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Evaluation and Improvement of Selected an Congested Segments in Main Urban Roadways

A Thesis

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

By

Dina Khaled Khelfa

B.Sc. in Civil Eng. / University of Babylon (2015-2016)

Higher Diploma in Transportation Eng. / University of Babylon (2018-2019)

Supervised By

Prof. Abdul Kareem Naji Abood

2022 AD **1443** AH

بسم الله الرحمن الرحيم:

﴿ يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ
دَرَجَاتٍ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ ﴾

صدق الله العلي العظيم

سورة المجادلة – 11

Supervisor Certification

I certify that this thesis which is entitled ***(Improvement of Some Congestion Segments In Main Urban Roadways)*** has been prepared by ***(Dina Khaled Khelfa)*** under my supervision at College of Engineering, Babylon University, in partial fulfilment of the requirements for the degree of Master of Science in Transportation Engineering.

Signature:

Name: ***Prof. Abdul Kareem Naji Abood***

Date: / / 2022

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I owe thanks to my family for their continued support and understanding during my pursuit of the master's degree that made the completion of the thesis possible. I greatly appreciate their belief in me.

Finally, many thanks to everybody who helped me and I forgot to mention him/her.

Dina Khaled Khelfa

Dedication

I Dedicate This Work with the Deepest Words of Gratitude and Appreciation

To my dear Father, my dear Mother who takes care of me since my childhood

To my sister and friends for their love and continuous support

Dina Khaled Khelfa

ABSTRACT

This study was conducted for the purpose of evaluating the extent of traffic congestion in selected sections in the urban center of Al-Hillah City, as congestion increased significantly due to the large population growth within the city and the increase in private cars ownership, in a way that is not proportionate with the capacity of roads in urban parts of the city. Congestion was measured by calculating the level of service for each section within the study area, and then suggesting appropriate solutions to reduce congestion and increase safety levels in these sections.

The study area included three multilane segments (a section of Street 60, Al-Tuhmazia Street and Al-Jamaa'ia Street), two unsignalized intersections (Al-Tuhmazia Intersection and Street 60/ Al-Taqah Street intersection) and one U-turn (Street 60 u-turn near the Al-Muahed Garage).

To achieve this goal, engineering surveys were carried out first, where the necessary information was collected, such as the number of lanes, the width of each lane, the width of the medians..etc., using the information provided by Al-Hillah City municipality office. Then, traffic volumes were collected for each segment in the morning peak hour (7:45 - 8:45 AM) and the evening peak hour (1:45 - 2:45 PM). Video using (Smart Traffic Analyzer) program.

The (HCS+T7F) program was used to analyze and calculate the level of service for multilane segments, while (SYNCHRO) program was used to analyze and calculate level of service for the unsignalized intersections. It was found that all sections in the study area operate at relatively low levels of service, ranging between (LOS C) and (LOS E), then, congestion cost was calculated and it was found the daily congestion costs on these segments ranged between (12M-18M ID).

The study concluded that the suggested Improvements has increased the overall level of service of the intersection from LOS (E) to LOS (C) at Al-Tuhmazia at-grade Intersection, from LOS (D) to LOS (C) at both directions of street 60, from LOS (E) to LOS (C) at both directions at Al-Jamaa'ia Street, from LOS (D,C) to LOS (C,B) at both directions respectively at Al-Tuhmazia Street and from LOS (D) to LOS (C) at Street 60/Al-Taqah Junction, while applying the suggested improvements on these segments would decrease the current congestion cost including traffic accident cost by 50% or more. At the end the study suggested a number of recommendations and alternatives to enhance traffic performance at study segments.

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Symbol	**Details**
CBD	Central Business District
STA	Smart Traffic Analyzer
FHWA	Federal Highway Administration
HCM	Highway Capacity Manual
HCS+T7F	Highway Capacity Software + TRANSYT-7F
LOS	Level of service
BFFS	Base Free Flow Speed
FFS	Free Flow Speed
PCU	Passenger Car Equivalent
VOC	Vehicle Operation Cost
PI	Personal Injury
F	Fatal
V/C ratio	Volume / Capacity Ratio
PC	Passenger Car
HV	Heavy Vehicle
PVC	Point of Vertical Curve
ADT	Average Daily Traffic
TWSC	Two-way Stop Controlled Intersection
AWSC	All-way Stop Controlled Intersection

CHAPTER ONE

INTRODUCTION

1.1: General:

Traffic congestion is a substantial problem that faces urban road networks. The main characteristics of traffic congestion are slower velocities, travel time increase, and vehicle queuing, this usually lead to driver discomfort and frustration, as well as traffic jams. The significance of this problem has increased since the 1980s in both developing and developed countries. Al-Hillah city similarly suffers from major congestions on several urban highways.

Congestion usually accompanies urban areas where the value of land is relatively high due to it being highly populated. There is a clear relationship between the population growth and congestion, as more population means more services, more activities and different types of trips within the urban area.

According to global reports of traffic, the yearly cost of congestion has increased significantly and it is continuously increasing, with more fuel and time waste every year.

