-8): Traffic Flow rate for each approach for Sayed Jawda Intersection (evening period).

Time	North	South	East	West	Flow rate(veh/hr)
4:00-4:15	1236	2340	2392	2480	8448
4:15-4:30	1432	2860	2284	2204	8780
4:30-4:45	1232	2792	2452	2320	8796
4:45-5:00	1284	2716	2312	2700	9012
5:00-5:15	1244	2732	2088	2488	8552
5:15-5:30	1352	3064	2248	2664	9328
5:30-5:45	1296	2952	2340	2376	8964
5:45-6:00	1204	2880	2320	2532	8936

3.8.1.4 Police Central Al-Hussein Intersection

It is a four signalized intersection. It is an intersection located between two important intersections (Sayed Jawda and Saif Saad Intersection) where the approach direction is the north and the approach direction the south is more congestion. This intersection is shown in Figure(3-8).



Figure(3-8): Central Al-Hussein intersection.

Traffic Volumes were calculated on Monday (18 -1-2021); the traffic volume for morning and evening periods for all vehicle classification has been calculated as shown in Tables (3-9) and (3-10), respectively.

Table(3-9): Traffic Flow rate for each approach for Central Al-Hussein intersection (morning period).

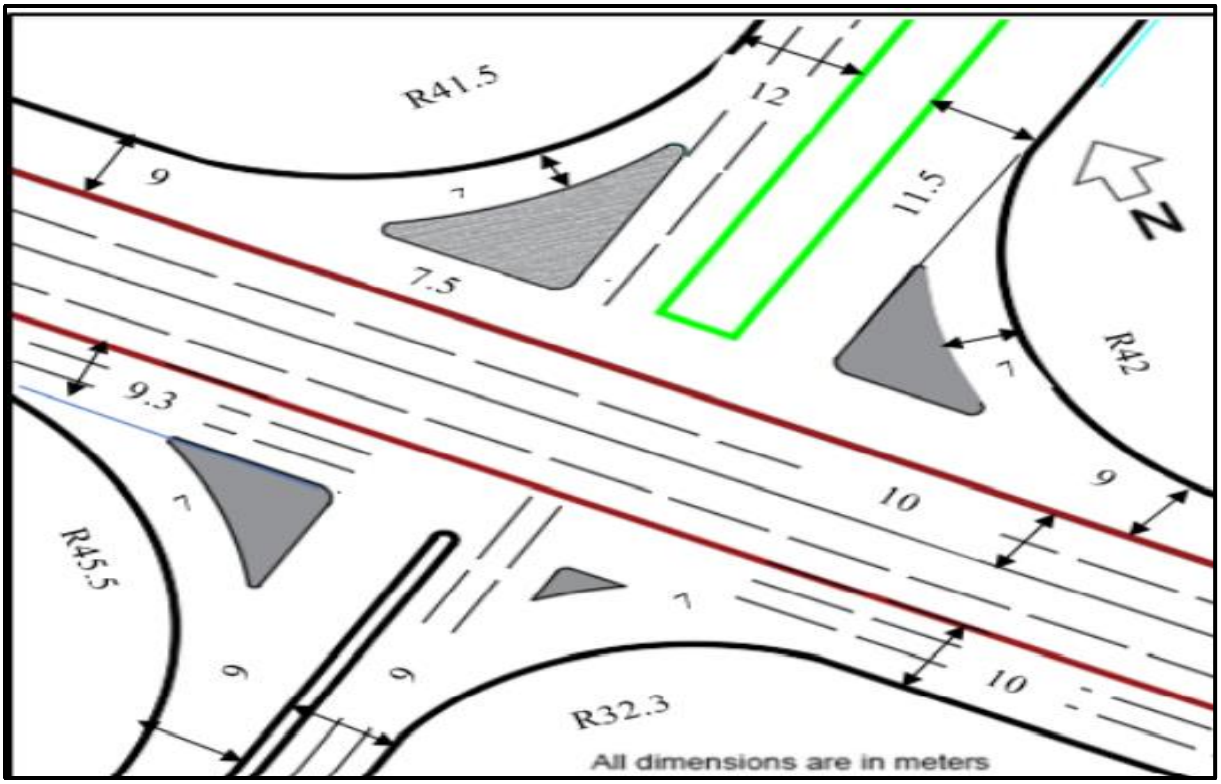
Time	North	South	East	West	Flow rate(veh/hr)
8:30 - 8:45	1868	2384	616	576	5444
8:45 - 9:00	2028	2172	508	508	5216
9:00 - 9:15	1760	2296	616	620	5292
9:15 - 9:30	1724	2016	620	536	4896
9:30 - 9:45	1912	1924	504	720	5060
9:45 - 10:00	1368	2332	648	636	4984
10:00 - 10:15	1684	2200	672	592	5148
10:15 - 10:30	1724	2860	588	744	5916

Table(3-10): Traffic Flow rate for each approach for Central Al-Hussein intersection (evening period)

Time	North	South	East	West	Flow rate(veh/hr)
4:00-4:15	1540	2136	684	712	5072
4:15-4:30	1452	2096	584	724	4856
4:30-4:45	1480	2148	632	648	4908
4:45-5:00	1712	2352	620	652	5336
5:00-5:15	1516	2320	692	560	5088
5:15-5:30	1584	2572	752	704	5612
5:30-5:45	1668	2124	712	712	5216
5:45-6:00	1496	2068	744	732	5040

3.8.1.5 Saif Saad Intersection

It is a signalized intersection with an overpass for through traffic in direction (east-west) and an under-pass for left-turn traffic in the north direction. The north direction leads to the center of the area while the east direction leads to the Najaf Road. This intersection is indicated in Figure(3-9).



Figure(3-9): Saif Saad Intersection.

The traffic volumes of the Saif Saad Intersection were calculated on Monday(25 -1 - 2021), using 4 cameras and the volumes were taken for two hours for the morning peak and two hours for the evening peak, this data is shown in Tables (3-11) and (3-12), respectively.

Table(3-11): Traffic Flow rate for each approach for Saif Saad Intersection (morning period)

Time	North	South	East	West	Flow rate(veh/hr)
8:30 - 8:45	1180	1488	1244	1056	4968
8:45 - 9:00	960	1320	1008	972	4260
9:00 - 9:15	1036	1256	864	856	4012
9:15 - 9:30	1092	1320	964	896	4272
9:30 - 9:45	1140	1484	856	824	4304
9:45 - 10:00	1080	1480	1152	932	4644
10:00 - 10:15	1316	1356	1056	1012	4740
10:15 - 10:30	1100	1464	1156	956	4676

Table(3-12): Traffic Flow rate for each approach for Saif Saad Intersection (evening period).

Time	North	South	East	West	Flow rate(veh/hr)
4:00-4:15	1364	1464	1028	968	4824
4:15-4:30	1192	1708	1148	1092	5140
4:30-4:45	1264	1948	1048	1048	5308
4:45-5:00	1168	1704	1136	1080	5088
5:00-5:15	1304	1676	1184	1128	5292
5:15-5:30	1248	1580	1108	1000	4936
5:30-5:45	1276	1684	1200	1136	5296
5:45-6:00	1240	1628	1172	1160	5200

3.8.1.6 Road No 1 (Fatima Al-Zahraa Street)

Fatima Al-Zahraa Street is a multilane divided urban street, with three lanes for each direction. It is (1.4) km in length and (45) m right of way. It has a (5) m width of the raised median. It represents the developing area of the city. The selected section begins at Hamza Al-Sagheer Street and ends at the newly-built overpass (Al-Dareeba) intersection, Three intersections(Al-Dareeba, alsafeena , sayed jawda) are located at this street, This street suffers from severe congestion due to the presence of many commercial and entertainment centers located on this street, as well as its connection to three important intersections in the city of Karbala. This street is shown in Figure (3-10) and It consists of six segments as indicated in Figure (3-11).Traffic surveys were conducted for all segments in the morning and evening periods. For all required data represent (PC= passenger car, MB= mini bus ,B= Bus , HV=heavy vehicle and MT= motorcycle) traffic Flow rate data for segment (1) for morning and evening periods as shown in Tables (3-13)and (3-14), respectively.

Figure(3-10): Fatima Al-Zahraa Street.

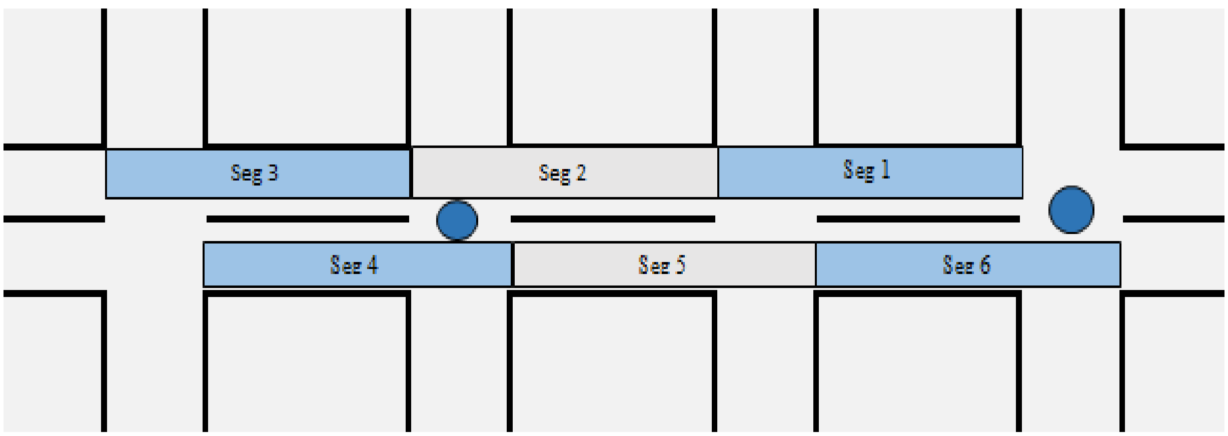


Figure (3-11): Segments of Road no.1(Fatima Al-Zahraa Street).

Table(3-13): Data of Segment 1 for Road no.1 (morning period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
8:30 - 8:45	1008	52	4	92	520	1676
8:45 - 9:00	1040	48	8	56	448	1600
9:00 - 9:15	1036	40	4	76	480	1636
9:15 - 9:30	1064	40	12	124	476	1716
9:30 - 9:45	1276	60	8	84	664	2092
9:45 - 10:00	1164	68	8	56	528	1824
10:00 - 10:15	1100	72	12	88	600	1872
10:15 - 10:30	1332	60	0	136	540	2068

Table(3-14): Data of Segment 1 for Road no.1 (evening period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
4:00-4:15	1408	80	0	72	832	2392
4:15-4:30	1376	64	0	72	772	2284
4:30-4:45	1412	52	8	116	864	2452
4:45-5:00	1368	48	0	64	832	2312
5:00-5:15	1184	48	0	68	788	2088
5:15-5:30	1336	68	4	80	760	2248
5:30-5:45	1392	56	0	92	800	2340
5:45-6:00	1296	40	4	48	932	2320

For Segment no. (2), the data is shown in Tables(3-15) and (3-16).

Table(3-15): Data of Segment 2 for Road no.1 (morning period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
8:30 - 8:45	744	12	4	52	388	1200
8:45 - 9:00	992	36	12	80	356	1476
9:00 - 9:15	868	28	20	44	360	1320
9:15 - 9:30	840	16	12	52	340	1260
9:30 - 9:45	1244	40	28	88	460	1860
9:45 - 10:00	1060	20	16	68	416	1580
10:00 - 10:15	1028	32	12	48	392	1512
10:15 - 10:30	1044	28	20	80	428	1600

Table(3-16): Data of Segment 2 for Road no.1 (evening period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
4:00-4:15	1108	4	0	48	360	1520
4:15-4:30	1152	0	8	64	384	1608
4:30-4:45	1200	8	12	44	408	1672
4:45-5:00	1184	16	20	80	448	1748
5:00-5:15	1204	4	12	68	428	1716
5:15-5:30	1260	12	0	36	348	1656
5:30-5:45	1400	0	4	28	364	1796
5:45-6:00	1208	8	12	52	404	1684

For Segment no. (3), the data is shown in Tables(3-17) and (3-18).

Table(3-17): Data of Segment 3 for Road no.1 (morning period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
8:30 - 8:45	1096	200	4	152	312	1764
8:45 - 9:00	992	180	8	144	264	1588
9:00 - 9:15	988	148	8	140	332	1616
9:15 - 9:30	988	188	4	144	404	1728
9:30 - 9:45	1236	220	0	160	444	2060
9:45 - 10:00	1000	140	16	180	452	1788
10:00 - 10:15	1448	228	8	148	420	2252
10:15 - 10:30	1416	224	8	152	380	2180

Table(3-18): Data of Segment 3 for Road no.1 (evening period)

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
4:00-4:15	1952	132	24	52	792	2952
4:15-4:30	1924	160	8	88	748	2928
4:30-4:45	2008	152	0	68	764	2992
4:45-5:00	2080	180	12	80	780	3132
5:00-5:15	2036	136	8	44	788	3012
5:15-5:30	1992	180	20	92	820	3104
5:30-5:45	2044	168	16	76	836	3140
5:45-6:00	2068	184	8	84	840	3184

Flow rate data for Segments no.4, no.5, and no.6 are indicated in Tables (3-19) to (3-24).

Table(3-19): Data of Segment 4 for Road no.1 (morning period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
8:30 - 8:45	1728	200	0	156	592	2676
8:45 - 9:00	1620	212	12	140	576	2560
9:00 - 9:15	1512	196	0	208	588	2504
9:15 - 9:30	1524	204	4	192	628	2552
9:30 - 9:45	1780	216	4	120	732	2852
9:45 - 10:00	1656	180	4	204	696	2740
10:00 - 10:15	1640	232	0	144	832	2848
10:15 - 10:30	1636	140	4	232	572	2584

Table(3-20): Data of Segment 4 for Road no.1 (evening period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
4:00-4:15	1612	152	8	104	752	2628
4:15-4:30	1660	120	0	84	716	2580
4:30-4:45	1600	160	4	100	744	2608
4:45-5:00	1628	180	12	88	772	2680
5:00-5:15	1584	172	8	80	804	2648
5:15-5:30	1600	128	0	92	792	2612
5:30-5:45	1532	148	12	108	784	2584
5:45-6:00	1464	132	0	96	820	2512

Table(3-21): Data of Segment 5 for Road no.1 (morning period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
8:30 - 8:45	432	8	0	36	260	736
8:45 - 9:00	480	20	8	28	224	760
9:00 - 9:15	440	12	0	24	240	716
9:15 - 9:30	368	16	0	36	280	700
9:30 - 9:45	460	20	0	52	308	840
9:45 - 10:00	656	28	12	40	272	1008
10:00 - 10:15	596	24	8	44	300	972
10:15 - 10:30	688	20	8	36	316	1068

Table(3-22): Data of Segment 5 for Road no.1 (evening period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
4:00-4:15	1900	24	0	20	180	2124
4:15-4:30	1916	36	0	8	148	2108
4:30-4:45	1932	36	8	24	208	2208
4:45-5:00	1952	28	4	8	244	2236
5:00-5:15	1928	44	0	16	260	2248
5:15-5:30	1892	40	8	4	220	2164
5:30-5:45	1932	20	0	0	232	2184
5:45-6:00	1980	36	8	12	264	2300

Table(3-23): Data of Segment 6 for Road no.1 (morning period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
8:30-8:45	1212	52	0	92	648	2004
8:45-9:00	1236	80	4	88	696	2104
9:00-9:15	1308	68	8	80	620	2084
9:15-9:30	1336	84	0	104	668	2192
9:30-9:45	1368	76	12	128	712	2296
9:45-10:00	1320	88	8	84	660	2160
10:00-10:15	1248	64	0	100	636	2048
10:15-10:30	1304	56	12	92	664	2128

Table(3-24): Data of Segment 6 for Road no.1 (evening period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
4:00-4:15	1372	84	0	64	960	2480
4:15-4:30	1184	44	0	92	884	2204
4:30-4:45	1280	52	0	84	904	2320
4:45-5:00	1400	72	4	64	1160	2700
5:00-5:15	1464	80	8	72	864	2488
5:15-5:30	1452	64	0	48	1100	2664
5:30-5:45	1388	72	4	68	844	2376
5:45-6:00	1296	44	4	48	1140	2532

3.8.1.7 Road No 2 (Al-Abbas Street)

This road is a multilane divided with 3 lanes in each direction, this road passes through three intersections (Sayed Jawda, Police Central Al-Hussein Neighborhood, Saif Saad), where this road intersects with Fatima Al-Zahraa Street. This street is considered one of the important streets in the city of Karbala, indicated in Figure (3-12) and it consists of six segments as indicated in Figure (3-13). The traffic flow rate data for all segments of Al-Abbas Street are shown in the following Tables (3-25)to (3-36) and all data are classified as (PC= passenger car, MB= minibus, B= Bus, HV=heavy vehicle, and MT= motorcycle).

Figure(3-12): Al-Abbas Street.

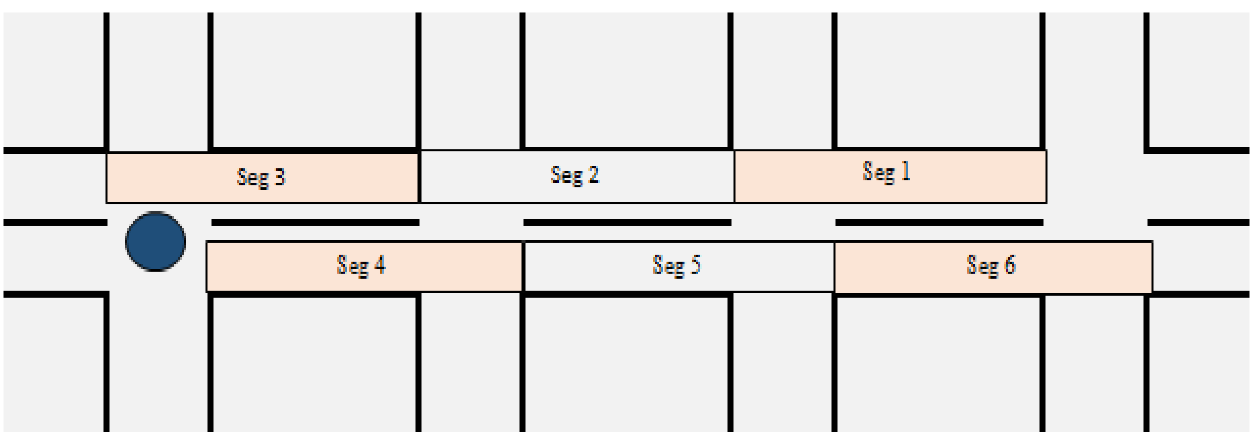


Figure (3-13): Segments of Road no.2(Al-Abbas Street).

Segment no. (1) starts from Saif Saad intersection and ends with the intersection of Police Central Al-Hussein, this data for this segment is shown in Tables (3-25) and (3-26) for morning and evening periods.

Table(3-25): Data of Segment 1 for Road no.2 (morning period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
8:30 - 8:45	1088	80	4	64	252	1488
8:45 - 9:00	940	44	0	72	264	1320
9:00 - 9:15	888	68	4	92	204	1256
9:15 - 9:30	916	88	0	72	244	1320
9:30 - 9:45	932	76	4	128	344	1484
9:45 - 10:00	1024	72	4	76	304	1480
10:00 - 10:15	932	100	0	124	200	1356
10:15 - 10:30	980	52	0	128	304	1464

Table(3-26): Data of Segment 1 for Road no.2 (evening period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
4:00-4:15	880	88	4	84	408	1464
4:15-4:30	1164	52	8	64	420	1708
4:30-4:45	1196	76	16	100	560	1948
4:45-5:00	1052	100	36	80	436	1704
5:00-5:15	1000	92	20	104	460	1676
5:15-5:30	988	68	8	76	440	1580
5:30-5:45	1032	76	16	80	480	1684
5:45-6:00	940	60	12	92	524	1628

The data of the second section, which starts from Police Central Al-Hussein intersection and ends with the intersection of sayed jawda is indicated in the Tables (3-27) and (3-28) for morning and evening periods, while Segment no. (3) starts from sayed jawda intersection and ends with the sequre , flow rates are indicated for this segment in Tables (3-29)and (3-30) .