The increasing number of vehicles and the lack of highway development in Al-hillah City contributed to the significance of the congestion problem, also the wasted vehicle operation cost (VOC) including fuel, oil, tire change and accidents maintenance. The spike of automobiles ownership in the recent decades has led to more congestion, travel time delay, and more pollution, as the lack of public transportation Systems made the general public turn to the ownership of private vehicles.

The undeveloped infrastructures of Al-Hillah city is simply not enough to keep up with the huge number of vehicles traveling on city roads. The lack of good city planning also contributed to the problem as new residential districts were built without organized design, which generated more traffic in certain areas than other areas did.

1.2: Problem Statement:

The study area involved (Al-Jamaa'ia Street, Al-Tuhmazia Street, a segment of Street 60, Al-Tuhmazia at ground intersection, Al-Taqah/Street 60 T-junction and Street 60 U-Turn near Garage Al-Muahad) These locations were selected for this study for many reasons:

1- Infrastructure problems and bad city planning:

- ❖ Insufficient infrastructures, such as the lack of bridges, interchanges, railways, expressways, subways, parking lots, exits, etc.
- ❖ placing a lot of government and private offices in the same region had increased the number of vehicles using the roads leading to those regions which led to major congestions within study area.

2- System Problems:

- ❖ In view of the growing traffic volumes in the study area, the corresponding lack of construction and maintenance works and the development of roads and intersections, this exacerbated the problem of traffic congestion in the urban area.
- ❖ The overlapping of traffic movements among vehicles on one hand, and vehicles and pedestrians on the other hand, led to a decrease in the operational speed of the vehicles, and thus reduced the level of service for the road, in addition to the emergence of many traffic accidents of various kinds.
- ❖ Constantly increasing traffic volumes of vehicles of different types, which were classified as passenger cars, buses and heavy vehicles (trucks)

according to AASHTO classification, led to reduce road capacity and safety levels and convenience factors in the study area.

- The lack of an efficient, effective and attractive system that adopts the activation of public transport with a clear planning and strategy led to an increase in personal vehicle trips and as a result led to an increase in the operating costs of VOC vehicles in addition to an increase in the trip time and delay time, as well as the occurrence of many cases of pollution in the air as a result of gases emitted from vehicle exhaust Traffic noise pollution increased in the study area. As there is a lack of public transportation systems like metros, trains and rapid transit, as public buses are the only means of public transportation in the city.
- The increasing rate of traffic accidents in the study area that result in death (Fatal F), personal injury (PI), or property damage, whose statistics were obtained from the Babylon Traffic Directorate, calls for looking at the problem and redesigning some congested areas that the study covered, in addition to the points of intersection of vehicular traffic with pedestrians.
- The presence of many security checkpoints due to the ongoing anti-terrorism proceedings in the country, and many closed streets for different reasons like road obstacles, double-parking, religious rituals, security reasons or unfinished constructions, all this has created more traffic pressure on some roads.
- Traffic signal problems like Insufficient green time.
- Breaking traffic rules is normalized in our society, as city drivers do not respect rules and regulations , which makes handling traffic flow more difficult

4- Demographic Problems:

- The percentage of population growth in Iraq in the last decade has an average of 2.58%, more population means more automobiles on the same roads.
- Numbers of automobiles has increased dramatically in recent years due to economic growth, not to mention the increase in the ownership of private cars that happened due to the lack of public transportation systems.

1.3: Study problem:

Traffic congestion problem has many negative effects on road networks and intersections in urban areas. For example, increasing Travel time delay, vehicle operation cost, not to mention air pollution levels, and traffic noise. which makes the roads work at full capacity and critical density, these factors contribute to a low level of service LOS, and less efficiency at caring traffic volume, and more traffic accidents all of this lead to a decrease in safety, convenience and efficiency factors of the road

1.4: Study Objectives:

This study aims to analyze and improve the traffic performance of three locations inside the multilane arterial highways in urban areas in Al-Hillah city. As those locations suffers from traffic congestion and conflict points between traffic movements, like Moving forward, maneuvering, and turning, which makes it one of the hazardous locations as it does not satisfy the safety requirements. Therefore, many accidents can cause deaths, personal energy or property damage. It also aims to specify the real causes of congestion at these locations and to present solutions and Alternatives to solve those problems. The study objectives are:

- Conducting engineering and traffic count surveys for the selected highway segments to collect the required data for analysis using different data collection methods.
- Calculating acceleration and deceleration lanes dimensions, storage bay, taper length, speed change lane and all essential parameters of the chosen segments and discussing those parameters technically and economically.
- Studying critical points, overlapping traffic movements and suggesting a turning type for both left and right sides that fits the nature of open medians and the surrounding properties, to set safety, efficiency and comfort factors.
- Studying the collected geometric data to pinpoint the current design problems causing traffic congestions and accidents.
- Analyzing the selected segments using Highway Capacity Software **(HCS+T7F)**. and **(SYNCHRO)** software.
- Highlighting safety problems at the selected segments and discussing the proper remedies to decrease possible accidents.
- Presenting a number of development methods and alternatives to solve the traffic problems discovered at the study sections, based on the results obtained after the data analysis.

1.5: Methodology :

The following methodology was adopted through this study:

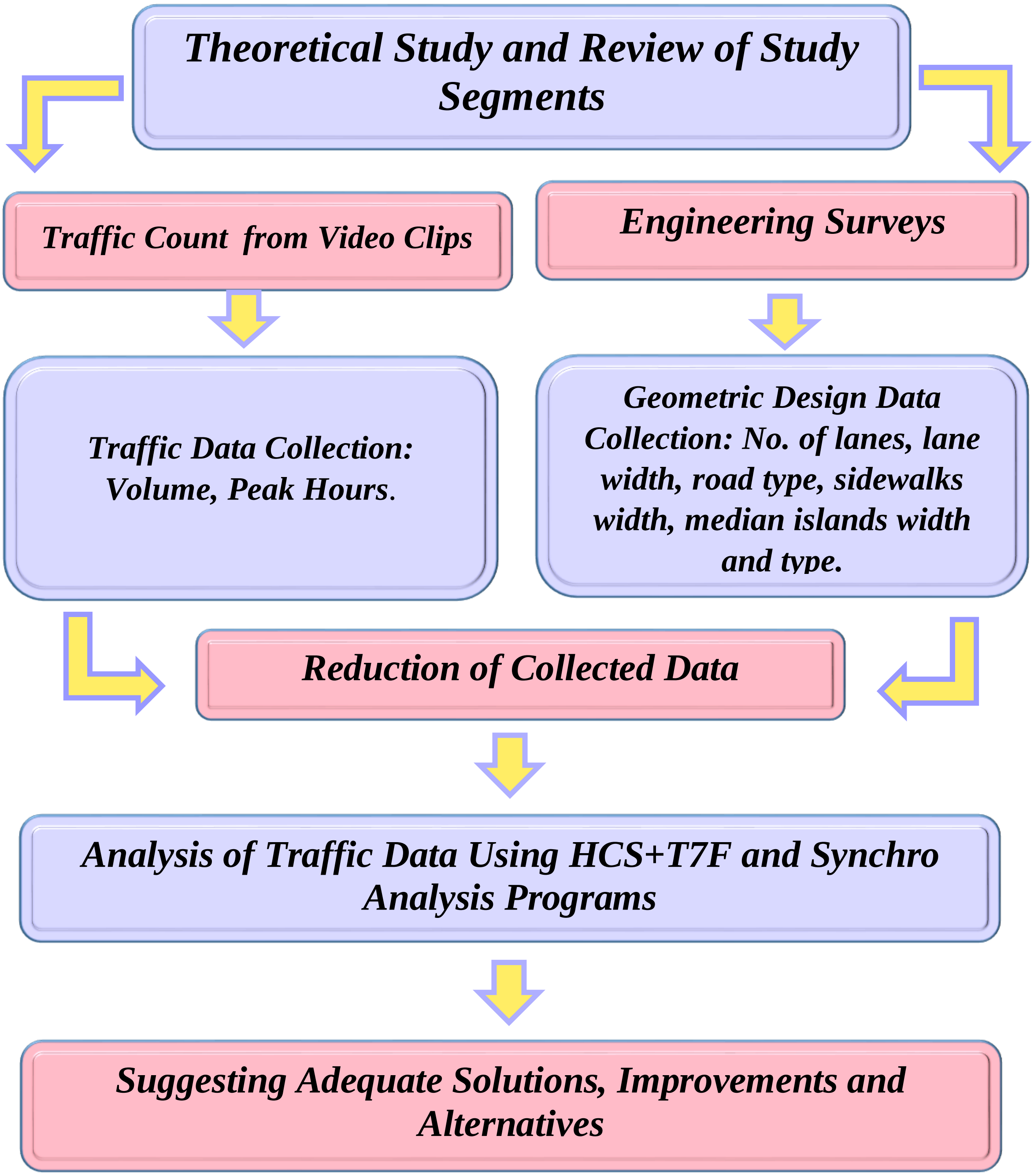

Figure (1.1): Study Methodology.

1.6: Study Structure :

This study consists of five chapters, and has the following structure:

Chapter one: Introduction.

The first chapter states the study problem, gives details of the objectives, methodology and structure of the study.

Chapter Two: Literature Review.

This chapter covers prior studies and researches, urban highways classification and their functions, urban multilane arterials characteristics and level of service, two way stop controlled intersections characteristics and level of service , types of Road turns, their designs, functions and characteristics, Acceleration & Deceleration Lanes properties and Traffic problems in urban areas

Chapter Three: Study Area Description & Data Collection.

This chapter includes an introduction to Al-Hillah City in terms of roads, intersections and land uses as well as the various trips and activities in study area, Study and count of traffic volumes in the selected road sections and the Implementation of engineering and traffic count surveys.

Chapter Four: Data Analysis and Improvements Presentation.

The forth chapter involves an analysis of current study area situation ,a Study of critical points and overlapping traffic movement, a study of the geometric design improvement suggested for study area and a suitable alternatives presentation for each section of study area.