Table(3-27): Data of Segment 2 for Road no.2 (morning period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
8:30 - 8:45	1604	244	12	88	436	2384
8:45 - 9:00	1528	172	4	100	368	2172
9:00 - 9:15	1532	180	16	120	448	2296
9:15 - 9:30	1324	232	8	112	340	2016
9:30 - 9:45	1308	152	8	80	376	1924
9:45 - 10:00	1556	216	20	92	448	2332
10:00 - 10:15	1464	172	16	144	404	2200
10:15 - 10:30	1944	256	28	108	524	2860

Table(3-28): Data of Segment 2 for Road no.2 (evening period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
4:00-4:15	1480	120	8	52	476	2136
4:15-4:30	1356	148	16	56	520	2096
4:30-4:45	1400	168	24	44	512	2148
4:45-5:00	1512	180	8	68	584	2352
5:00-5:15	1604	172	8	36	500	2320
5:15-5:30	1688	188	0	80	616	2572
5:30-5:45	1368	124	12	60	560	2124
5:45-6:00	1312	160	0	48	548	2068

Table(3-29): Data of Segment 3 for Road no.2 (morning period)

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
8:30 - 8:45	1240	84	8	52	804	2188
8:45 - 9:00	1200	96	8	36	768	2108
9:00 - 9:15	1280	80	12	28	756	2156
9:15 - 9:30	1324	152	8	112	804	2400
9:30 - 9:45	1460	120	20	80	792	2472
9:45 - 10:00	1408	132	16	68	764	2388
10:00 - 10:15	1512	160	20	84	772	2548
10:15 - 10:30	1580	172	8	128	800	2688

Table(3-30): Data of Segment 3 for Road no.2 (evening period)

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
4:00-4:15	1200	116	0	84	940	2340
4:15-4:30	1480	152	0	92	1136	2860
4:30-4:45	1520	132	4	80	1056	2792
4:45-5:00	1428	124	4	48	1112	2716
5:00-5:15	1372	120	0	76	1164	2732
5:15-5:30	1612	116	4	72	1260	3064
5:30-5:45	1560	100	4	88	1200	2952
5:45-6:00	1536	108	0	36	1212	2880

Tables (3-31) to (3-36) show the traffic flow data for Segments 4, 5, and 6, where these sections are opposite to the direction of Segments 1, 2, and 3.

Table(3-31): Data of Segment 4 for Road no.2 (morning period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
8:30 - 8:45	764	120	8	40	356	1288
8:45 - 9:00	772	92	4	28	348	1244
9:00 - 9:15	800	80	12	36	376	1304
9:15 - 9:30	816	100	8	40	392	1356
9:30 - 9:45	840	88	16	44	412	1400
9:45 - 10:00	844	80	12	56	392	1384
10:00 - 10:15	908	132	20	68	420	1548
10:15 - 10:30	936	112	12	76	452	1588

Table(3-32): Data of Segment 4 for Road no.2 (evening period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
4:00-4:15	712	92	8	28	396	1236
4:15-4:30	924	132	4	16	356	1432
4:30-4:45	740	112	4	20	356	1232
4:45-5:00	764	92	4	28	396	1284
5:00-5:15	800	100	0	24	320	1244
5:15-5:30	840	120	8	44	340	1352
5:30-5:45	784	136	4	40	332	1296
5:45-6:00	720	80	8	36	360	1204

Table(3-33): Data of Segment 5 for Road no.2 (morning period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
8:30 - 8:45	1260	216	20	100	272	1868
8:45 - 9:00	1332	196	24	112	364	2028
9:00 - 9:15	1136	168	8	88	360	1760
9:15 - 9:30	1088	196	40	80	320	1724
9:30 - 9:45	1244	140	60	116	352	1912
9:45 - 10:00	848	140	40	84	256	1368
10:00 - 10:15	1052	180	36	120	296	1684
10:15 - 10:30	1092	160	24	76	372	1724

Table(3-34): Data of Segment 5 for Road no.2 (evening period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
4:00-4:15	1016	104	0	48	372	1540
4:15-4:30	952	100	8	36	356	1452
4:30-4:45	960	108	4	68	340	1480
4:45-5:00	1080	132	4	52	444	1712
5:00-5:15	1040	96	0	40	340	1516
5:15-5:30	1052	128	8	36	360	1584
5:30-5:45	1112	144	16	44	352	1668
5:45-6:00	916	112	8	40	420	1496

Table(3-35): Data of Segment 6 for Road no.2 (morning period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
8:30 - 8:45	952	68	0	28	132	1180
8:45 - 9:00	712	44	4	40	160	960
9:00 - 9:15	784	56	8	44	144	1036
9:15 - 9:30	848	48	12	24	160	1092
9:30 - 9:45	828	52	0	64	196	1140
9:45 - 10:00	824	40	0	40	176	1080
10:00 - 10:15	916	52	8	52	288	1316
10:15 - 10:30	784	28	4	60	224	1100

Table(3-36): Data of Segment 6 for Road no.2 (evening period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
4:00-4:15	912	44	8	36	364	1364
4:15-4:30	808	52	4	28	300	1192
4:30-4:45	772	56	8	40	388	1264
4:45-5:00	784	36	0	28	320	1168
5:00-5:15	860	40	4	36	364	1304
5:15-5:30	828	28	8	28	356	1248
5:30-5:45	812	36	4	44	380	1276
5:45-6:00	792	48	12	32	356	1240

3.8.1.8 Road No 3 (Al-Iskan Street)

This road has three lanes in each direction, it passes through Al-Safeena Roundabout, it is considered one of the congestion streets especially in the evening period because it contains doctors' clinics, this street, as shown in Figure(3-14), consists of two segments as indicated in Figure (3-15). The street was divided into two segments, Segment no. (1) is in the direction of the Al-Safeena roundabout and the second segment is in the opposite direction. Traffic flow data for the two segments are indicated in Tables(3-37) to (3-40).

Figure(3-14): Al-Iskan Street.

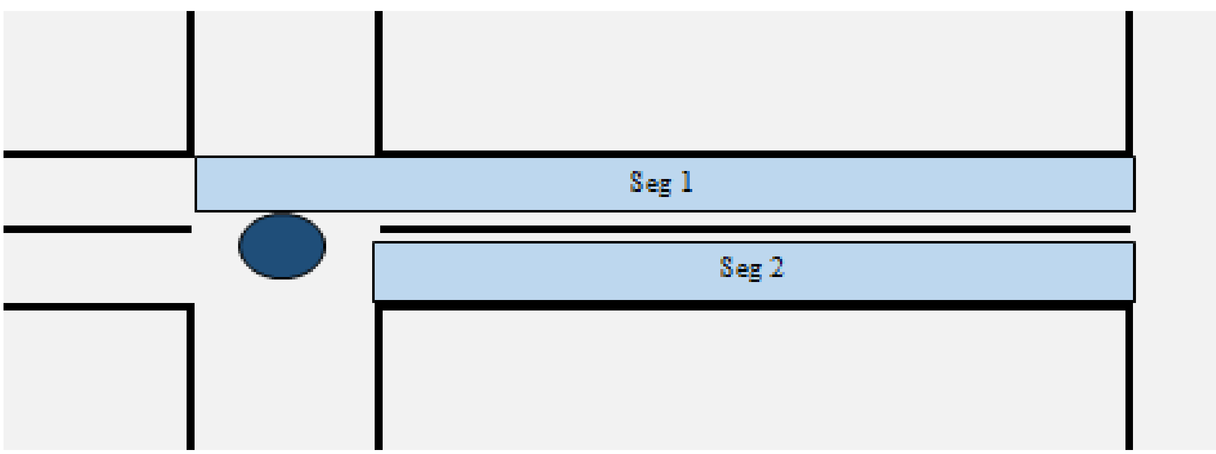


Figure (3-15): Segments of Road no.3 (Al-Iskan Street) .

Table(3-37): Data of Segment 1 for Road no.3 (morning period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
8:30 - 8:45	1024	28	40	72	392	1556
8:45 - 9:00	832	16	32	80	372	1332
9:00 - 9:15	812	36	28	52	348	1276
9:15 - 9:30	784	36	20	44	356	1240
9:30 - 9:45	1040	40	24	80	392	1576
9:45 - 10:00	924	20	28	68	360	1400
10:00 - 10:15	824	24	36	56	344	1284
10:15 - 10:30	868	20	36	88	364	1376

Table(3-38): Data of Segment 1 for Road no.3 (evening period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
4:00-4:15	1644	36	24	36	352	2092
4:15-4:30	1696	40	12	28	344	2120
4:30-4:45	1656	48	16	52	392	2164
4:45-5:00	1732	52	36	44	424	2288
5:00-5:15	1924	32	12	24	376	2368
5:15-5:30	1728	44	20	36	340	2168
5:30-5:45	1692	40	28	44	388	2192
5:45-6:00	1704	28	40	28	408	2208

Table(3-39): Data of Segment 2 for Road no.3 (morning period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
8:30 - 8:45	788	20	12	48	340	1208
8:45 - 9:00	832	28	12	44	392	1308
9:00 - 9:15	780	36	20	60	348	1244
9:15 - 9:30	816	40	16	44	360	1276
9:30 - 9:45	1092	48	8	60	392	1600
9:45 - 10:00	1076	36	8	68	384	1572
10:00 - 10:15	1012	28	16	80	360	1496
10:15 - 10:30	1064	28	12	64	352	1520

Table(3-40): Data of Segment 2 for Road no.3 (evening period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
4:00-4:15	1312	20	12	52	324	1720
4:15-4:30	1356	16	0	40	380	1792
4:30-4:45	1280	8	8	32	356	1684
4:45-5:00	1328	24	20	68	360	1800
5:00-5:15	1680	8	8	36	384	2116
5:15-5:30	1468	12	4	44	348	1876
5:30-5:45	1400	8	12	28	364	1812
5:45-6:00	1364	0	4	36	336	1740

3.8.1.9 Road No 4 (Ramadan Street)

It is considered one of the important streets in the city where this road suffers from traffic congestion. The number of lanes for each direction is 3 lanes, it contains two footbridges. This street starts from at Al-Dareeba intersection and it leads to the Al-Hur district of the city, as well as to the University of Karbala and many government institutions, this street, as shown in Figure(3-16), consists of two segments as indicated in Figure (3-17).

Figure(3-16): Ramadan Street.

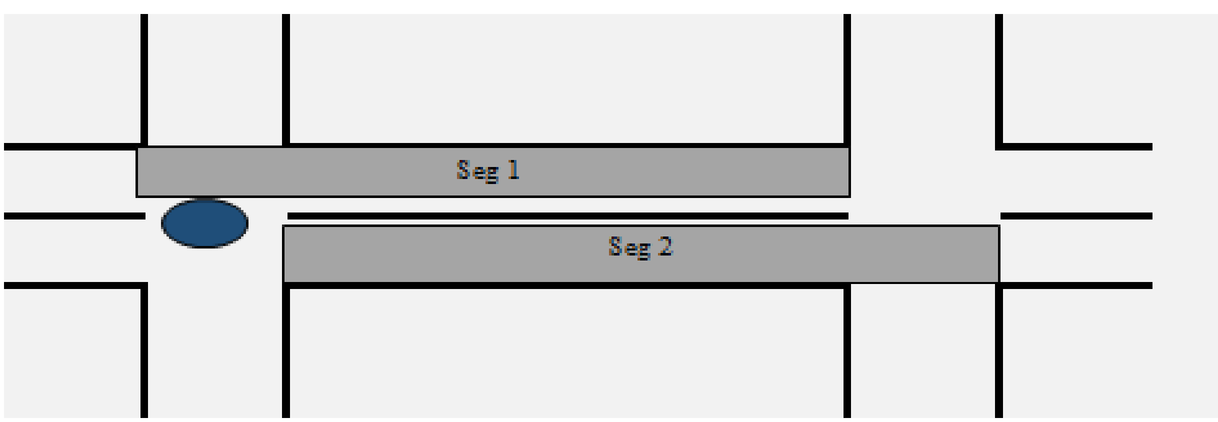


Figure (3-17): Segments of Road no.4(Ramadan Street)

The traffic volumes of Ramadan street were calculated on Tuesday (2 -2 -2021), using one camera and the volumes were taken for two hours for the morning and evening peak. These data are indicated in Tables(3-41) to (3-44) .

Table(3-41): Data of Segment 1 for Road no.4 (morning period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
8:30 - 8:45	1096	200	4	152	312	1764
8:45 - 9:00	992	180	8	144	264	1588
9:00 - 9:15	988	148	8	140	332	1616
9:15 - 9:30	988	188	4	144	404	1728
9:30 - 9:45	1236	220	0	160	444	2060
9:45 - 10:00	1000	140	16	180	452	1788
10:00 - 10:15	1448	228	8	148	420	2252
10:15 - 10:30	1416	224	8	152	380	2180

Table(3-42): Data of Segment 1 for Road no.4 (evening period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
4:00-4:15	1952	132	24	52	792	2952
4:15-4:30	1924	160	8	88	748	2928
4:30-4:45	2008	152	0	68	764	2992
4:45-5:00	2080	180	12	80	780	3132
5:00-5:15	2036	136	8	44	788	3012
5:15-5:30	1992	180	20	92	820	3104
5:30-5:45	2044	168	16	76	836	3140
5:45-6:00	2068	184	8	84	840	3184

Table(3-43): Data of Segment 2 for Road no.4 (morning period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
8:30 - 8:45	1728	200	0	156	592	2676
8:45 - 9:00	1620	212	12	140	576	2560
9:00 - 9:15	1512	196	0	208	588	2504
9:15 - 9:30	1524	204	4	192	628	2552
9:30 - 9:45	1780	216	4	120	732	2852
9:45 - 10:00	1656	180	4	204	696	2740
10:00 - 10:15	1640	232	0	144	832	2848
10:15 - 10:30	1636	140	4	232	572	2584

Table(3-44): Data of Segment 2 for Road no.4 (evening period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
4:00-4:15	1612	152	8	104	752	2628
4:15-4:30	1660	120	0	84	716	2580
4:30-4:45	1600	160	4	100	744	2608
4:45-5:00	1628	180	12	88	772	2680
5:00-5:15	1584	172	8	80	804	2648
5:15-5:30	1600	128	0	92	792	2612
5:30-5:45	1532	148	12	108	784	2584
5:45-6:00	1464	132	0	96	820	2512

Because of the importance of this street and the continuous traffic congestion, the traffic volumes were calculated in a period when the traffic congestion was low and the calculation was done at (5:20)AM in the morning and the calculation was within an hour and 15 minutes and the results appear in Tables (3-45) and (3-46).

Table(3-45): Data of Segment 1 for Road no.4 (morning period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
5:20-5:35	196	76	4	68	120	464
5:35-5:50	220	72	40	92	96	520
5:50-6:05	324	112	4	84	132	656
6:05-6:20	192	128	8	76	120	524
6:20-6:35	260	104	12	104	148	628

Table(3-46): Data of Segment 2 for Road no.4 (morning period).

Time	PC	M.B	B	HV	MT	Flow(veh/hr)
5:20-5:35	316	84	0	104	308	812
5:35-5:50	448	128	0	120	332	1028
5:50-6:05	480	108	8	72	576	1244
6:05-6:20	588	152	8	136	504	1388
6:20-6:35	644	100	12	96	556	1408

3.9 Pollution Data

Transportation caused by the movement of vehicles, especially cars, that invaded cities in an unprecedented way throughout history, polluting the city's environment in terms of air pollution and noise. The smoke from car exhaust leads to an imbalance of the components of the atmosphere near the earth's surface, where the percentage of carbon dioxide gas increases, where Pollution levels vary in time and place in the same city, so the level of air pollution is higher in the city center and at main streets and intersections according to the density of vehicle traffic, and it also rises at specific times of the day, which are the times of the people going to work and returning from it, and its height increases during workdays over days Holidays.

Due to the effect of vehicle movement on environmental pollution, gas emissions (CO and CO2) were calculated using (GASMET DX4040) device, The Gasmet DX4040 is capable of sub-ppm detection without using sorbent traps for sample pre-concentration, which guarantees fast response times. Zero calibration with clean air or nitrogen is the only calibration required, carrier gases, special test gases, or other consumables are not needed. The suggested air quality specification for EPA (2009) Environmental Ministry as **(Al-Anbari et al., 2020):**

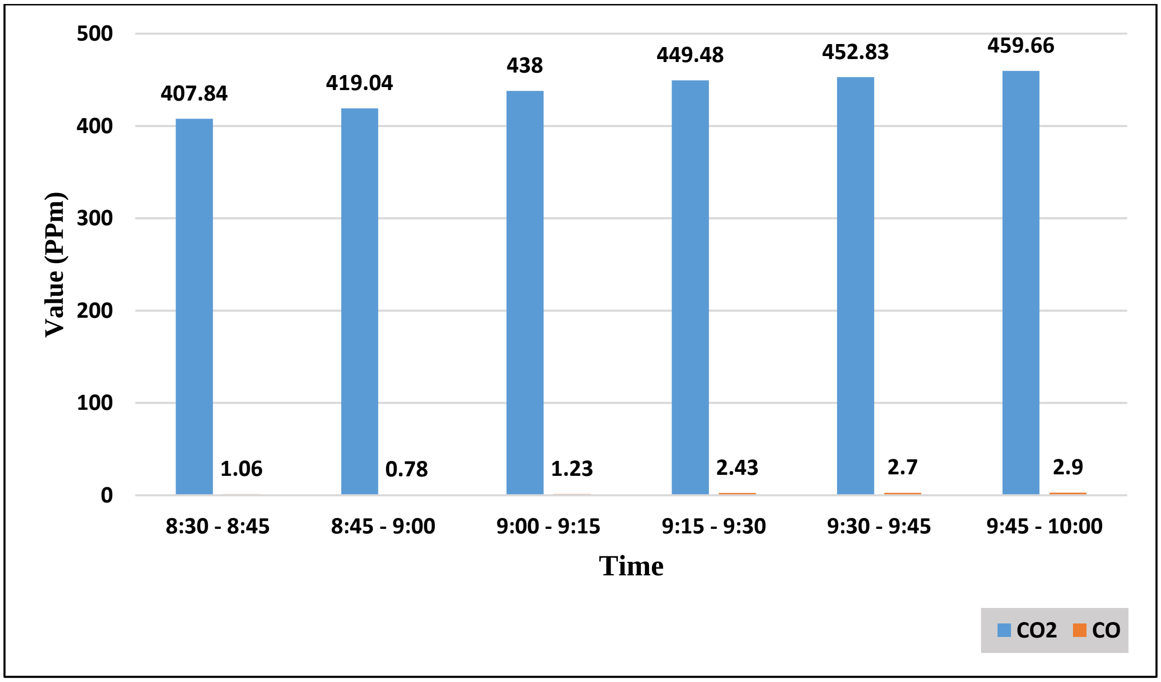
CO (Iraqi suggested limit = 35 ppm)

CO2 (Iraqi suggested limit =300 ppm)

Gas emission measurement was performed for the selected intersections during the morning peak, the Pollution data for the (Al-Dhareeeba, Sayed Jawda, Central Al-Hussein, saif saad) intersection and Ramadan Street as illustrated in Figures (3-18),(3-19),(3-20),(3-21),(3-22)and (3-23)

1. Al- Dhareeba Intersection

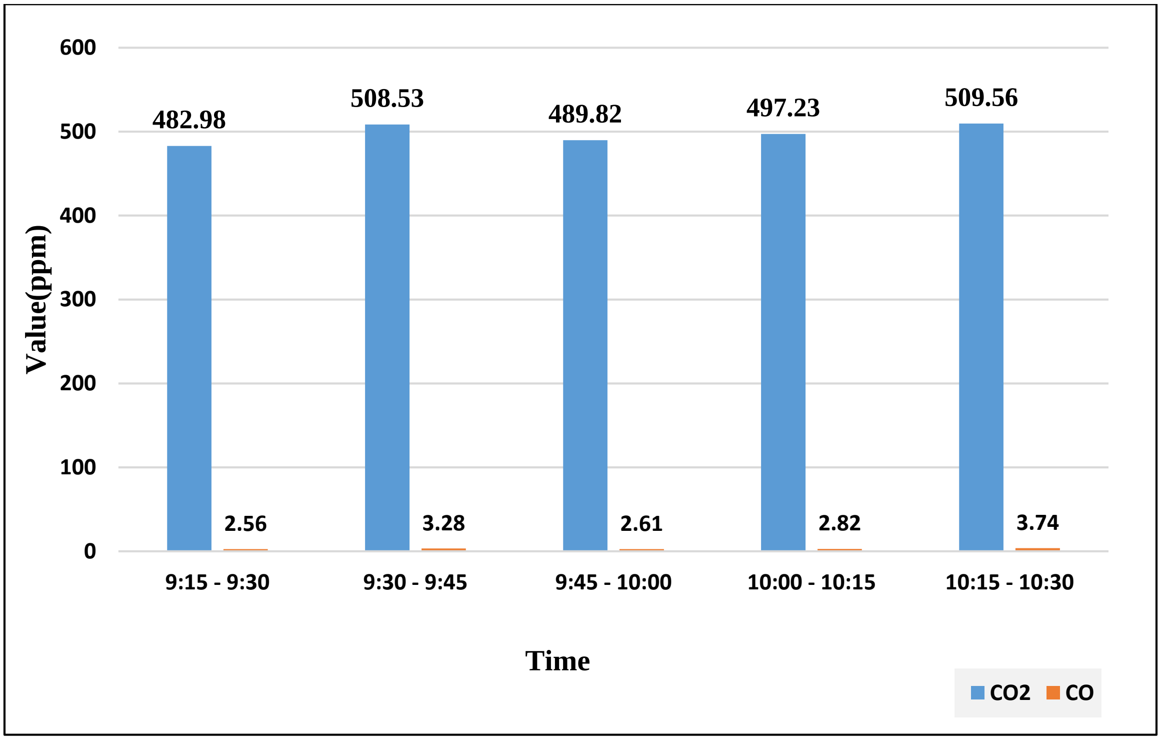
The gas emissions rates were calculated for the Al-Dhareeba intersection for every 15 minutes) for one hour and 30 minutes. Figure(3-18) demonstrates the values (CO2 and CO) for intersection, where it was observed that some of them are within the permissible limits, whereas others have higher values than the proposed specifications.