Chapter Five: Conclusions and recommendations

This chapter presents study conclusions and recommendations.

CHAPTER TWO

BASIC CONCEPTS AND LITERATURE REVIEW

2.1: Introduction:

This chapter involves earlier studies handling congestion problem on urban transportation facilities in Iraq. An assessment of these studies showed that, not many studies were done in Al-Hillah City regarding congestion problem, which emphasize the importance of this study. Several concepts and notion from earlier studies were integrated in this study.

In addition to the literature review, basic concepts of the operational analysis of study segments, and an overall review of traffic congestion problem causes and impacts were presented in this chapter.

2.2: Urban Roads Characteristics:

Urban roads are defined as roads located within the boundaries of residential communities in cities or towns. Urban roads are usually characterized by low to medium limits of design speeds, many access points, and medium to high residential/commercial growth. Intersections, walkways, and on street parking are usually what characterize these roads . **[MDOT, 2015]**

Urban roads can be classified based on design criteria into:

***1*. Freeways/Expressways:** they are divided roadways with fully controlled access and two or more lanes in both directions devoted to the special usage of traffic flow. **[HCM, 2010]**

The role of urban freeways/expressways is to carry large traffic volumes while supporting high travel speeds, they link the main spots that creates traffic. sharp grades are evaded. Pedestrians crossing at these roads is not permitted.

2. **Arterial Streets:** Urban arterials comes under the freeways in the roadways hierarchy, they usually supports big traffic volumes and less travel speed compared to freeways, Pedestrians are only allowed to pass them at road intersection. **[FHA, 2000]**

   Arterials are classified into major and minor arterials. Major urban arterials assists main axes of motion that has the maximum traffic volumes and lengthiest traveling spans. Combined within and amid principle rural roadways. On the other hand, minor urban arterials supports traveling of less spans and less mobility than major urban arterials. With moderate access of land, although it does not breach living quarters. **[Gerry Forbes, 2019]**

3. **Sub-Arterial Streets:** These are streets that supports less mobility than the main arterial streets, spacing between them can fluctuate from 0.5 km in CBDs to (3 - 5 km) in suburban regions. Packing and unpacking of goods is typically not allowed on sub-arterial streets, and pedestrians are permitted to pass them only at intersections. **[Suryakanta, 2015]**

4. **Collector Streets:** theses streets supports moderate to low capacity as they transfers traffic volumes from local streets to arterial streets and vice versa. These streets are made to supply access to residential areas, therefore they provide more accessibility but less mobility than arterial streets. Pedestrian crossing is allowed. **[Johns Creek, 2016]**

5. **Local Streets:** these roads are the neighborhood road system. They moderately have little to no through traffic and typically supports local movements. They provide full access to residential areas and services, but offers low levels of mobility. Table (2.1) demonstrates design speed limits for each roadway class.

Table (2.1): Ranges for Design Speeds in Urban Areas. [AASHTO, 2011]

Highway Type	Terrain	Design Speed	
		Metric (km/h)	US Customary (mph)
Freeways/Expressways	Level	MIN. 80	MIN. 50
	Rolling	MIN. 80	MIN. 50
	Mountainous	MIN. 80	MIN. 50
Arterials/Sub-Arterials	Level	50 - 100	30 - 60
	Rolling	50 - 100	30 - 60
	Mountainous	50 - 100	30 - 60
Collector Streets	Level	+ 50	+ 30
	Rolling	+ 50	+ 30
	Mountainous	+ 50	+ 30
Local Streets	Level	30 – 50	20 – 30
	Rolling	30 – 50	20 – 30
	Mountainous	30 – 50	20 – 30

2.3: Urban Multilane Arterials:

Multilane arterials usually have two lanes or more in each direction, and a posted speed range within (60-100 km/h), commonly divided by median islands, though these roads can be as well un-divided. Vehicular volumes usually fluctuates from (15,000 - 40,000) veh/day. On these roadways, signalization can be allowed at main intersections which enable fractional access control. **[Tom V. Mathew, 2009]**

- **Multilane roadways base circumstances are:**

• At least 3.6m lane width;

• At least 3.6m side clearance in flow direction;

• Only passenger cars;

• No direct access points;

• A separated roadway;

• (FFS) greater than 100 km/h.

2.3.1: Capacity for Multilane Arterial Highways:

Capacity is characterized by the highest amount of vehicles passing through a certain point per hour under predominant circumstances; it is regularly evaluated based on expected values for saturation flow. Capacity depends on roadway situation like the width and number of lanes, lane use, grades, in addition to signalization settings. **[HCM, 2010].**

The Highway Capacity Manual method is suggested for calculating capacity and LOS of multilane highways. Equations (2.1) , (2.2) presents capacity, base capacity and heavy vehicles adjustment factor.

$$Capacity = Base\ Capacity\ \times f_{HV} \times No.of\ Lanes \ldots\ldots (2.1)$$

$$Base\ Capacity = \ 1{,}000 + 20\ \times FFS \ldots\ldots (2.2)\ ;$$

$$for\ FFS \leq 60; \quad otherwise\ use\ Base\ Capacity = 2{,}200$$

Where:

$\boldsymbol{FFS}$ = Free flow speed

$\boldsymbol{f_{HV}}$ = Adjustment for heavy vehicles. Table (2.2) shows FFS and Capacity for multilane highways.