Figure(3-18): CO_2, CO values for Al-Dhareeba Intersection.

2. Sayed Jawda Intersection

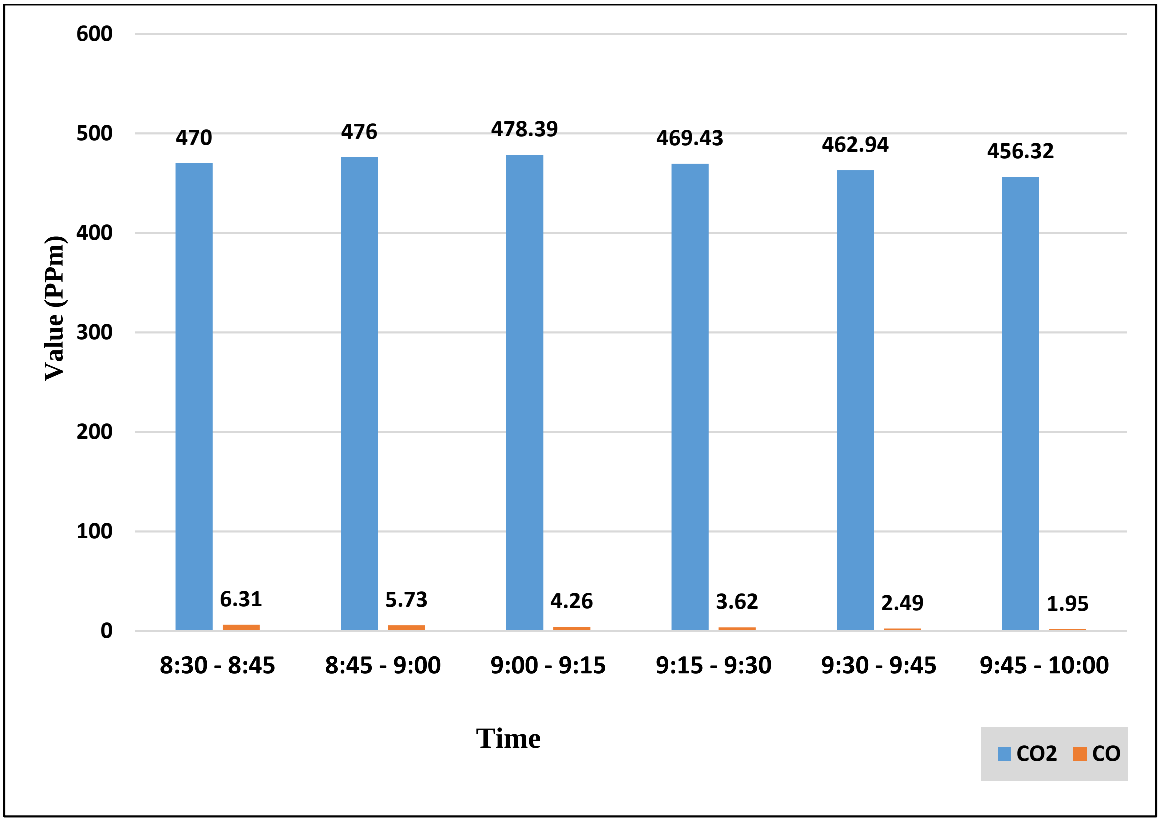
Figure(3-19) displays the results of gas emissions (CO, CO2) for the Sayed Jawda intersection, as it was measured from (9:15 AM) to (10:30 AM) Where the results showed that (CO_2) has exceeded the permissible limit according to the Iraqi limits, while (CO) was within the acceptable limits.



Figure(3-19): CO_2, CO values for Sayed Jawda Intersection.

3. Central Al-Hussein Intersection

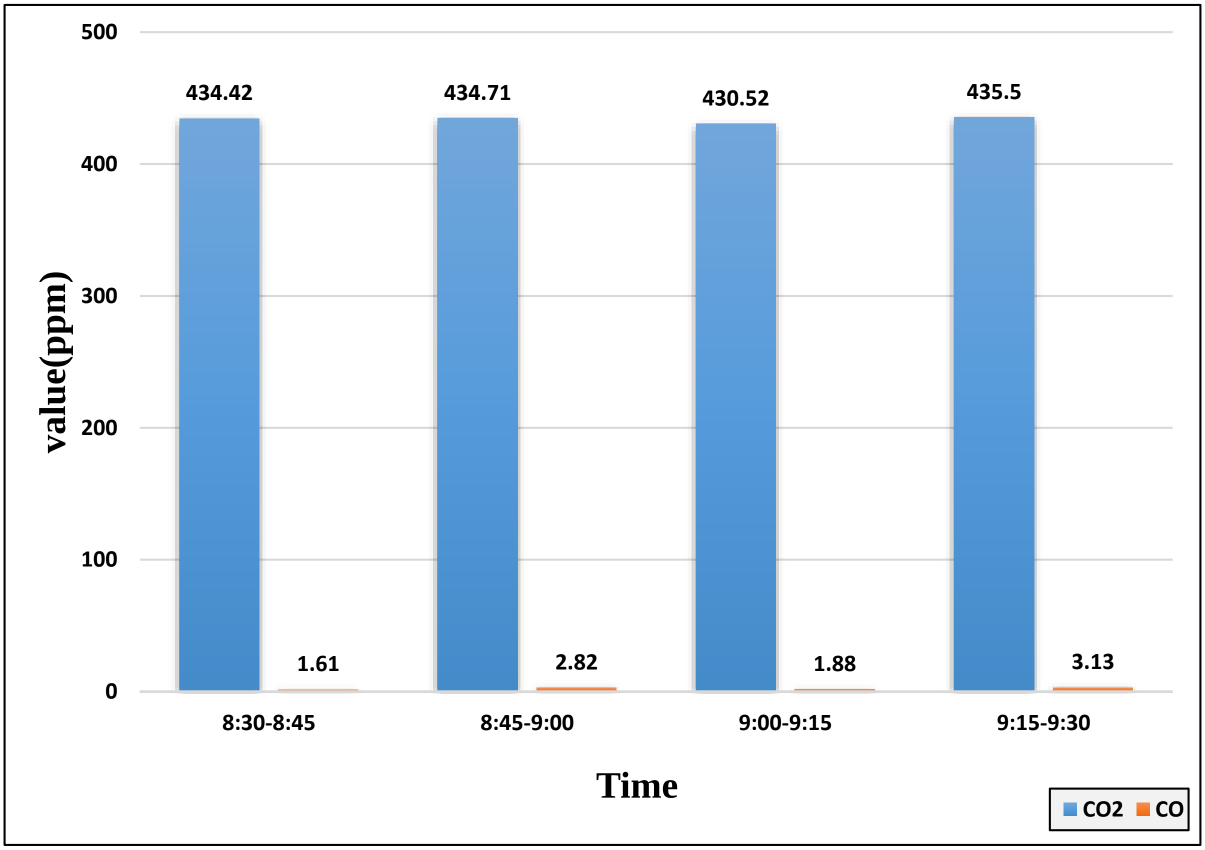
Gas emission was measured on Monday (18 -1-2021) from (8:30 AM) to (10:00 AM), where Figure(3-20) presents the results of gas emissions (CO, CO2) for the central Al-Hussein intersection. It was found that the gas emission concentration gradually increased.



Figure(3-20): CO_2, CO values for Central Al-Hussein Intersection

4.Saif Saad Intersection

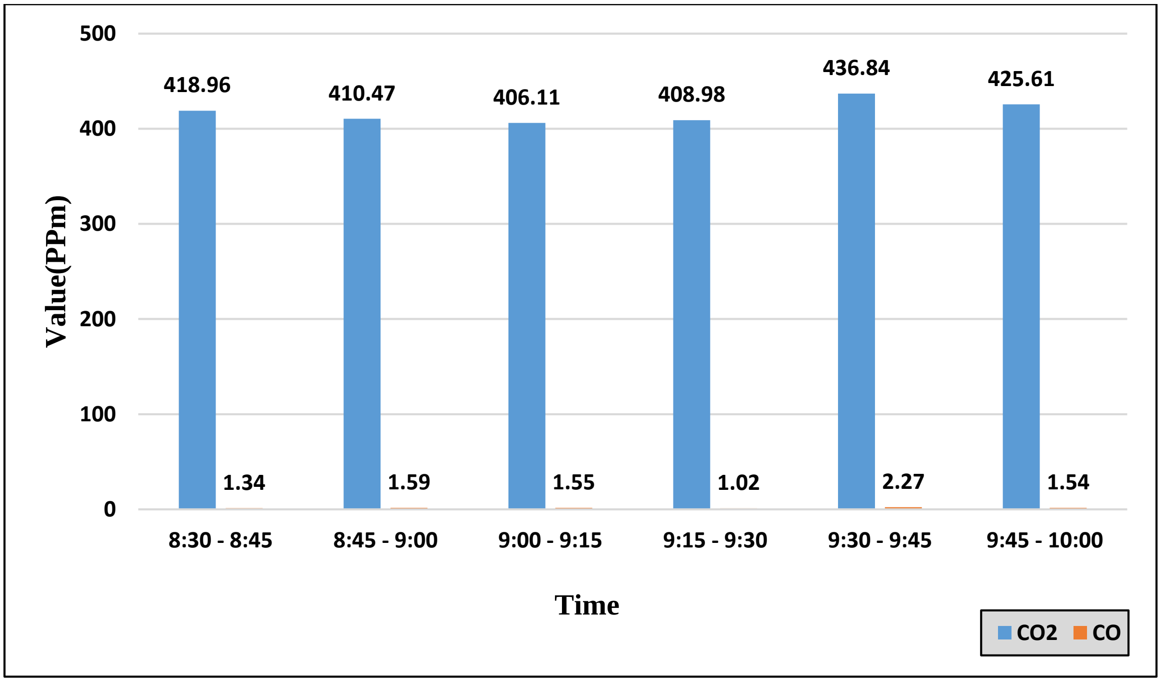
Figure(3-21) shows the results of gas emissions (CO, CO2) for the Saif Saad Intersection, this data was taken on Monday (25-1-2021), as it was measured every 15 minutes during one hour from (8:30 AM) to (9:30 AM). The results showed that (CO_2) has higher values than the specifications for air quality, while (CO) was within the acceptable limits.



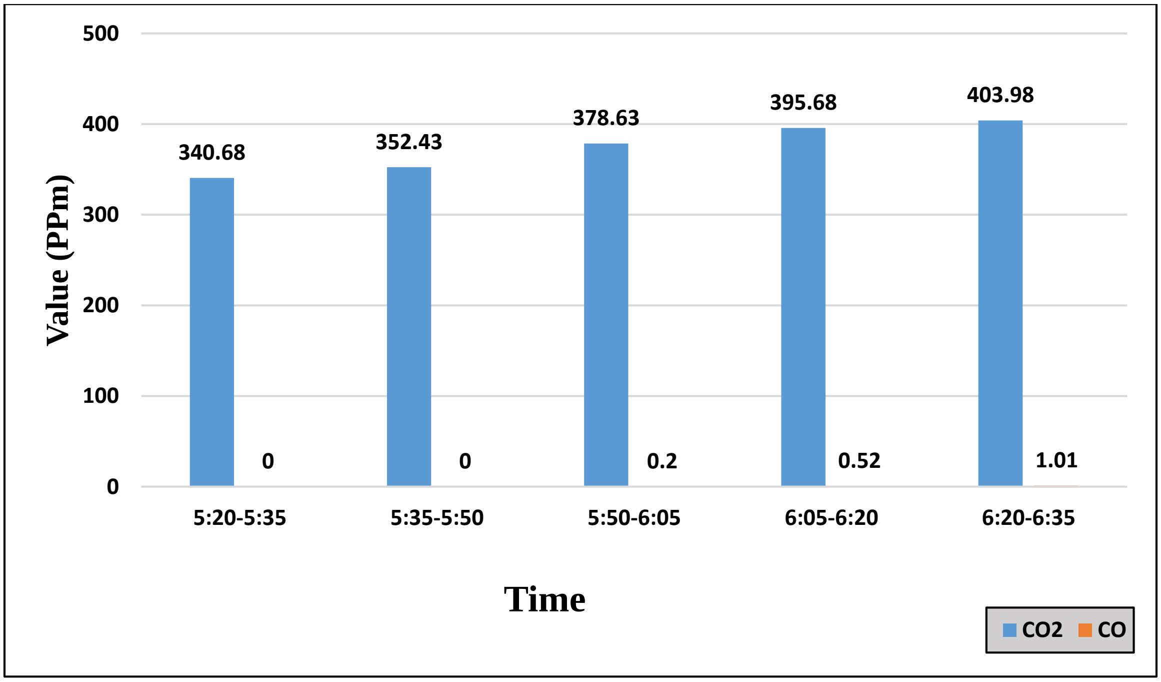
Figure(3-21): CO_2, CO values for Saif Saad Intersection.

5. Ramadan Street

Gas emission data were taken on Tuesday (2- 2 - 2021) by using (GASMET DX4040) device, where it was measured twice the first during one hour and 30 minutes from (8:30 AM) to (10:00 AM) and the second during the period from (5:20 AM) to (6:35 AM). Figures (3-22)and (3-23) display the results of gas emissions (CO, CO_2) for Ramadan Street.



Figure(3-22): CO2, CO values for Ramadan Street during the period from (8:30 AM) to (10:00 AM).



Figure(3-23): CO2, CO values for Ramadan Street during the period from (5:20 AM) to (6:35 AM).

3.10 Travel Time Data

The presence of traffic control on a street segment tends to reduce vehicle speeds below the average running speed. A speed characteristic that captures the effect of traffic control is average travel speed. This speed is computed as the length of the segment divided by the average travel time. The travel time is the time taken to traverse the street segment, inclusive of any stop-time delay. Segment length represents the distance between the boundary intersections that define the segment **(HCM, 2000).**

Table (3-47): Class for the selected roads and calculated average travel time.

Road No	Local Name	segment No	lanes/dir	Length (m)	Average Travel time (second)
1	Fatima Al-Zahraa	1	3	234	114
		2		443	57
		3		790	97
		4		811	109
		5		418	120
		6		269	51
2	Al- Abbas Street	1	3	964	128.5
		2		572	97
		3		777	80
		4		776	86.5
		5		568	95.8
		6		944	127
3	Al-Iskan Street	1	3	1430	121
		2		1380	133
4	Ramadan Street	1	3	1670	147
		2		1710	166

These data include the measuring of travel times for each internal link within the selected network, before calculating travel time, roads are divided into several segments Table(3-47) reveals the number of selected roads, segments for each road , the length of each segment and average travel time . Travel time or the time required to traverse a route between any two points of interest is a fundamental measure in transportation. Therefore, after determining the segment for each road in the study area according to the HCM 2000, using a car with a voice recorder turned on and a stopwatch to record the average travel time. by fixing the length in which the vehicle is traveling to determine congestion measures .

3.11 Free-Flow Speed Data

Free Flow Speed (FFS) is the average travel speed of the traffic stream when traffic volume is sufficiently low that drivers are not influenced by the presence of other vehicles and when intersection traffic control is not present or is sufficiently distant as to not affect speed choice **(HCM 2000).** Free-flow speed was calculated by using a Speed Gun, A radar speed gun (also a radar gun and speed gun) is a device used to measure the speed of moving vehicles. It was used to measure the speed of the vehicle during the study period. A set of values for these speeds are given in Appendix (A). The device shown in Figure (3-24).

Figure(3-24): Speed gun device.

3.12 Software used for data analysis

After collecting traffic and pollution data , GIS program was used to determine the road network for Karbala city and the TransCAD program was used to represent the data . Also, specific road network for Karbala city is analyzed and evaluated using SIDRA INTERSECTION 8.0.

3.12.1 ArcGIS 10.5

Geographic information systems (GIS) can play a major role in the management of mapped or spatial data before, during, and after traffic congestion. A geographic Information System (GIS) is a computer system for capturing, storing, querying, analyzing, and displaying geographic data **(ESRI, 2006)**. GIS represents a new paradigm for the organization of information and the design, the essential aspect of which is the use of the concept of location as the basis of structuring information systems. The advancement of GIS can be put to effective use to map and analyze road traffic situations using tools like linear referencing, spatial analysis, and query which can be easily performed, enhanced by graphical representation. Road characteristics, vehicle origin and destination, vehicular traffic congestion nature, and volume data can be integrated to enhance the analysis of road traffic situation along road corridors**(Oluwasegun,2015)**

3.12.2 SIDRA INTERSECTION 8.0

For data analysis, SIDRA software is utilized. SIDRA is a micro-analytical program that is extensively used in traffic engineering for a lane-by-lane study of different junction types. It was created by the Australian Road Research Board (ARRB) to analyze the traffic performance of signalized intersections. It calculates measures of effectiveness (MOE) such as intersection capacity, total delay, queue lengths, and Level of service using traffic models and an iterative approximation approach **(Akcelik et al .,1999)**

The following points briefly provide an overview of SIDRA **(Akcelik, 2009 b):**

• It is an advanced micro-analytical tool for the evaluation of alternative intersection designs.

• It is used as an aid for the design and evaluation of signalized intersections, pedestrian crossings, single point interchanges, roundabouts, roundabout metering, and give-way /yield sign-control.

• It can be calibrated for local conditions. The parameters used for calibration are saturation flow rate, and lane utilization factor for signalized intersections, and environmental factor, and entry/circulating flow for roundabouts.

• Analyze many design alternatives to optimize the intersection geometry, signal phasing, and timings specifying different strategies for optimization.

• Carry out a design life analysis to assess the impact of traffic growth.

• Carry out a parameter sensitivity analysis for calibration, optimization, evaluation, and geometric design purposes.

• Analyze oversaturated conditions making use of the time-dependent delay, queue length, and stop rate models.

3.12.3 TransCAD 4.5

TransCAD is the only software package that fully integrates GIS with demand modeling and logistics functionality. This makes TransCAD ideal for many types of transportation applications including:

1. Network Analysis.

2. Transportation Planning and Travel Demand Modeling.

3. Transit Analysis.

4. Traffic Assignment.

5. Vehicle Routing and Logistics.

Chapter Four

Data Analysis and Results Discussion

4.1 Introduction

This chapter explains the results of spatial analysis of road networks for the study area, and the results of data analysis will be presented. These results included determining the class of each urban street located in the selected network in addition to determining the LOS based on the calculated FFS, the average travel speed, and v/c ratio, and knowing the relationship between traffic volumes and pollution concentrations. After that, the selected intersections are evaluated using the Sidra program.

4.2 Characteristics of the road network

The assessment of the road network by using the measures developed in graph theories depending on links (edges), nodes (vertices)

From the graph in Figure (4-1):

- Number of edges (e) =91
- Number of vertices (v)= 67
- Number of separate non-connecting sub-graphs (p) = 9

Having reported these indices in chapter two, the values of these indices are:

1- α (Alpha) index

The α index is calculated using Equation (2-1) as follows:

$$\alpha = 91 - 67 + 9 / (2*67) - 5 = 0.256$$

The $\boldsymbol{\alpha}$ index compares the number of closed circuits in a network (e-v+p) against the maximum possible number of circuits which it might have (2v-5) and it is a measure of rotation (density of road network in a specific area). The value ranges between zero and unity, the index value is (0.256) which means that the connectivity is very low.

2- $\boldsymbol{\beta}$ (Beta) index

From Equation (2-2); the value of :

$$\boldsymbol{\beta} = 91/67 = 1.4$$

According to the β index, the road network was only slightly complex (a very connected network) since the index is slightly above one, as well as that which refers to the length of links, was short. Thus; $\boldsymbol{\beta}$ index differentiates simple topological structures from complicated topological structures. The current value indicates that one network.