Table (2.2): FFS and Capacity for Multilane Highways. [HCM, 2010]

FFS (km/hr)	Capacity (pc/hr/ln)
100	2200
90	2100
80	2000
70	1900

2.3.2: Level of Service of Multilanes:

Each two of the next three operational features can define LOS for a multilane roadway:

1-Volume/capacity (V/C) ratio.

2-Speed, (average travel speed), km/hr.

3-Density, pc/km/ln.

Every one of these three parameters specifies the way a roadway handles traffic stream. As speed fluctuates within a narrow variety, it is unreliable gauge of performance quality. Density, that is a parameter that shows the degree of closeness of vehicles within the stream can be directly observed. **[Khisty and Lall, 2003].**

Table (2.3) shows FFS and flow rate capacity for multilane roadways according to the level of service.

Table (2.3): FFS and Flow Rate Capacity for Multilane Highways. [HCM, 2010]

FFS (km/hr)	Level of Service				
	A	B	C	D	E
100	660	1,080	1,550	1,980	2,200
90	600	990	1,430	1,850	2100
80	550	900	1,300	1,710	2000
70	490	810	1,170	1,550	1,900

2.4: Un-Signalized Intersections:

An intersection can be generally described as a zone where two or more roadways intersect or meet; they are points of possible conflicts between vehicles. **[C.A. O'Flaherty, 2006]**

Every intersection has to include through and cross movements on one or more of connected roadways and could involve turning movements. These movements can be controlled by a number of ways, for example; signals, Traffic signs, and channelization, depending on intersection type. Intersections are complicated parts of any roadway, because vehicles traveling in different directions try to conquer the same area the at same period of time, adding to that pedestrians who want to use the same area in order to cross. **[Tom V. Mathew, 2009]**

They are intersections where a STOP or a YIELD sign controls no less than one movement. These intersections involve:

1- Two-way stop-controlled (TWSC).

2- All-way stop-controlled (AWSC).

3- Roundabouts.

Traffic operations on un-signalized intersections oblige drivers on minor streets to evaluate gaps sizes alongside the major street and choose an appropriate one to pass or to join the stream. **[L. Elefteriadou, 2014]**.

Minor-street approaches capacity is influenced by the next factors:

1- The scattering pattern of available gaps in the major-streets.

2- The gap sizes necessary to complete the wanted movements (Gap acceptance).

2.4.1: Two-Way Stop Controlled Intersections (TWSC):

This intersection can be described as an un-signalized intersection with uncontrolled major streets, and stop sign controlled minor streets, Fig.1 shows the general layout of the intersection.

Minor street approaches generates left, through, and right turning movements, in addition to left turns from major street approaches. High traffic volume traveling on major streets restricts the chances for vehicles traveling on minor street to go in or pass. On minor streets, through and right-turn movements is prioritized over the corresponding left-turns. The capacity of minor movements is affected by; the movements priority rules, geometric design of the intersection and the traffic volume attempting the movement. **[HCM, 2010]**

Automobiles at two-way stop controlled intersections must cross many conflict zones to pass through the intersection. In the condition of unsaturated flow, vehicles can go into the intersection once every conflict zone is free of conflict movements. **[Li, Tian & Deng, 2011]**

2.4.4: Capacity and Degree of Saturation:

Capacity is characterized by the highest amount of vehicles passing through a certain point per hour under predominant circumstances; it is regularly evaluated based on expected values for saturation flow. Capacity depends on roadway situation like the width and number of lanes, lane use, grades, in addition to signalization settings.

The v/c ratio also known as the (degree of saturation), characterizes the adequacy of an intersection to put up with traffic demand. If this ratio is less than 0.85 then it has expected that the capacity is acceptable and vehicles are not expected to involve in major delays. While a ratio near, equal or more than 1.0 promotes an unstable traffic flow in addition to delays and queuing. If the Degree of Saturation (v/c) at the intersection is greater than 1.0, the intersection functions at LOS F, unrelatedly of the actual control delay. **[HCM, 2010].**

2.4.5: Control Delay:

Delay is a vital factor of performance for traffic facilities with interrupted flow. Control delay is the primary performance quality for estimating LOS at un-signalized intersections. It involves delay related to vehicles decelerating ahead of an intersection, delay used up stopped on an intersection approach, delay used up as vehicles advance in the queue, and delay needed for vehicles acceleration to their preferred speed. Equation (2.3) shows the control delay formula:

$$d = t_s + 900T\left[(X-1) + \sqrt{(X-1)^2 + \frac{h_d X}{450T}}\right] + 5 \quad \ldots\ldots (2.3)$$

Where:

d = Average control delay (s/veh),

$\mathbf{X} = \frac{v}{c}$ = Degree of Saturation,

t_s = Service time (sec),

$h_d = \frac{3600}{c}$ = Departure headway (sec), and

T = Length of analysis period (hr).