3- γ (Gamma) index

The **(γ)** index is calculated according to Equation (2-3) as follows:

$$\boldsymbol{\gamma} = \frac{91}{3(67-2)} = 0.467$$

The **(γ)** index compares the actual number of edges in a network (e), against the maximum possible number of circuits which it might have (3(v-2)) and it is measuring the connection for the road network. The value ranges between zero and unity. A value closer to zero indicates a simpler network with fewer links where a value closer to unity indicates a better-connected network with more Links.

4. Grid Tree Pattern (GTP)

This index is a measure for identifying the pattern of the network, varying from (0) in the case of tree pattern to (1) in the case of a grid pattern. The grid-tree pattern (GTP) from Equation (2-4) :

$$\textbf{GTP index}=91- 67 +9 / ((\sqrt{67}) - 1)^2= 0.639$$

A larger GTP index implies greater connectedness for network Karbala city.

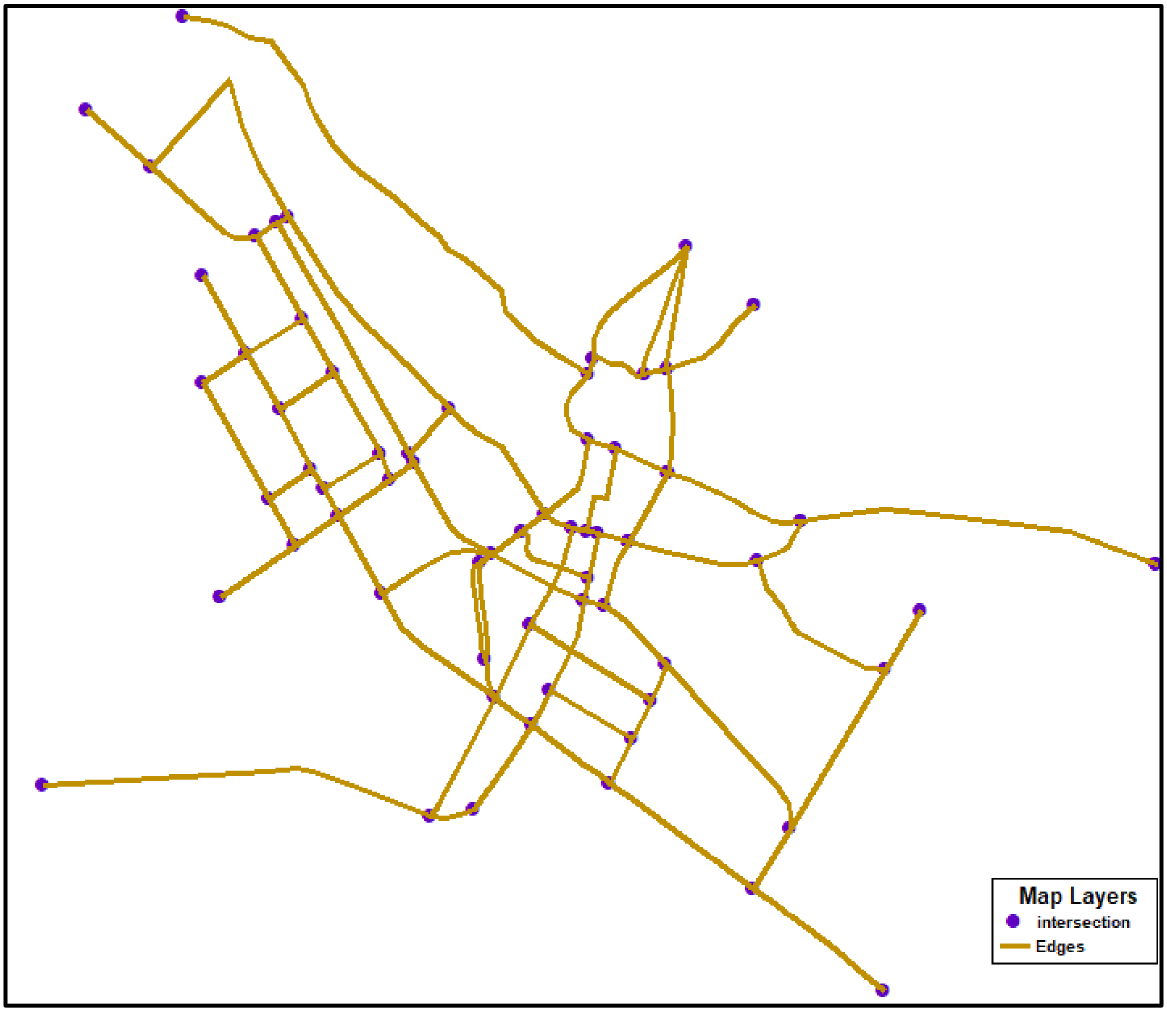


Figure (4-1): Topological form of the road network for the study area.

4.3 Peak Hour Factor

The peak hour factor (PHF) was defined as a means of quantifying the difference between a maximum 15-min flow rate and the hourly volume within the peak hour as in Equation (4-5) **(Mcshane, 2004),** After calculating the traffic volumes for the specific intersections, the peak hours during the day were selected, the peak hour was determined from (9:30) to (10:30) AM for the morning period, while for the evening period, it was from (5:00) to (6:00) PM. PHF value for morning period as shown in Tables (4-1) to (4-5) for specified intersections, respectively.

$$\textbf{PHF} = \frac{\textit{Hourly volume}}{\textit{max.rate of flow}}$$

$$\text{PHF} = \frac{\textit{Hourly volume}}{4 * \text{V15}}$$

Where: -

PHF= Peak-hour factor.

V15= Volume during the peak 15 min of the peak hour, on veh/15min.

Table (4-1): PHF Values for Al-Dhareeba intersection.

Intersection name	Approach	PHF
Al-Dhareeba	North	0.94
	South	0.93
	East	0.76
	West	0.87

Table (4-2): PHF Values for Al-Safeena intersection.

Intersection name	Approach	PHF
Al-Safeena	North	0.97
	South	0.89
	East	0.88
	West	0.91

Table (4-3): PHF Values for Al- Sayed Jawda intersection.

Intersection name	Approach	PHF
Al- Sayed Jawda	North	0.93
	South	0.94
	East	0.94
	West	0.94

Table (4-4): PHF Values for Police Central Al-Hussein intersection.

Intersection name	Approach	PHF
Police Central Al-Hussein	North	0.91
	South	0.82
	East	0.90
	West	0.91

Table (4-5): PHF Values for Saif Saad intersection.

Intersection name	Approach	PHF
Saif Saad	North	0.88
	South	0.97
	East	0.91
	West	0.90

4.4 Class of road based on FFS

According to the results of FFS obtained by the Gun-Speed instrument, the obtained speed is indicated by the following sub-sections for each road. In brief, the class for each mentioned road has been determined according to the FFS as indicated in Table (4-6). In this table, the class has been determined according to HCM 2000, the results indicate that all the roads are full into urban street classes as indicated in Table (4-6).

4.4.1 Road no.1(Fatima Al-Zahraa Street)

This road consists of six Segments: Segments 1 and 6 located between Sayed Jawda intersection and Hamza Al-Sagheer roundabout, Segments 2 and 5 located between Sayed Jawda intersection and Al-safeena roundabout, Segments 3 and 4 located between Al-Safeena roundabout and Al-Dhareeba intersection, the results of FFS for Segments as indicated in Figures (4-2) and (4-3), respectively.

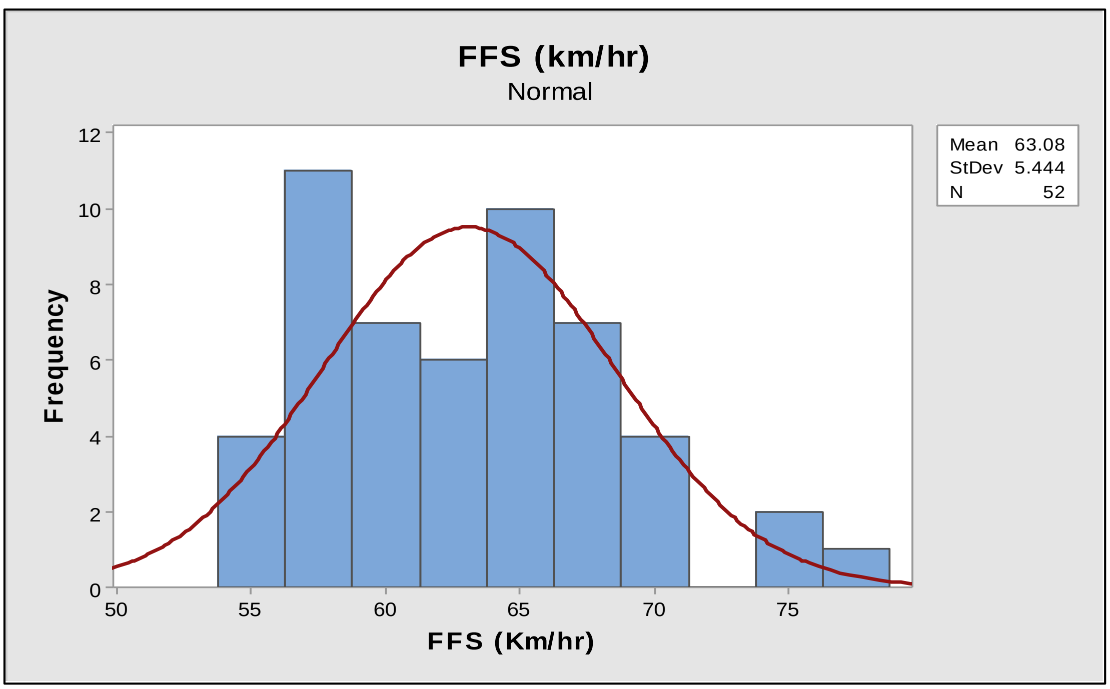


Figure (4-2): FFS for Road no.1 .

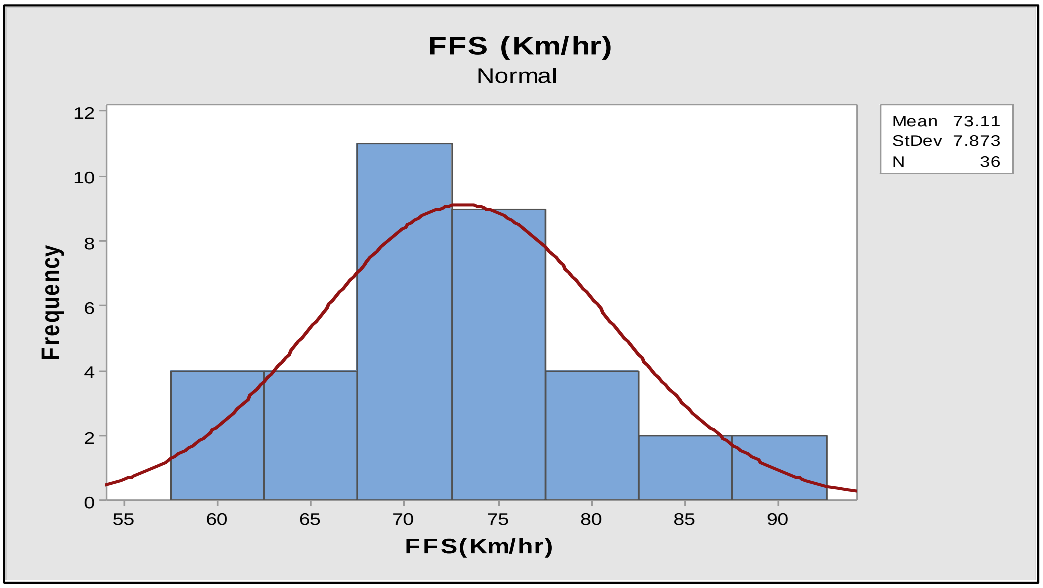


Figure (4-3): FFS for Road no.1 .

4.4.2 Road no.2 (Al-Abbas Street)

This road consists of six Segments: Segments no.1and no.6 (between Saif Saad Intersection and Police Central Al-Hussein Intersection), Segments no.2 and no.5 (between Police Central Al-Hussein Intersection and Sayed Jawda Intersection), Segments no.4 and no.5 (between Sayed Jawda intersection and roundabout), Figures (4-4), (4-5) and (4-6) reveal that the FFS for all segments.

.

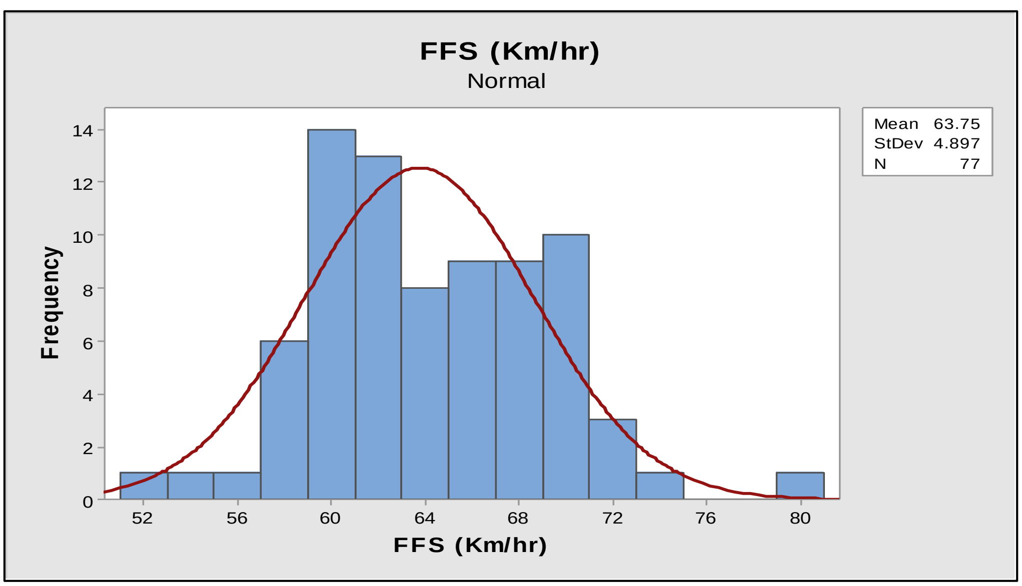


Figure (4-4): FFS for Road no.2 .

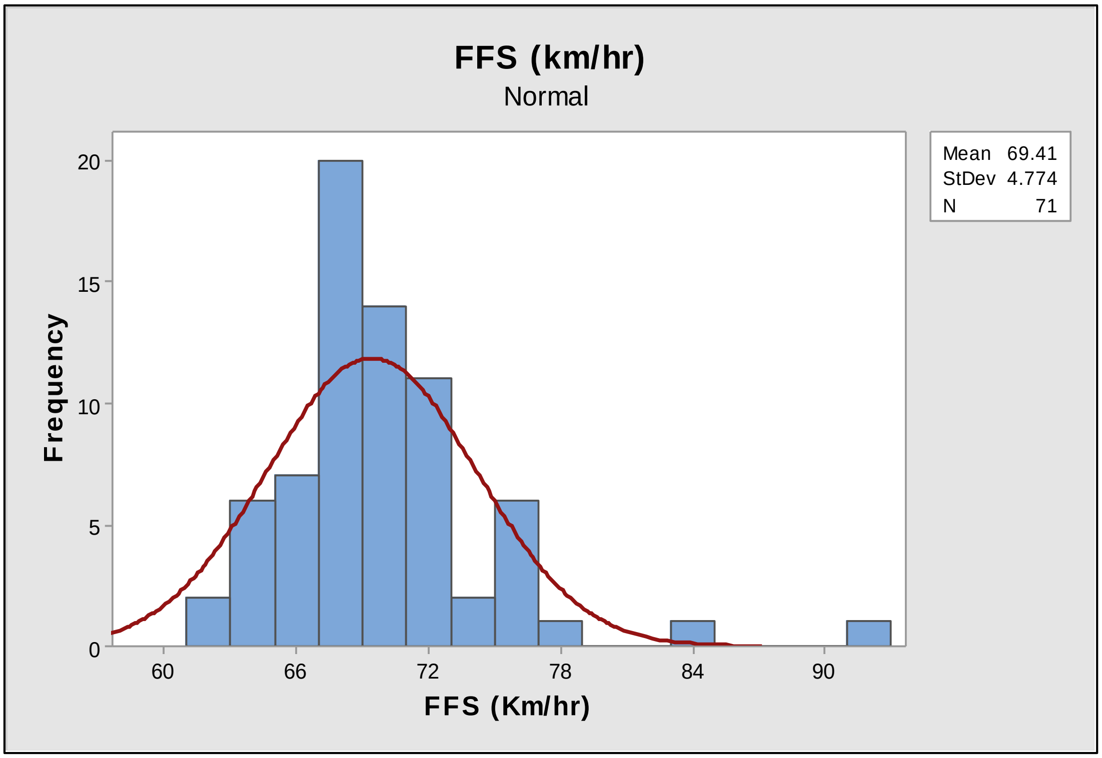


Figure (4-5): FFS for Road no.2 .

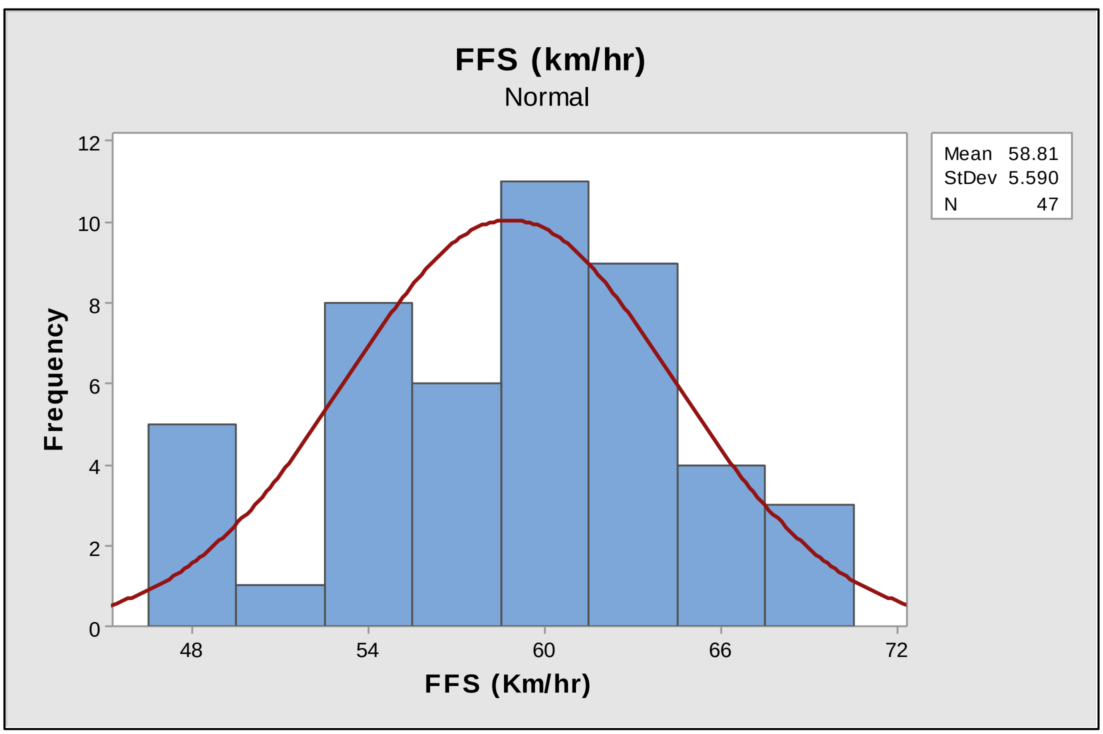


Figure (4-6): FFS for Road no.2 .

4.4.3 Road No 3 (Al-Iskan Street)

The results of FFS for the two Segments: one toward the North of the city and the second toward the South of the city as indicated in Figure (4-7).