Level of service (LOS) is defined by HCM as a quantitative classification of measures of performance that represent quality of service. There is six levels of service, extending from A to F. LOS A characterizes the best operational situation from passenger's viewpoint and LOS F the worst. Therefore LOS is considered as a degree of traffic density or congestion. Table (2.4) shows the level of service for two-way stop-controlled intersection according to control delay values, while Figure (2.1) shows the stage quality of level of service with control delay.

Table (2.4): LOS for (TWSC) intersection. [HCM,2010]

Level of Service	Control delays (s/veh)
A	0-10
B	> 10-15
C	> 15-25
D	> 25-35
E	> 35-50
F	> 50

2.5: Median U-Turns:

Although Median opening have several benefits, it as well a point of potential congestion and accidents. The recurrent interludes in traffic flow, like ones generated from on or off turns on high-speed highways, create multiple acceleration and deceleration movements. These commotions in the flow of traffic would necessitate a sequence of choices that is too complex for regular drivers. Thus, it is understandable that thoughtful locating of median openings has vital significance in increasing safety levels on multilane roadways. **[TXDOT, 2020].**

There are many types of median openings, like; no median opening, median crossover with and without left turn bay, directional median crossover and two way left turn lanes, as shown in Figure (2.2):

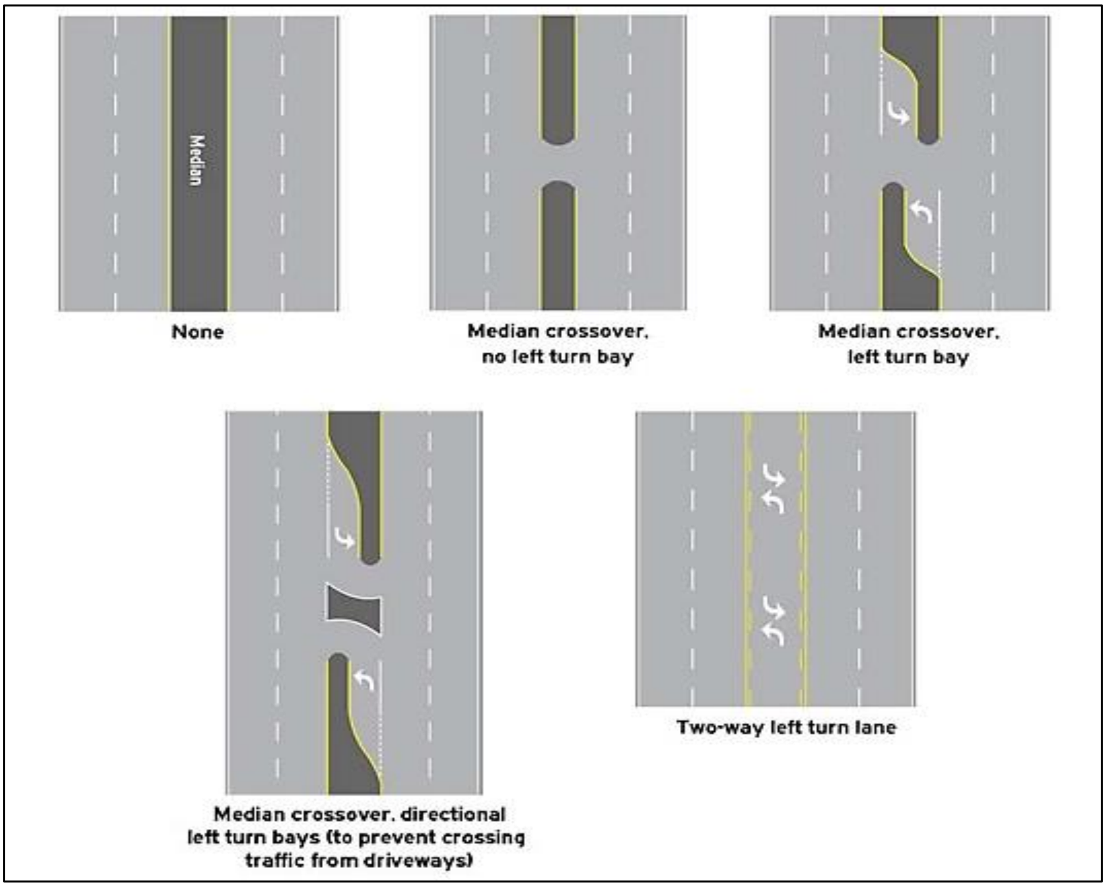

Figure (2.2): Types of median openings. **[Debra Kennaugh, 2017]**

[Brown, Tarko and Fricker, 1998] Created a model that calculates number of and the degree of harshness accidents on multilane roads. The research showed that the existence of RM (Raised Median) enhances flow safety, and that segments bordered by signalized intersections that have no median openings ensure more safety than segments that have openings.

U-turns are typically made available from an left-turn lane at an un-signalized intersection. Automobiles doing U-turn movements at an uncontrolled or stop controlled intersection usually conflicts with the major roadway and right-turning traffic stream. **[Pan Liu, 2006]**

Drivers using U-turns have to make a decision of taking a gap amid the consecutive vehicles arriving on through direction after it has reached at an adjacent area of median opening. This portrays the importance of “Gap Acceptance” concept.

Median U-turns are mainly used as an opportunity to manage left turns, in order to minimize crashes and increase the flexibility of traffic performance while having high traffic demand on both of divided arterial directions. U-turns reduce the number of conflict points. The behavior of drivers using U-turn is one of the key reasons of congestion and accidents on urban roadways**.** **[Wu, Sun, Li & Chen, 2020]**

Choosing a directional median opening would abolish many issues related to crossing and left turning maneuvers on multilane roadways **[Liu, Zhou and Yang, 2007]**.

Hence, substituting a full median opening with a directional one will reduce points of conflict from (32 to 8), Figure (2.3) demonstrate the differences between the two designs. Therefore, it will facilitate traffic performance and decrease accidents.

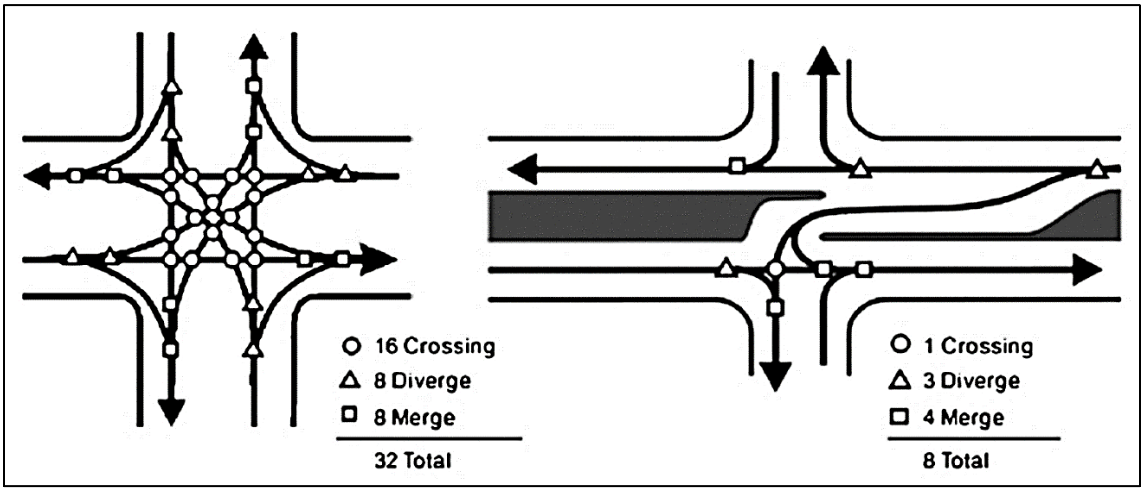

Figure (2.3): Conflict points at a classic four legs at grade intersection vs. a directional median opening. [TRB, 2004]

2.5.1: Capacity of U-Turns:

Several characteristics influences the capacity of median U-Turn. These include; the through traffic movement in the destination that clashes with the U-turn movement and the critical gap the follow up time for U-turn movement.

[Al-Masaeid, 1999] proposed a linear reversion prototype to estimate capacity of U-turning volume and to discover the influence of diverse characteristics that may influence the capacity approximation.

The researcher as well computed the critical gap and follow-up time to estimate the capacity grounded on the model of gap acceptance proposed by HCM. According to the previous study, Equations (2.4), (2.5) and (2.6) were achieved:

$$C = 799 - 0.31\, q_c \; .... (2.4)$$

$$C = 799 - 0.62\, q_{cp} \; .... (2.5)$$

$$C = 1{,}545 - 790\, e^{\frac{qc}{3600}} \; ...... \; (2.6)$$

Where:

C = Capacity of U-turn movement (PCU/h).

q_c = Conflicting traffic flow (PCU/h).

q_{cp} = Conflicting traffic flow per lane. (PCU/h/ln).

Moreover, the study evaluation presented a link between the average total delay and the conflicting flow. The study indicated that linear and exponential formulas are appropriate to define the connection between the two parameters. Although, the exponential formula was proven to ensure a better statistic feature. Equation (2.7) was as follows:

$$TD = 6.6 \times e^{qc/1200} \dots\dots (2.7)$$

Where:

TD = Average Total Delay (sec/veh).

Figure (2.4) and (2.5) shows a scatter plot of the relationship between both capacity and average total delay with the conflicting traffic flow.