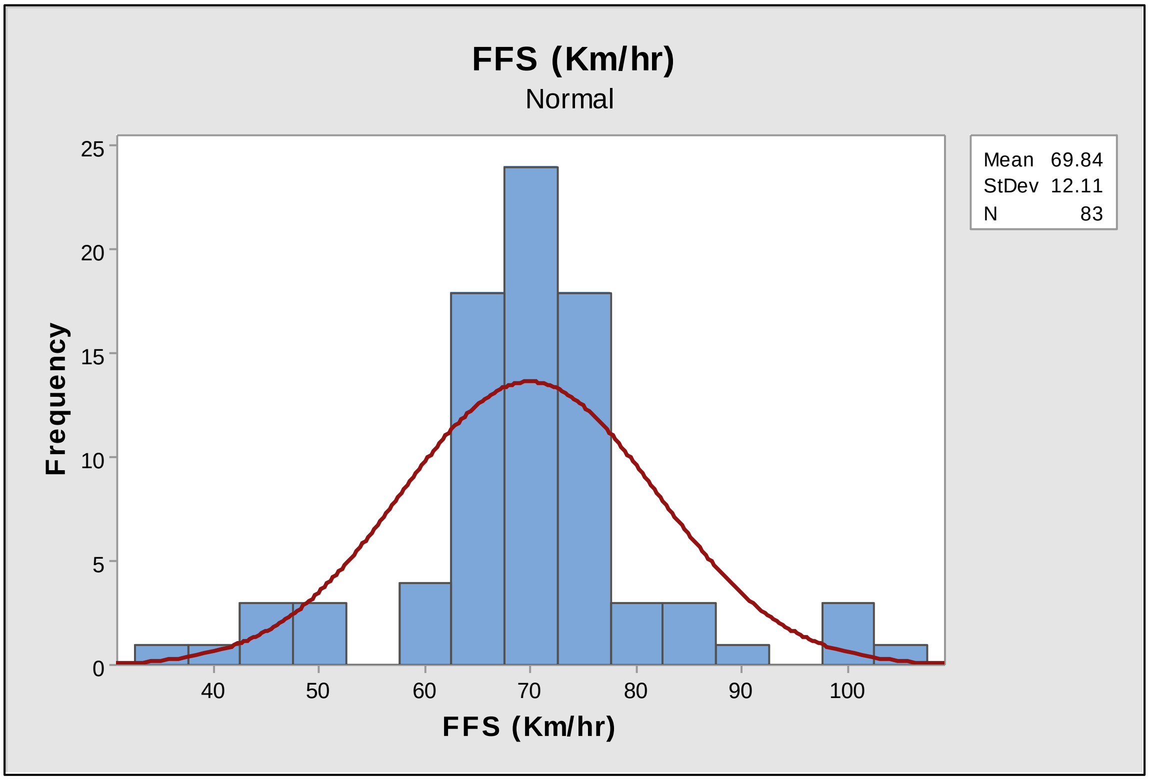


Figure (4-7): FFS for Road no.3 .

4.4.4 Road No 4 (Ramadan Street)

This road consists of two Segments: Segment no.1 which is located between the Al-Dhareeba intersection and roundabout toward the West and the second one is for the opposite direction as indicated in Figure (4-8).

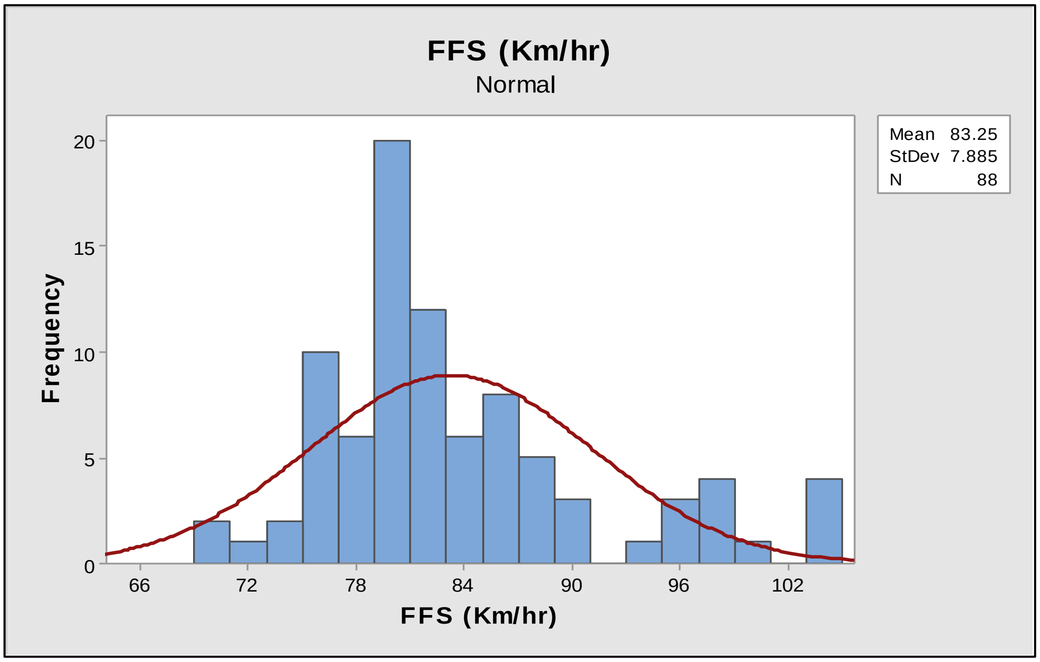


Figure (4-8): FFS for Road no.4 .

Table (4-6): Class for the selected roads according to HCM 2000.

Road no.	Segment no.	FFS	Class by FFS
1	1	63.08	II
	2	63.08	II
	3	73.11	I
	4	73.11	I
	5	63.08	II
	6	63.08	II
2	1	63.75	II
	2	69.41	II
	3	58.81	II
	4	58.81	II
	5	69.41	II
	6	63.75	II
3	1	69.84	II
	2		
4	1	83.25	I
	2		

4.5 LOS according to average travel speed

After determining the class of each section based on the free flow speed, urban streets are evaluated based on the average travel speed, as it is considered one of the basic measures of service in urban streets. It is calculated by collecting field data for travel times.

Referring to Table 2.4, the LOS for selected roads in the selected Karbala road network has been mainly evaluated according to measuring the average travel speed (average travel time) using a car with a voice recorder turned on and a stopwatch to record the average travel time.

Table (4-7): LOS based on average travel speed-HCM 2000.

Road no.	Segment no.	FFS	Class by FFS	Average speed (Km/hr)	LOS
1	1	63.08	II	7	**F**
	2	63.08	II	28	**D**
	3	73.11	I	29	**E**
	4	73.11	I	26.8	**E**
	5	63.08	II	12.5	**F**
	6	63.08	II	19	**F**
2	1	63.75	II	27	**D**
	2	69.41	II	21	**F**
	3	58.81	II	35	**C**
	4	58.81	II	32	**D**
	5	69.41	II	21	**F**
	6	63.75	II	26.8	**D**
3	1	69.84	II	42.5	**C**
	2			37.4	**C**
4	1	83.25	I	41	**C**
	2			37	**D**

Table (4-7) reveals the LOS for each segment. For Road no.1 in all segments except Segment no.2, suffering from low LOS Types (F and E) this decrease is due to the traffic congestion that prevails on this street as the main road, While Road no.2 is within a good service level, except Segments no.2 and no.5, it is within a low service level. As LOS for Road no.3 and Road no.4 of Types (C and D).

4.6 LOS based on V/C

Referring to the collected data as explained in Chapter Three, the calculated flow rate has been represented as in Figures (4-9) and (4-10) for morning and evening periods, respectively. the capacity was calculated from Table(2-5) , which was explained in chapter Two .Then, predicted LOS according to v/c as indicated in Tables (4-8) and (4-9) for the morning period. While LOS according to v/c for evening period as shown in Table (4-10).

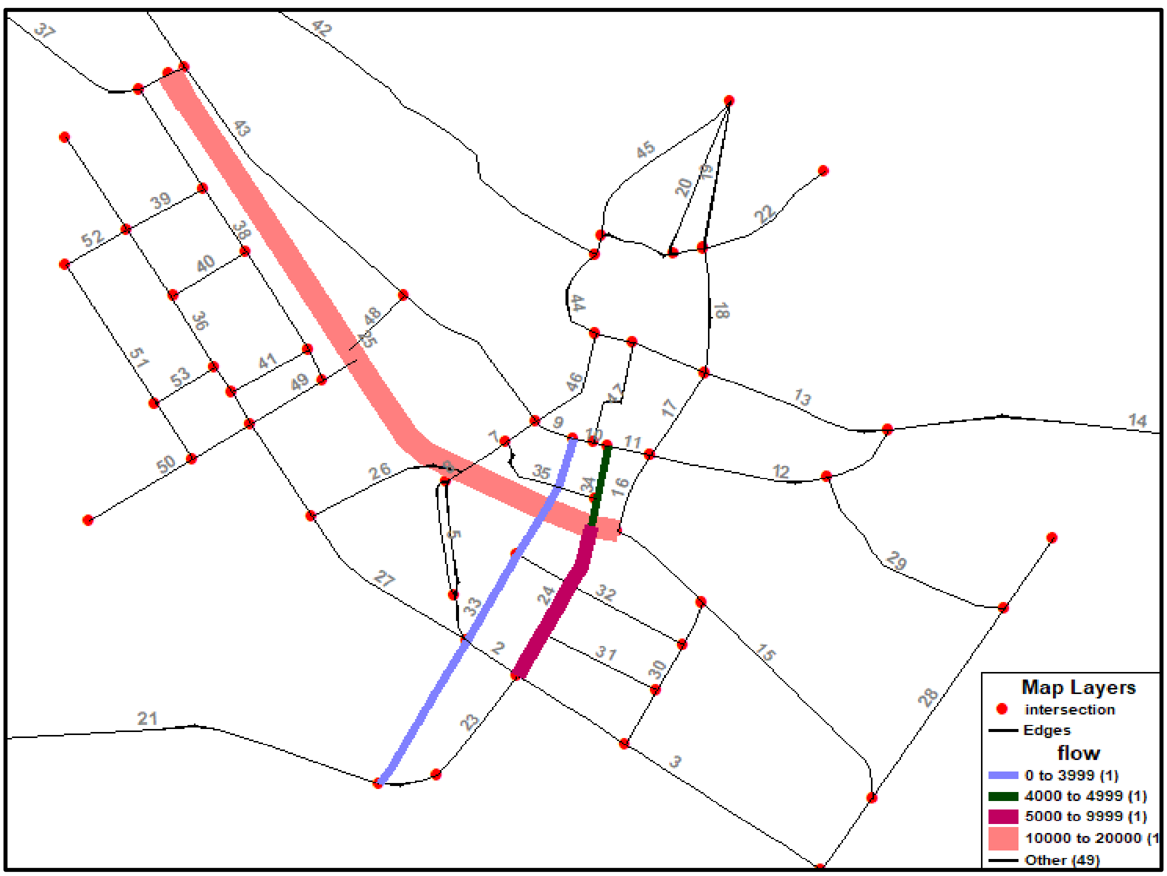


Figure (4-9): Flow map for Karbala network morning peak.

Table (4-8): LOS based on v/c adopted from HCM 2000.

Class	LOS Based on the volume-to-capacity ratio (v/c)					
	A	B	C	D	E	F
I	N/A	≥ 0.74	0.75-0.81	0.82-0.89	0.89-1.0	>1
II	N/A	N/A	≥ 0.84	0.85-0.94	0.95-1.0	>1
III	N/A	N/A	≥ 0.60	0.61-0.94	0.95-1.0	>1
IV	N/A	N/A	≥ 0.78	0.79-0.96	0.97-1.0	>1

N/A - not achievable given assumptions below.

Table (4-9): LOS for selected Segments based on v/c(for morning period).

Road no.	Segment no.	FFS	Class by FFS	Max.V(vph)	capacity	V/C	LOS
1	1	63.08	II	2092	2670	0.78	C
	2	63.08	II	1860	2670	0.7	C
	3	73.11	I	2252	3430	0.66	B
	4	73.11	I	2852	3430	0.83	D
	5	63.08	II	1068	2670	0.4	C
	6	63.08	II	2296	2670	0.86	D
2	1	63.75	II	1484	2670	0.56	C
	2	69.41	II	2860	2670	1.07	F
	3	58.81	II	2688	2670	1.01	F
	4	58.81	II	1588	2670	0.59	C
	5	69.41	II	2028	2670	0.76	C
	6	63.75	II	1316	2670	0.49	C
3	1	69.84	II	1576	2670	0.59	C
	2			1600	2670	0.6	C
4	1	83.25	I	2252	3430	0.66	B
	2			2852	3430	0.83	D

*: This means the current LOS is the best one; however, the actual one could be better than this LOS.

According to the measure of (v/c), it was found that Segments no.1, no.2, no.3, and no.5 for Road no.1 within LOS (C and B). This indicates a good level of service and stable operations while Segment no.4 and no.6 within LOS (D). This indicates a slight increase in traffic. For road no.2, (v/c <1) for all Segments except for Segments no. 2 and no.3 the ratio was greater than 1, meaning that the level of service for the two segments was of Type (F). Whereas Segments 1and 2 for Road no.3, within LOS (C) Indicates a good level of service and stable operations. For Road no.4, for Segment no.1 within LOS (B), and Segment no.2 within LOS (D).

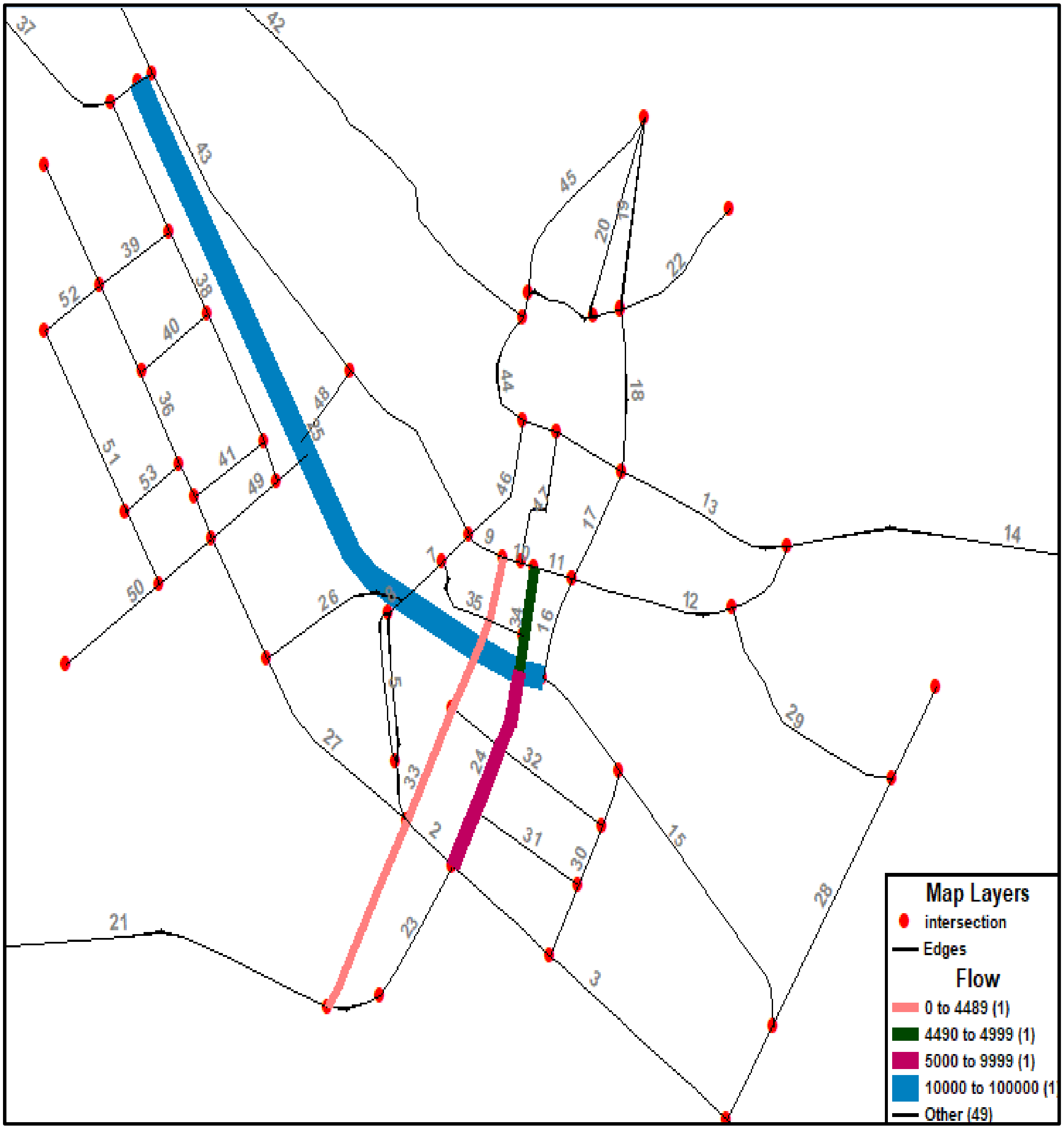


Figure (4-10): Flow map for Karbala network evening peak.

Table (4-10): LOS for selected Segments based on v/c(for evening period).

Road no.	Segment no.	FFS	Class by FFS	Max.V(vph)	capacity (veh/hr)	V/C	LOS
1	1	63.08	II	2452	2670	0.92	D
	2	63.08	II	1796	2670	0.67	C
	3	73.11	I	3184	3430	0.93	E
	4	73.11	I	2680	3430	0.78	C
	5	63.08	II	2300	2670	0.86	D
	6	63.08	II	2664	2670	0.99	E
2	1	63.75	II	1948	2670	0.73	C
	2	69.41	II	2572	2670	0.96	E
	3	58.81	II	3064	2670	1.15	F
	4	58.81	II	1432	2670	0.54	C
	5	69.41	II	1668	2670	0.62	C
	6	63.75	II	1304	2670	0.49	C
3	1	69.84	II	2368	2670	0.89	D
	2			2116	2670	0.79	C
4	1	83.25	I	3184	3430	0.93	E
	2			2680	3430	0.78	C

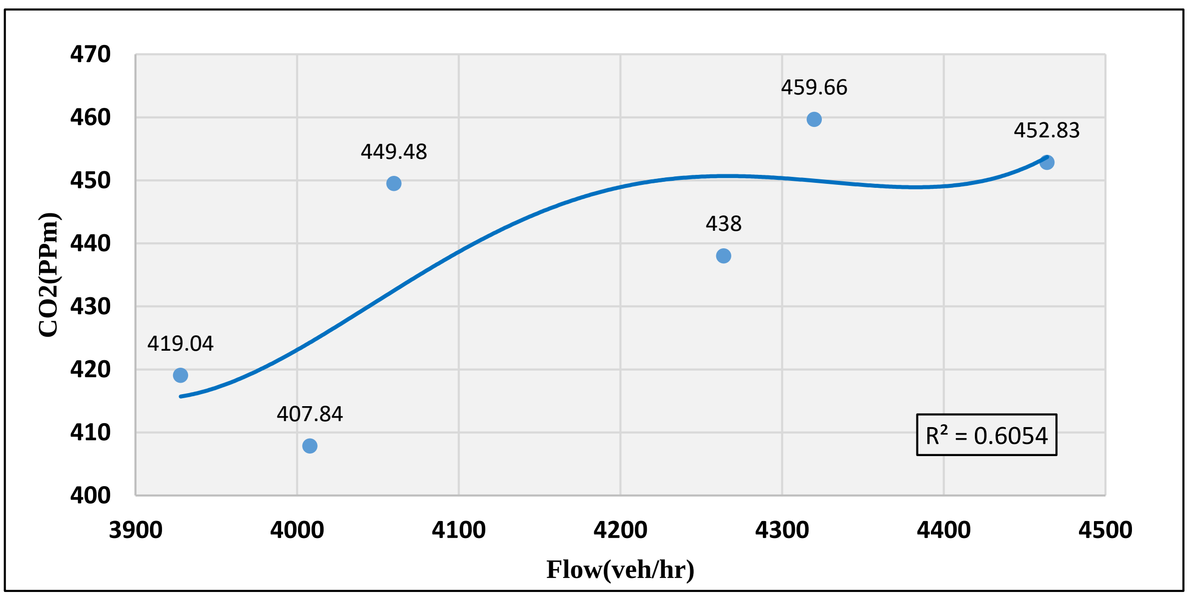
For evening period , a lot of links with (v/c<1.0) have been observed as indicated in Table (4-10).

4.7 Relationship Between Gas Pollution and Flow Rate

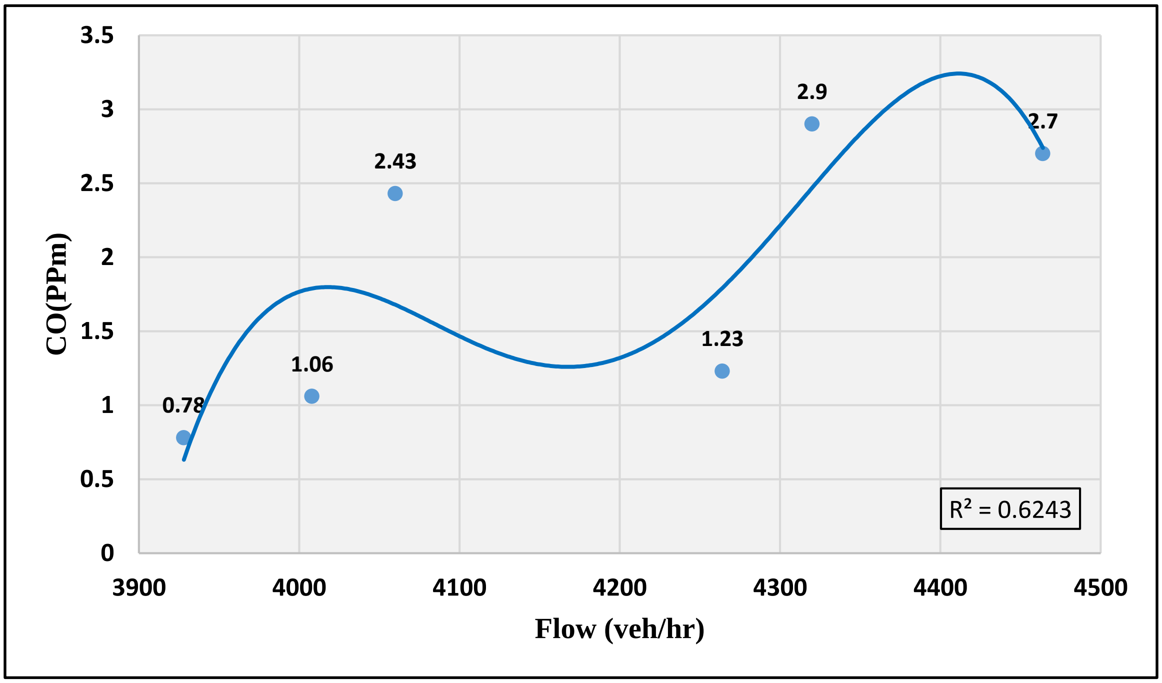
In urban areas, traffic flow is one of the main sources of air pollutants, therefore After collecting flow data and pollution data as mentioned previously, the relationship of flow and pollution gases (CO2 and CO) has been investigated as shown in Figures (4-11) to (4-22), However, these relations are approximately increasing with flow increasing.

1. AL-Dhareeba intersections

Figures (4-11) and (4-12) demonstrate the effect of flow rate on (CO_2 and CO), respectively. It was observed that there is an increase in gas emissions with the increase in traffic volumes, The increase in traffic volumes leads to an increase in the level of congestion, and thus will lead to the consumption of more fuel, all of which will lead to the emission of gas (CO_2 and CO). It was also noted that there is a slight variation in emission rates due to the effect of temperature and wind speed on the rate of pollution.



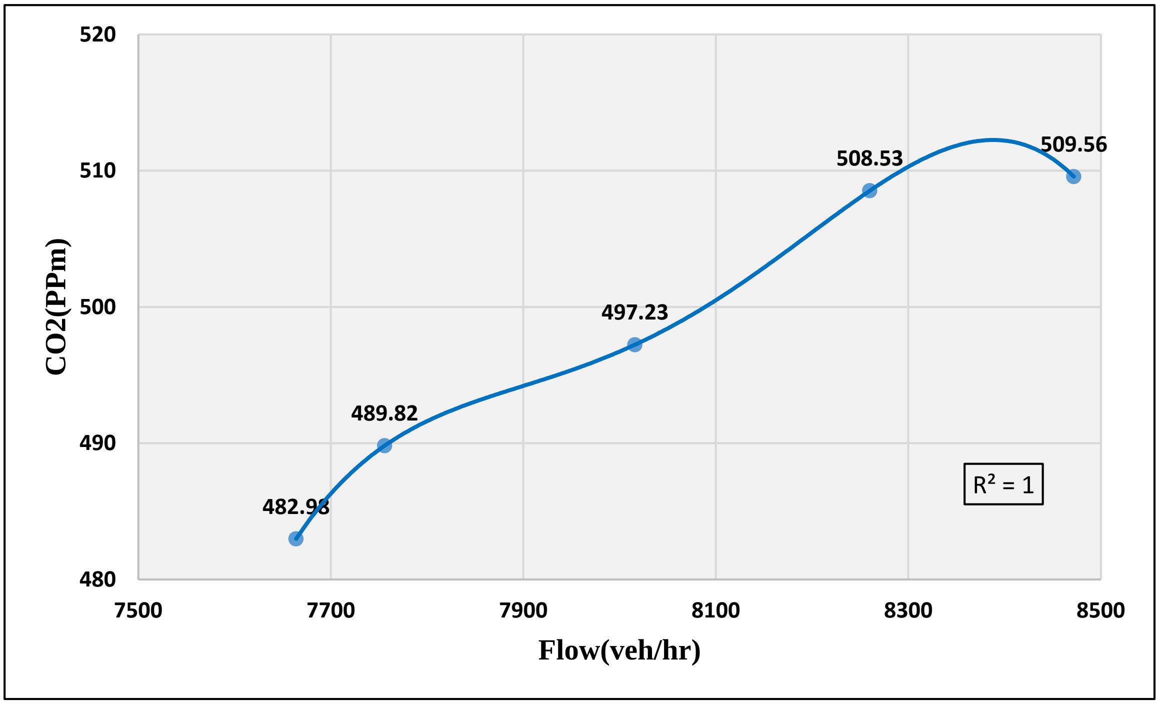
Figure(4-11): Traffic flow rate impact on CO_2 for AL-Dhareeba intersections.



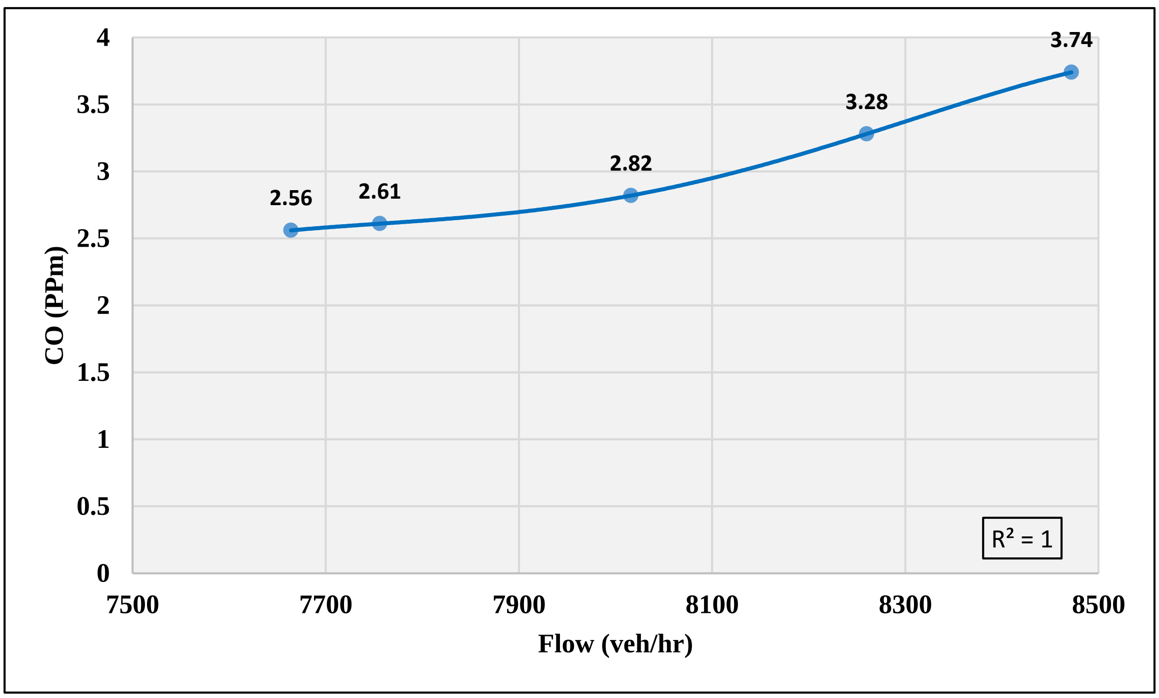
Figure(4-12): Traffic flow rate impact on CO for AL-Dhareeba intersections.

2. Sayed Jawda Intersection

Air pollution is one of the most complex environmental problems, Therefore, the traffic volumes of Sayed Jawda intersection were calculated and gas emissions were calculated at the same time. The results showed that gaseous pollutants increase with the increase in traffic flow rates at the intersection because vehicle stops and delays and frequent traffic congestion lead to a rise in pollutant emission concentrations more than the permissible limits that were mentioned in the Iraqi borders. Figure (4-13) illustrates the effect of flow rate on (CO_2) for Sayed Jawda Intersection and Figure (4-14) shows the effect of flow rate on (CO) for Sayed Jawda Intersection.



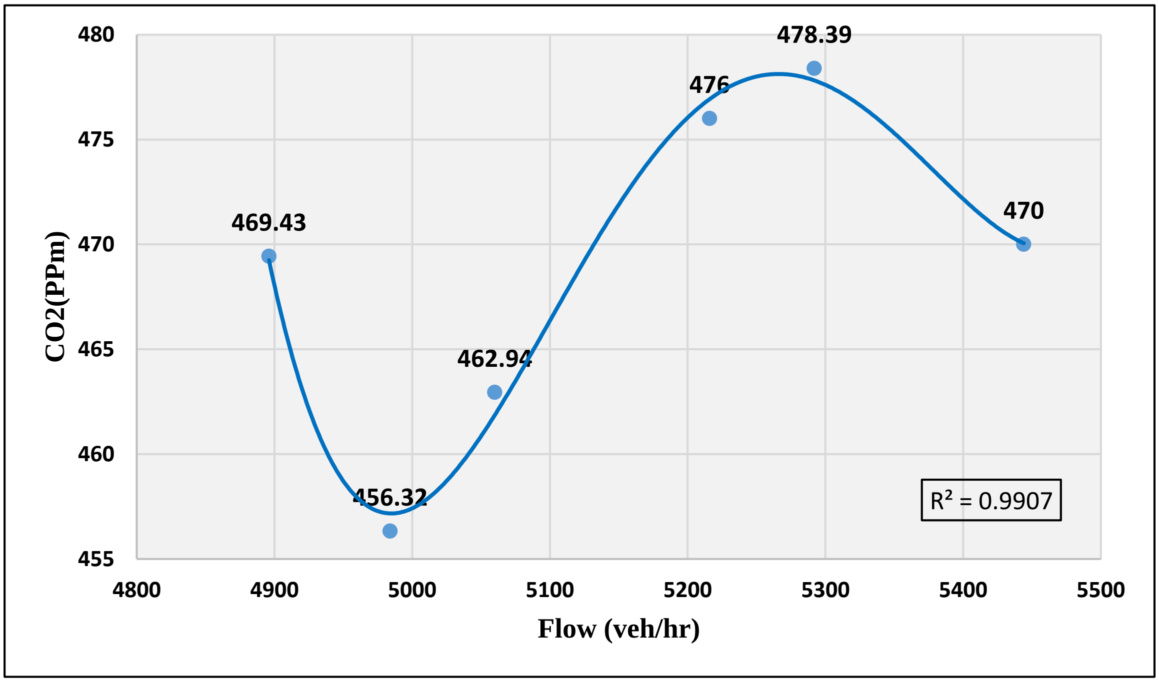
Figure(4-13): Traffic flow rate impact on CO_2 for Sayed Jawda intersections.



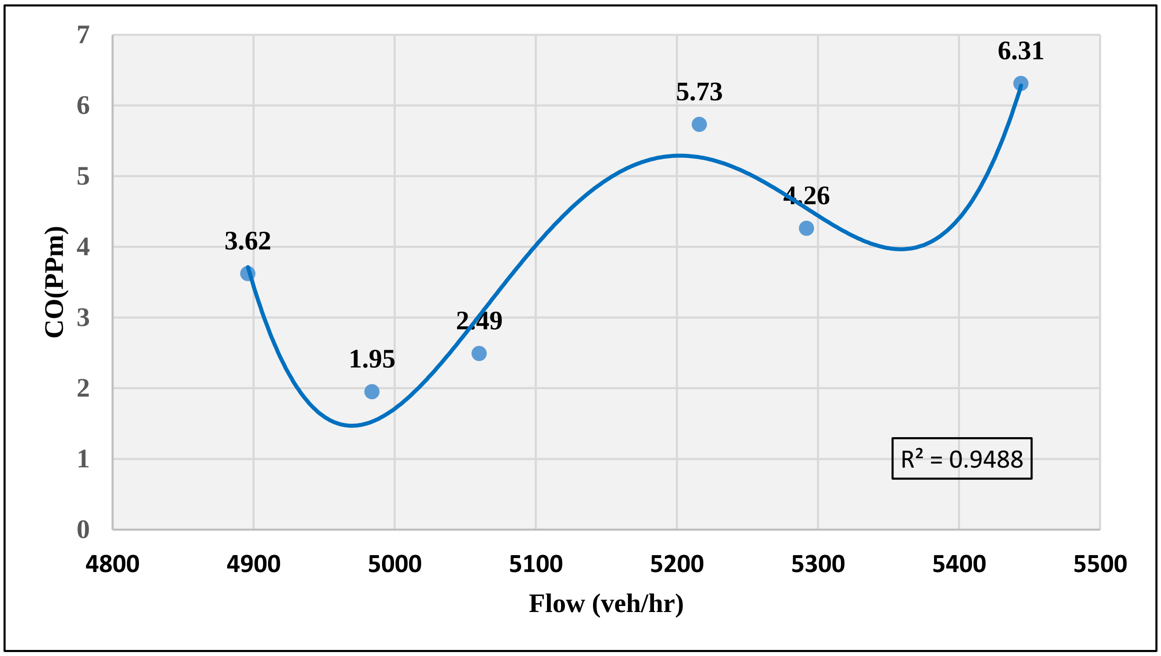
Figure(4-14): Traffic flow rate impact on CO for Sayed Jawda intersections.

3. Police Central Al-Hussein Intersection

Traffic flows have the greatest impact on the level of environmental pollution, Because of the unstable traffic movements and the sudden stop of the vehicles, where most of the vehicles operate with little efficiency and the changing weather factors all increase the gaseous pollutants, it was observed that gas(CO_2) increased with an increase in the traffic flow rate for a gas that exceeded the permissible limits, while the gas (CO) was within the permissible limits. Figures (4-15) and (4-16) show the effect of flow rate on (CO2 and CO) for Police Central Al-Hussein Intersection.



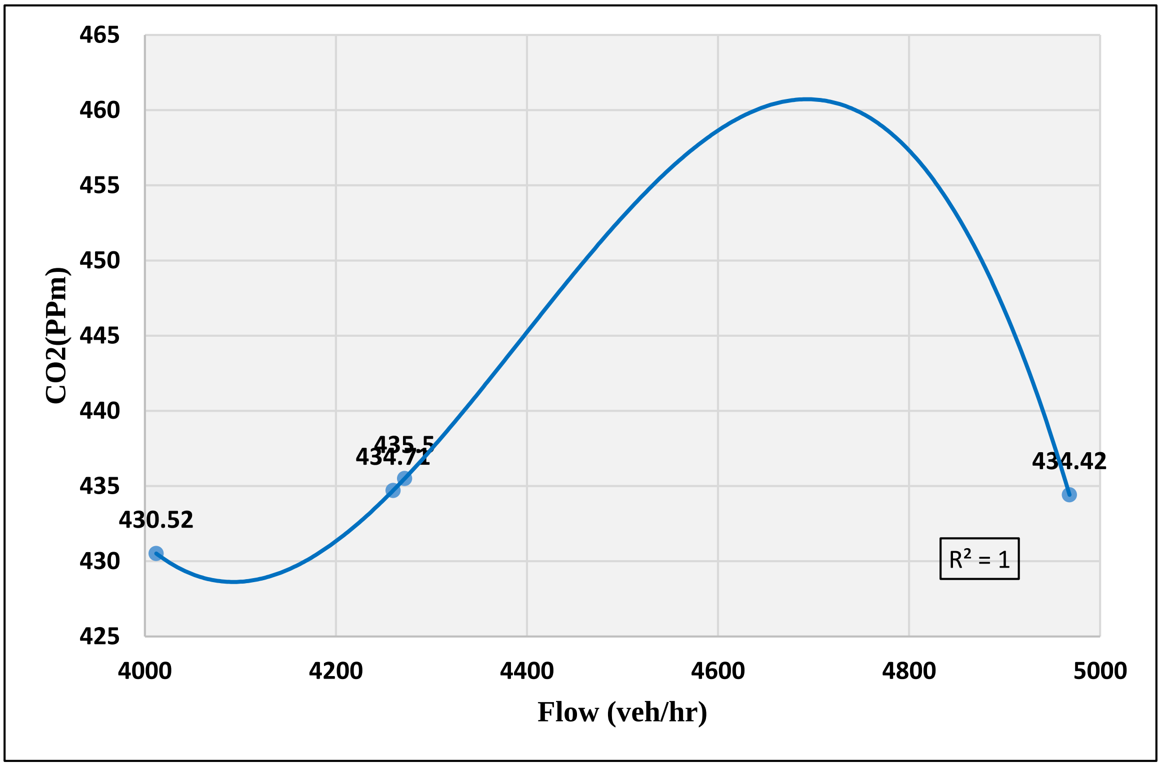
Figure(4-15): Traffic flow rate impact on CO2 for Police Central AlHussein intersections.



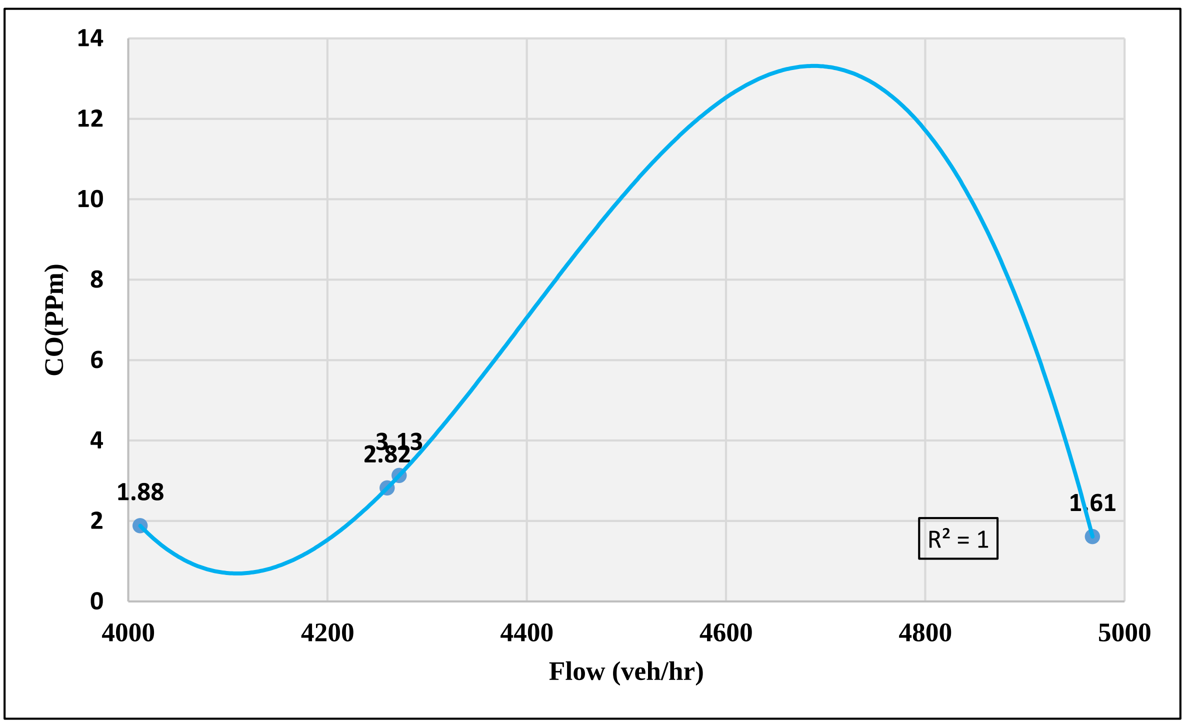
Figure(4-16): Traffic flow rate impact on CO for Police Central Al-Hussein intersections.

4.Saif Saad Intersection

A traffic survey was conducted at Saif Saad Intersection from (8:30 to 9:30) AM at the same time, gas emissions were calculated to know the effect of traffic on gas emissions, as the measurements showed that pollution increases with the increase in the number of vehicles and the decrease in their speed at the intersection, Figures (4-17) and (4-18) show the effect of flow rate on (CO_2 and CO) for Saif Saad Intersection.



Figure(4-17): Traffic flow rate impact on CO_2 for Saif Saad Intersection



Figure(4-18): Traffic flow rate impact on CO for Saif Saad Intersection

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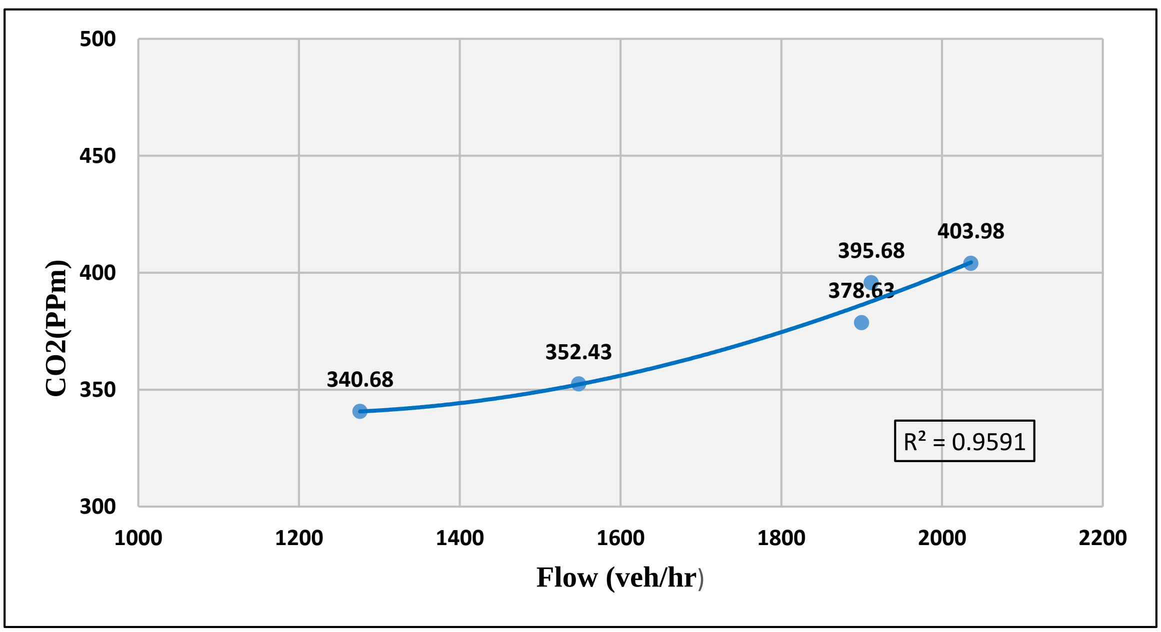
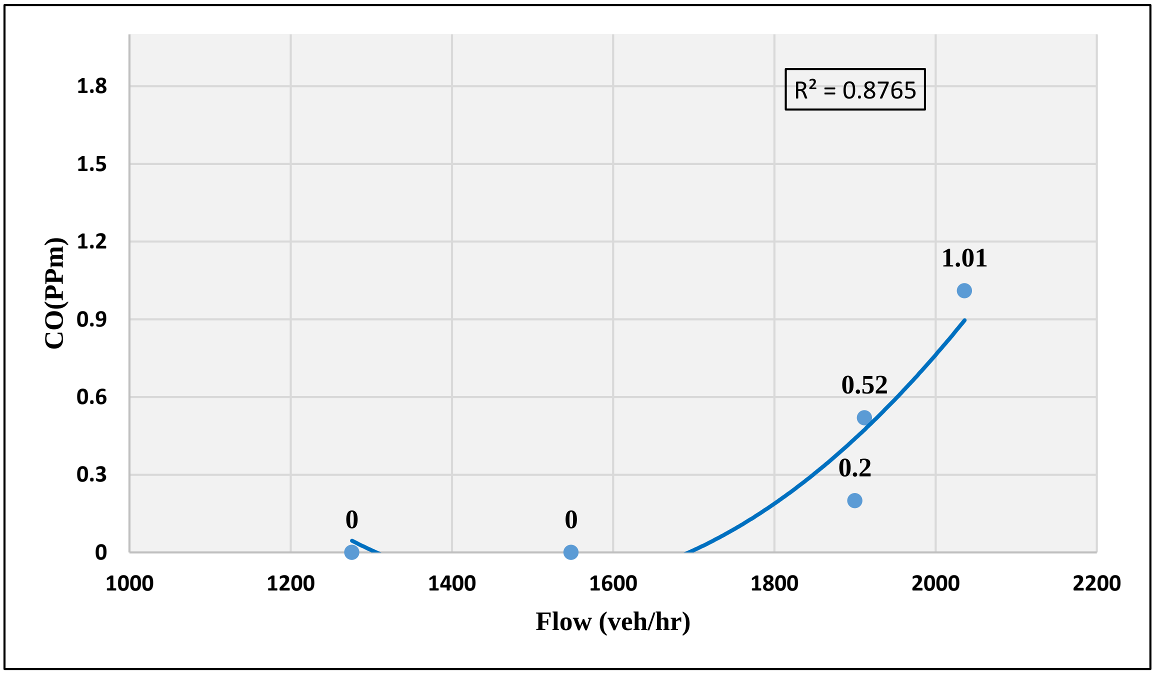
5. Ramadan Street

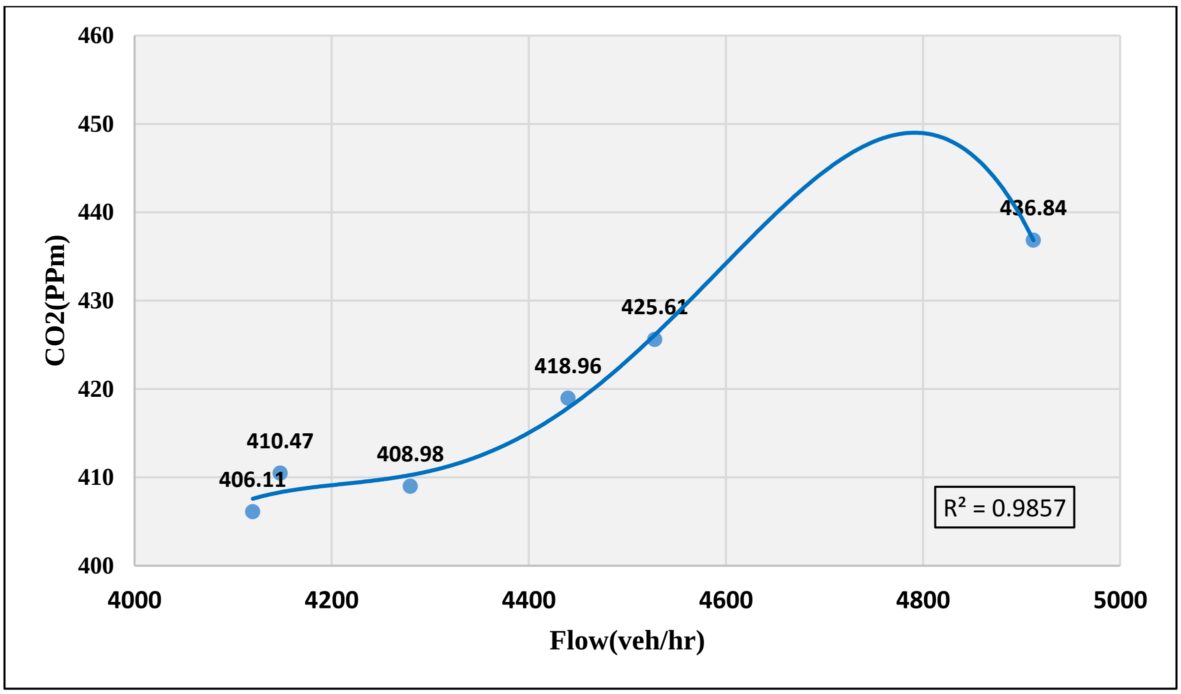
A traffic survey was conducted for Ramadan Street, which is considered one of the important streets in the city of Karbala. The traffic volumes and gas emission were calculated during two periods, this is in order to ensure that the emission of gases increases gradually with the increase in the flow ,the first was from (5:20 AM) to (6:35 AM) and the second was from(8:30 AM) to (10:00 AM), where the first period was with low traffic volumes, the measurements showed a gradual and clear increase in the emission of gases. With an increase in traffic volumes, while the second period from was experiencing congestion, a cumulative increase in the concentration of pollutants was observed, due to the increase in traffic density and changes in the speed of traffic flow leading to energy consumption and gas emissions, Figures (4-19) and (4-20) indicate the effect of flow rate on (CO_2 and CO) from (5:20 AM) to (6:35 AM) and Figures (4-21) and (4-22) indicate the effect of flow rate on (CO_2 and CO) from (8:30 AM) to (10:00 AM).



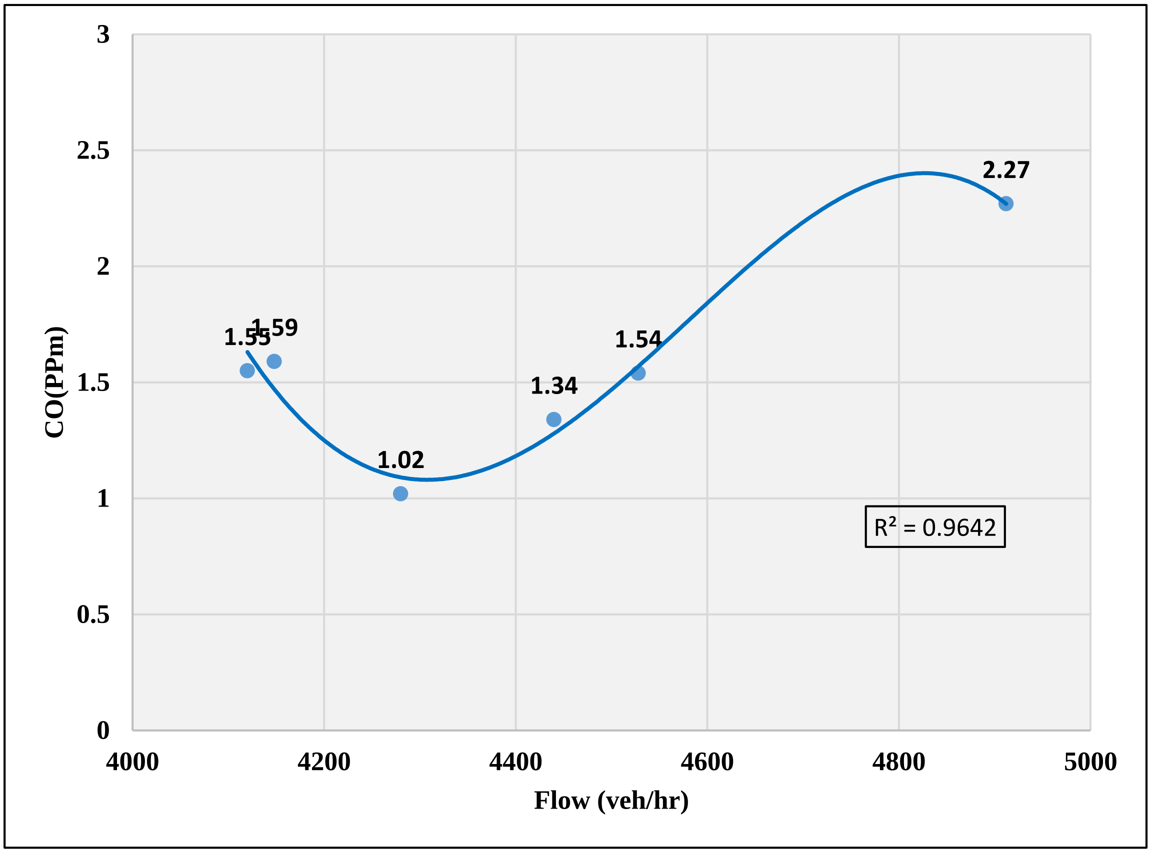
Figure(4-19): Traffic flow rate impact on CO_2 for Ramadan Street from (5:20 AM) to (6:35 AM).



Figure(4-20): Traffic flow rate impact on CO for Ramadan Street from (5:20 AM) to (6:35 AM).



Figure(4-21): Traffic flow rate impact on CO2 for Ramadan Street from (8:30 AM) to (10:00 AM).



Figure(4-22): Traffic flow rate impact on CO for Ramadan Street from (8:30 AM) to (10:00 AM).

Therefore, the pollution data for (CO2 and CO) were represented by using the TransCAD program For a specific study area, Figures (4-23) and (4-24) show the pollution results from the TransCAD program.

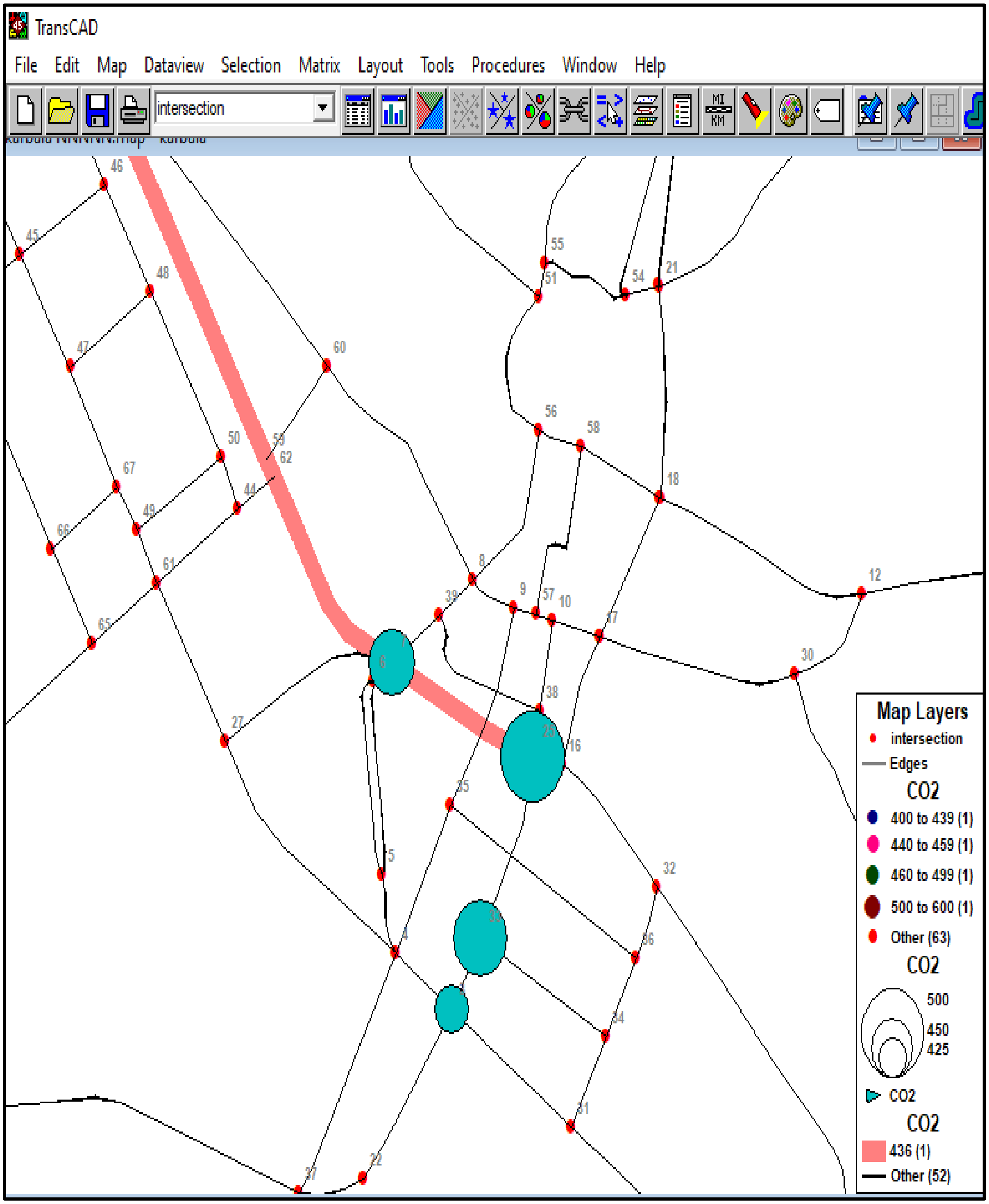


Figure (4-23): Results for CO_2 pollution.

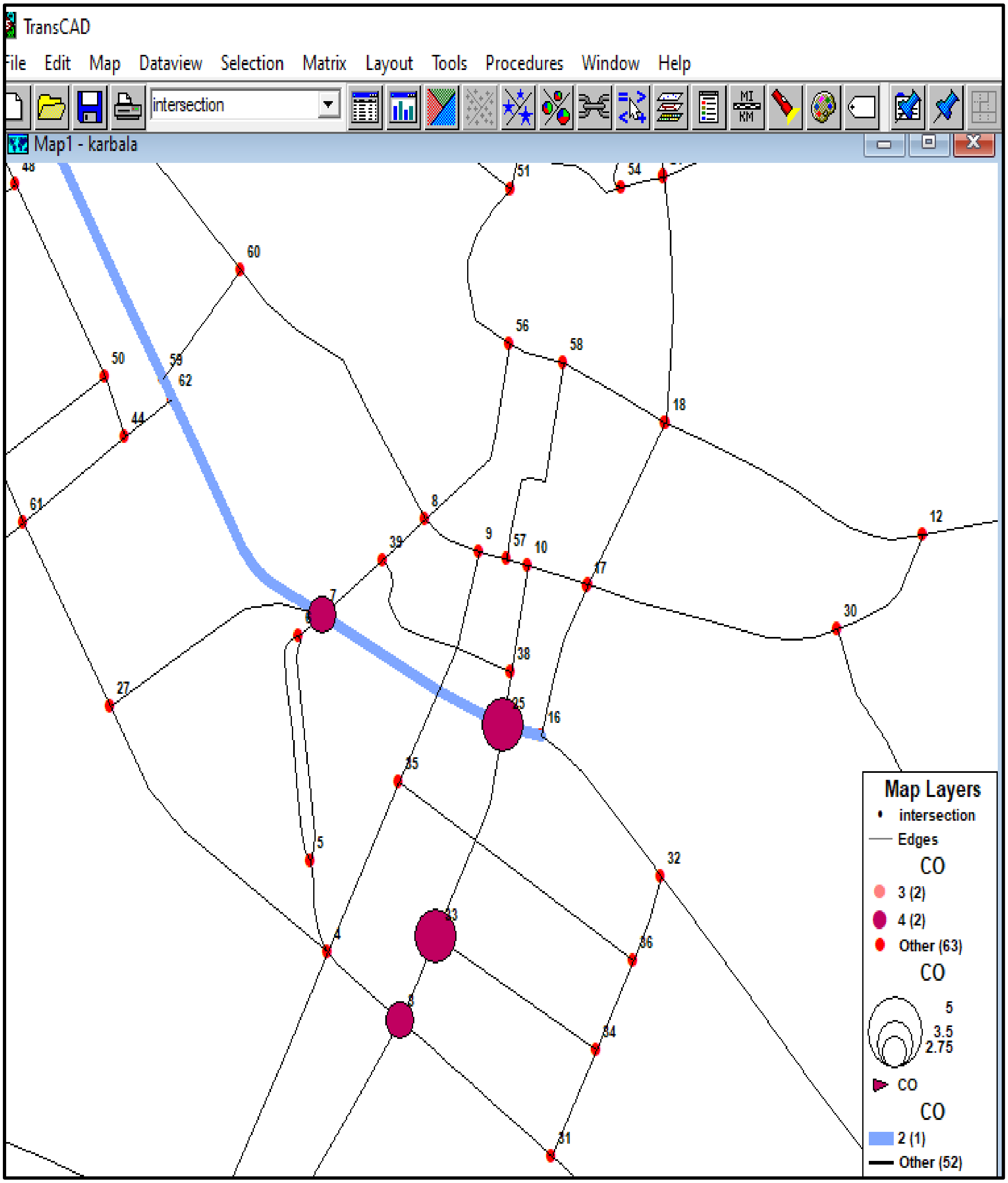


Figure (4-24): Results for CO pollution.

4.8 Evaluation of Selected Intersections

For LOS evaluation for selected intersections, it is required to calculate the average delay, which represents the main factor to evaluate the LOS at the intersection that operates with a traffic signal. Sidra software is used for traffic engineering are used to calculate the existing LOS for selected intersections.

1.Al-Dahreeba Intersection

Al-Dahreeba intersection, which is considered one of the important intersections in the city of Karbala, was evaluated using the Sidra Software, where the average delay for the morning peak was (277.4 sec/veh), In this case, the intersection operates within LOS (F) according to the classification of HCM 2000. As for the evening peak, the average delay was (935.8 sec/veh), as the intersection operates within LOS (F). It was noticed that the average delay of the evening peak is higher than the morning peak and that the service level of the intersection in the two peaks operates within LOS (F) according to the classification of HCM 2000. Tables (4-11) and (4-12) indicate the average delay and LOS for each intersection approach, for morning and evening period, respectively.

Table (4-11): LOS and delay according to SIDRA 8.0 for AL-Dhareeba intersection. (morning period)

Intersection name	Approach	Average Delay (sec/veh)	Level of Service (LOS)
Al-Dareeba	North	409.3	**F**
	South	179.8	**F**
	East	234.4	**F**
	West	276.2	**F**
Summary			
Intersection Average delay = 277.4 sec			**LOS = F**

Table (4-12): LOS and delay according to SIDRA 8.0 for AL-Dhareeba intersection. (evening period)

Intersection name	Approach	Average Delay (sec/veh)	Level of Service (LOS)
Al-Dareeba	North	959.4	**F**
	South	1142.8	**F**
	East	761.8	**F**
	West	739.9	**F**
Summary			
Intersection Average delay = 935.8 sec			**LOS = F**

2. Al-Safeena Roundabout

The LOS was evaluated for each approach at Al-Safeena intersection, and it was found that the intersection suffers from an average delay equal to (415.5 sec/veh) and LOS (F) at morning period, average delay equal to (605.1 sec/veh) and LOS (F) at evening period, Tables (4-13) and (4-14) indicate the average delay and LOS for each intersection approach, for morning and evening period, respectively.

Table (4-13): LOS and delay according to SIDRA 8.0 for Al-Safeena Roundabout. (morning period)

Intersection name	Approach	Average Delay (sec/veh)	Level of Service (LOS)
Al-Safeena	North	298.5	**F**
	South	31.5	**C**
	East	1015.7	**F**
	West	9.4	**A**
Summary			
Intersection Average delay = 415.5 sec/veh			**LOS = F**

Table (4-14): LOS and delay according to SIDRA 8.0 for Al-Safeena Roundabout. (evening period)

Intersection name	Approach	Average Delay (sec/veh)	Level of Service (LOS)
Al-Safeena	North	789.9	**F**
	South	742.3	**F**
	East	402.7	**F**
	West	432.4	**F**
Summary			
Intersection Average delay = 605.1 sec/veh			**LOS = F**

3.Sayed Jawda Intersection

SIDRA software is adopted to analyze traffic conditions and calculation of estimated delay for each traffic movement at each approach. After specifying the peak hour which represents the design hour volume, it is very important to estimate the level of service (LOS) at Sayed Jawda intersection with existing geometric design and traffic flow, it was found that the average delay for the morning peak was (935.6 veh/sec) and the average delay for the evening peak was (966 veh/sec), which shows that the intersection operates within LOS (F) according to the classification of HCM 2000. Tables (4-15) and (4-16) indicate the average delay and LOS for each intersection approach, for the morning and evening periods, respectively.

Table (4-15): LOS and delay according to SIDRA 8.0 for Sayed Jawda intersection. (morning period)

Intersection name	Approach	Average Delay (sec/veh)	Level of Service (LOS)
Sayed Jawda	North	390.3	**F**
	South	1178.1	**F**
	East	767.1	**F**
	West	1179.5	**F**
Summary			
Intersection Average delay = 935.6 sec			**LOS = F**

Table (4-16): LOS and delay according to SIDRA 8.0 for Sayed Jawda intersection. (evening period)

Intersection name	Approach	Average Delay (sec/veh)	Level of Service (LOS)
Sayed Jawda	North	283.5	**F**
	South	1102.2	**F**
	East	864.1	**F**
	West	1256.4	**F**
Summary			
Intersection Average delay = 966 sec			**LOS = F**

4. Police Central Al-Hussein Intersection

The traffic performance of Police Central Al-Hussein Intersection was evaluated using the Sidra program, the results show that most of the intersections suffer from an oversaturation condition with high total delay values and unacceptable level of service (LOS F), The average delay was (355.1 sec/veh) for the morning period and the average delay was (250 sec/veh) at evening period according to the classification of HCM 2000, Tables (4-17) and (4-18) indicate the average delay and LOS for each intersection approach, for morning and evening period, respectively.

Table (4-17): LOS and delay according to SIDRA 8.0 for Police Center intersection. (morning period)

Intersection name	Approach	Average Delay (sec/veh)	Level of Service (LOS)
Police Central Al-Hussein	North	230.8	**F**
	South	449.3	**F**
	East	411.8	**F**
	West	248.7	**F**
Summary			
Intersection Average delay = 355.1 sec/veh			**LOS = F**

Table (4-18): LOS and delay according to SIDRA 8.0 for Police Center intersection. (evening period)

Intersection name	Approach	Average Delay (sec/veh)	Level of Service (LOS)
Police Central Al-Hussein	North	259.6	**F**
	South	285.2	**F**
	East	179.1	**F**
	West	182.4	**F**
Summary			
Intersection Average delay = 250 sec/veh			**LOS = F**

5.Saif Saad Intersection

By using Sidra Software show that the intersection is operating at LOS(F) for two periods, with a high intersection delay (168.9 sec/veh)at morning period and the average delay is (252.9 sec/veh) at evening period according to the classification of HCM 2000, Tables (4-19) and (4-20) indicate the average delay and LOS for each intersection approach, for morning and evening period, respectively.

Table (4-19): LOS and delay according to SIDRA 8.0 for Saif Saad intersection. (morning period)

Intersection name	Approach	Average Delay (sec/veh)	Level of Service (LOS)
Saif Saad	North	129.5	**F**
	South	229.2	**F**
	East	135	**F**
	West	174.9	**F**
Summary			
Intersection Average delay = 168.9 sec/veh			**LOS = F**

Table (4-20): LOS and delay according to SIDRA 8.0 for Saif Saad intersection. (evening period)

Intersection name	Approach	Average Delay (sec/veh)	Level of Service (LOS)
Saif Saad	North	303.7	**F**
	South	312.8	**F**
	East	159.9	**F**
	West	208.3	**F**
Summary			
Intersection Average delay = 252.9 sec/veh			**LOS = F**

Chapter Five

Conclusions and Recommendations

5.1 Conclusions

1. Using the Sidra program, the LOS of all intersections was evaluated. It was found that the LOS for all intersections is (F), with a high level of control delay.
2. The air pollutions (CO_2, CO) values for (Al-Dhareeba, Al-Safeena, Al-Sayed Jawda, Police Central Al-Hussein, Saif Saad) intersections and Ramadan Street increased when traffic flow increased.
3. The Iraqi limits for CO_2 for all intersections are exceeded the acceptable limits, whereas the CO values were within the permissible limits.
4. The percentage of roads that fall into Class I is 25 %, Whereas 75 % represent the percentage of both Class II.
5. Evaluation of traffic operation based on average travel speed express that the level of service for street segments are 25 % of segments operated with LOS C, 31.25 % operated with LOS D, 12.5 % operated with LOS E, and 31.25 % worked with LOS F.
6. For the morning period, evaluation of traffic operation based on the (V/C) ratio express that the level of service for street segments is 12.5 % of segments operated with LOS B, 56.25 % operated with LOS C, 18.75 % operated with LOS D, and 12.5 % operated with LOS F. For the evening period, evaluation of traffic operation based on the (V/C) ratio express that the level of service for street segments is 50 % of segments operated with LOS C, 18.75 % operated with LOS D,25 % worked with LOS E, and 6.25 % operated with LOS F.

7. There is a slight difference between the LOS based on average travel speed and v/c ratio. This difference is originated based on the difference followed by each method.
8. The connectivity indications for Karbala city show weak connectivity according to its indices. The values of Alpha index = 0.256 , Beta index = 1.4 and Gamma index = 0.467 .

5.2 Recommendations for future work

1. Supporting public transportation to get rid of congestion and mean a good alternative in terms of low cost and reduce gas emissions.
2. Increasing the green spaces in the region leads to a reduction in the rates of emissions of gases resulting from vehicle exhaust.
3. Prevent street parking and improve traffic control at intersections to reduce traffic congestion.

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APPENDICES

Appendix-A

Sample of Free-Flow Speed Data

Table (A-1) Free-Flow Speed Data for Ramadan Street.

Vehicle NO	Speed	Vehicle NO	Speed
1	104	35	95
2	104	36	80
3	103	37	86
4	82	38	89
5	85	39	88
6	78	40	79
7	70	41	82
8	82	42	84
9	75	43	79
10	75	44	80
11	70	45	79
12	72	46	50
13	74	47	98
14	76	48	100
15	82	49	104
16	84	50	88
17	85	51	85
18	86	52	75
19	87	53	44
20	83	54	32
21	80	55	42
22	79	56	82
23	81	57	79
24	84	58	75
25	85	59	73
26	52	60	79
27	33	61	80
28	47	62	80
29	82	63	85
30	95	64	87
31	98	65	78
32	97	66	79
33	90	67	80
34	94	68	80

Table (A-2) Free-Flow Speed Data for Al-Iskan Street.

Vehicle No	Speed	Vehicle No	Speed
1	74	38	70
2	75	39	50
3	43	40	73
4	60	41	74
5	65	42	75
6	73	43	76
7	75	44	98
8	79	45	65
9	70	46	73
10	85	47	72
11	87	48	44
12	68	49	72
13	66	50	73
14	66	51	74
15	65	52	69
16	67	53	64
17	72	54	65
18	65	55	88
19	40	56	86
20	72	57	49
21	66	58	52
22	74	59	62
23	76	60	75
24	77	61	71
25	74	62	65
26	75	63	72
27	73	64	70
28	72	65	80
29	71	66	61
30	72	67	43
31	71	68	62
32	68	69	69
33	65	70	101
34	64	71	102
35	66	72	105
36	65	73	80
37	72	74	70

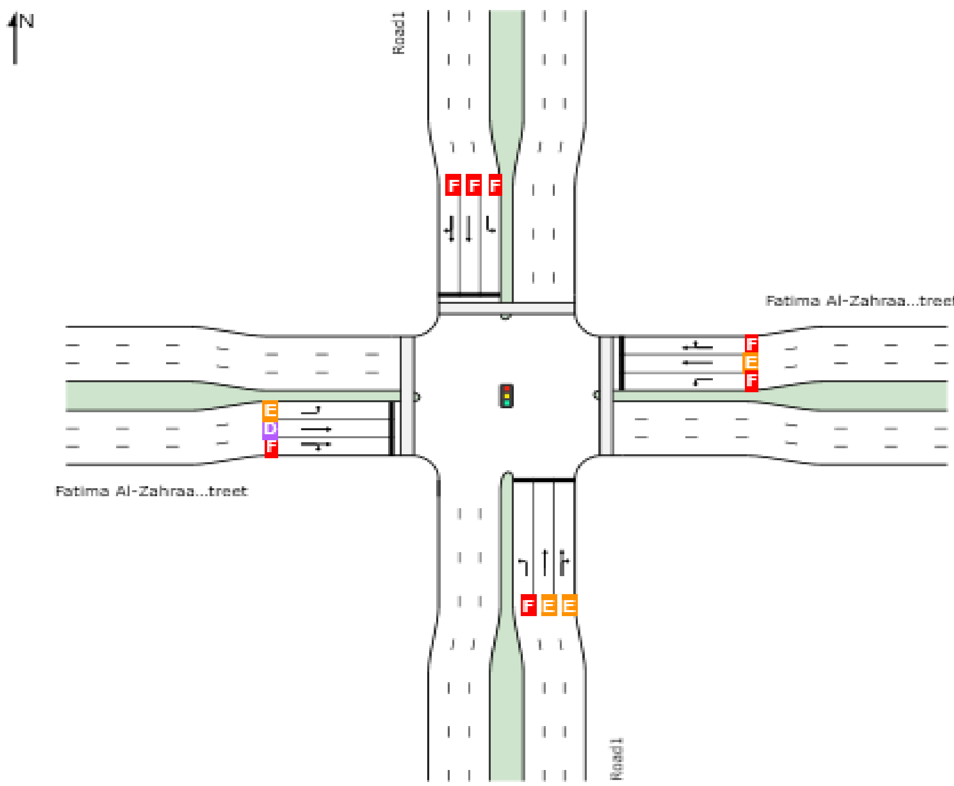
Appendix-B

Sample of SIDRA INTERSECTION

1. AL-Dhareeba intersections

The outputs of the Sidra program for Al-Dahreeba intersection during the morning period .

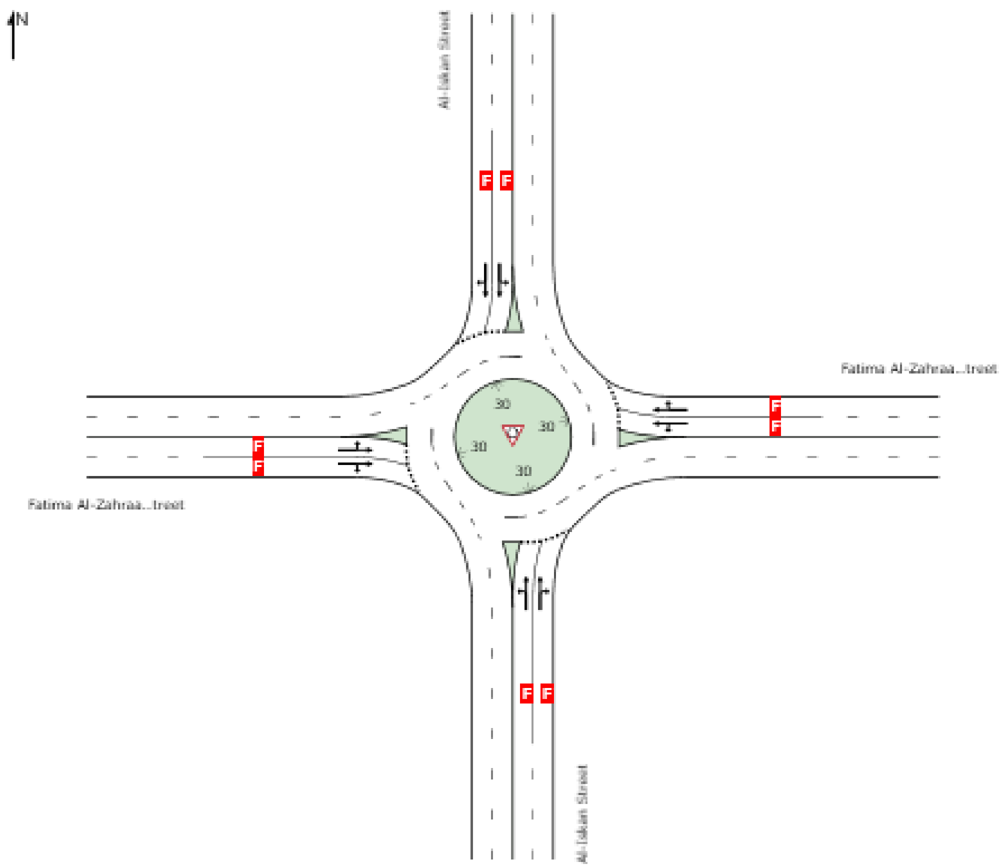
	Approaches				Intersection
	South	East	North	West	
LOS	F	F	F	F	F



2. Al-Safeena Roundabout

The outputs of the Sidra program for Al-Safeena Roundabout during the evening period .

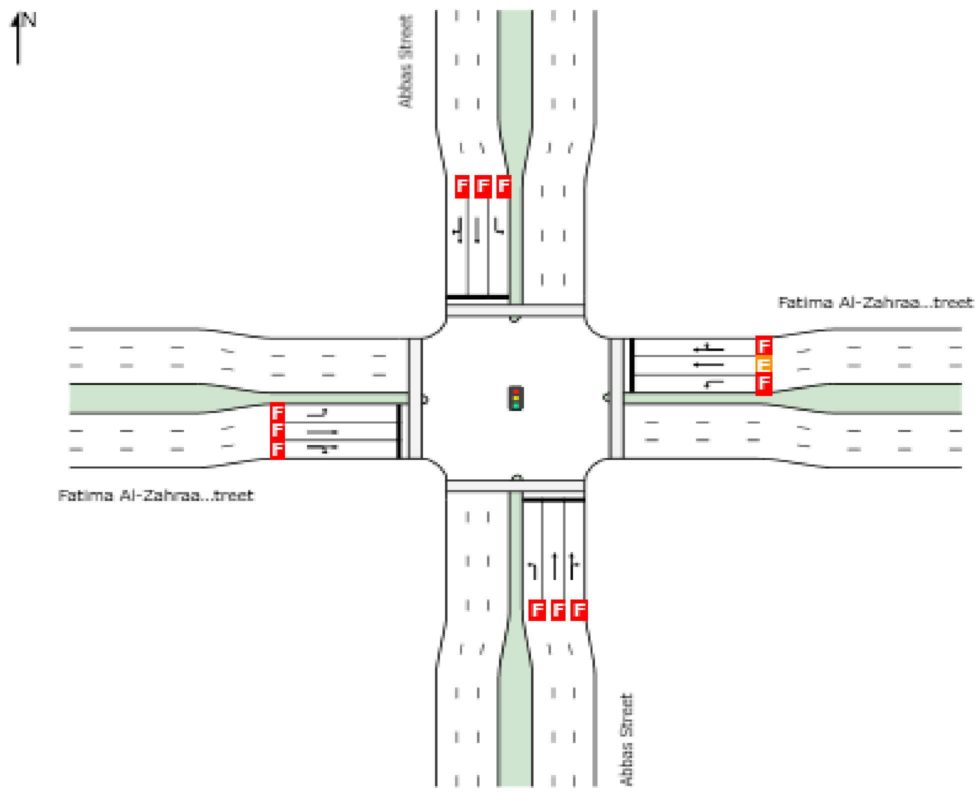
	Approaches				Intersection
	South	East	North	West	
LOS	F	F	F	F	F



3. Sayed Jawda Intersection

The outputs of the Sidra program for Sayed Jawda Intersection during the evening period .

	Approaches				Intersection
	South	East	North	West	
LOS	F	F	F	F	F



الخلاصة

تعتبر مدينة كربلاء المقدسة من أشهر المدن في العالم الإسلامي لما لها من طابع ديني ,لذلك شهدت المدينة زيادة في اعداد الوافدين اليها على مدار العام بالإضافة الى الازدهار الاقتصادي الذي اجتاح المدينة كل هذا أدى الى زيادة عدد الرحلات اليومية وزيادة تدفق حركة المرور .

تتناول هذه الدراسة تقييم الأداء المروري لتقاطعات وطرق حضرية مختارة , حيث تتكون منطقة الدراسة من خمسة تقاطعات وأربع شوارع حضرية .بعد تحديد منطقة الدراسة يتم جمع البيانات المرورية بواسطة تقنية تصوير الفيديو ومن ثم استخراج البيانات من أفلام الفيديو اما يالنسبة لقياس التلوث البيئي تم استخدام جهاز (GasmetDX4040) لقياس انبعاث غاز ثاني أوكسيد الكربون وأحادي أوكسيد الكربون . بعد تقسيم الشوارع الحضرية الى عدة مقاطع تم حساب وقت الرحلة لجميع المقاطع وحساب سرعة التدفق الحر.

تم استخدم يرنامج (SIDRA INTERSECTION) لتحليل وتقييم التقاطعات ,كما استخدم برنامج (GIS) لحساب عدد الروابط والعقد بالشبكة اما برنامج (TransCad) تم استخدامه لتمثيل الشبكة.

اما مرحلة التحليل فقد تضمنت تقييم شبكة الطرق بأستخدام عدة مؤشرات لمدينة كربلاء حسب المؤشرات ستظهر ان الشبكة ضعيفة الترابط , (Alpha index =0.256 , Beta index = 1.4 Gamma index = 0.467 , Grid Tree Pattern =0.639) بعد ذلك تم تصنيف الطرق على أساس متوسط سرعة الرحلة وحساب مستوى الخدمة لها وكذلك حساب السعة لجميع المقاطع وتقييم مستوى الخدمة على أساس (V/C).

بعد ذلك تم انشاء علاقة بين معدل التدفق وانبعاثات الغازات لمعرفة تأثير الازدحام المروري المتزايد على التلوث البيئي وأخيرا تم تقييم التقاطعات بأستخدام برنامج (Sidra) وتبين ان التقاطعات تعاني من زيادة في حجم حركة المرور حيث كان مستوى الخدمة لجميع التقاطعات (F).

جمهورية العراق

وزارة التعليم العالي والبحث العلمي

جامعة كربلاء

كلية الهندسة

قسم الهندسة المدنية

التقييم المروري والتلوث لشبكة طرق مختارة في مدينة كربلاء

رسالة مقدمة الى كلية الهندسة في جامعة كربلاء

كجزء من متطلبات نيل درجة الماجستير في الهندسة المدنية

(هندسة البنى التحتية)

من قبل :

نرجس باسل ذياب

بكالوريوس في الهندسة المدنية /جامعة كربلاء (2015-2016)

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سبتمبر
2021