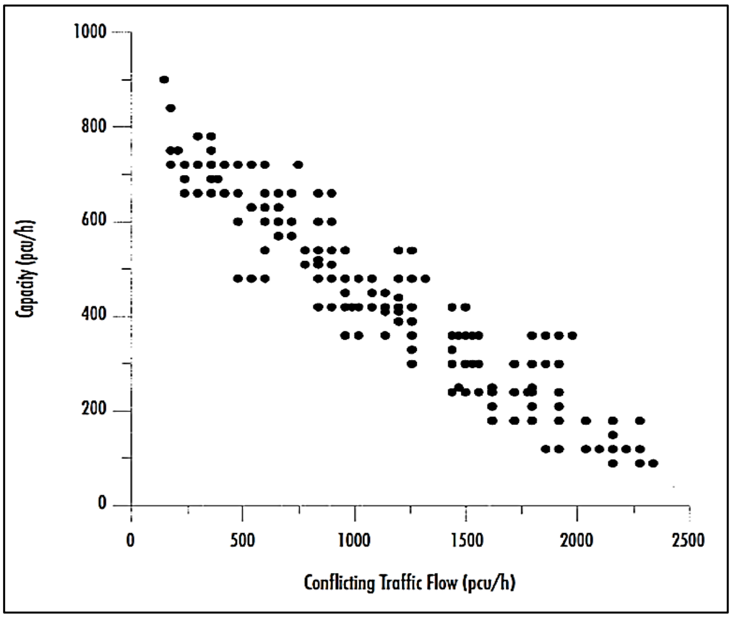

Figure (2.4): Scatter plot of U-turn capacity conflicting traffic flow. [Al-Masaeid, 1999]

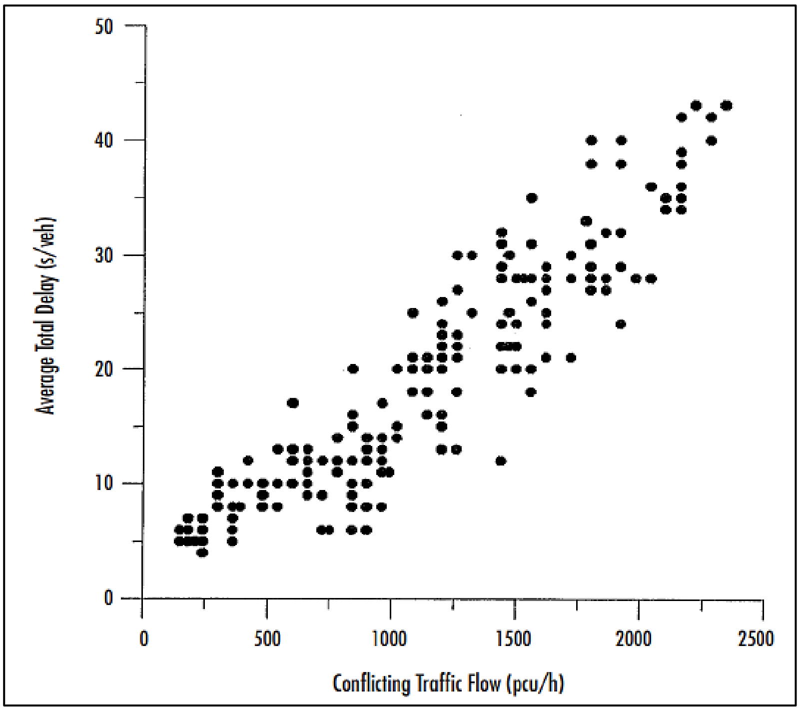

Figure (2.5): Scatter plot of U-turn average total delay and conflicting traffic flow. [Al-Masaeid, 1999]

2.5.2: Types of Speed Change Lanes:

On urban arterial streets, speed change lanes delivers a switch from low-speed roadways to high-speed roadways and vice versa. The existence of such lanes enhances the safety by decreasing the variance in speed between the two combining roads. They make available distance for deceleration and potential storage for vehicles making turn movements. **[TX RDM, 2020]**

Speed change lanes has two kinds, Acceleration and deceleration lanes, according to the tasks of these lanes, the following sections details these two types.

2.5.2.1: Acceleration lanes:

These lanes are utilized to increase the speed, to help transitioning from a low-speed road to a high-speed road. When a vehicle arrives to a high-speed road like highways or expressways, the driver has to raise the vehicle speed in order to join the high speed traffic stream safely, or else, this entrance causes interruptions to other vehicles traveling in the major traffic stream. acceleration lanes let vehicles that are merging into the main street to accelerate in order to match the speed of main traffic stream. **[TX A&M, 2013]**

2.5.2.2: Deceleration lanes:

These lanes are utilized to reduce the speed, to help transitioning from a high-speed road to a low-speed road. When a vehicle leaves a high-speed road, the driver has to decrease the vehicle speed in order to join the low speed traffic stream safely, or else, crashes with other vehicles might happen. **[AASHTO, 2011]**

These lanes permit traffic flow leaving main streets at intersections to decelerate to a safer speed to create a left or right turning movement with no disturbance of the major traffic stream.

2.5.3: Speed Change Lanes Components:

There are two components of speed change lanes, which used by turning vehicles, these lengths are:

1- Deceleration length (including Taper length).

2- Storage length. Figures (2.6) and (2.7) demonstrates the design of left turn lanes on urban streets, while Figure (2.8) demonstrates the design of right turn lanes on urban streets.

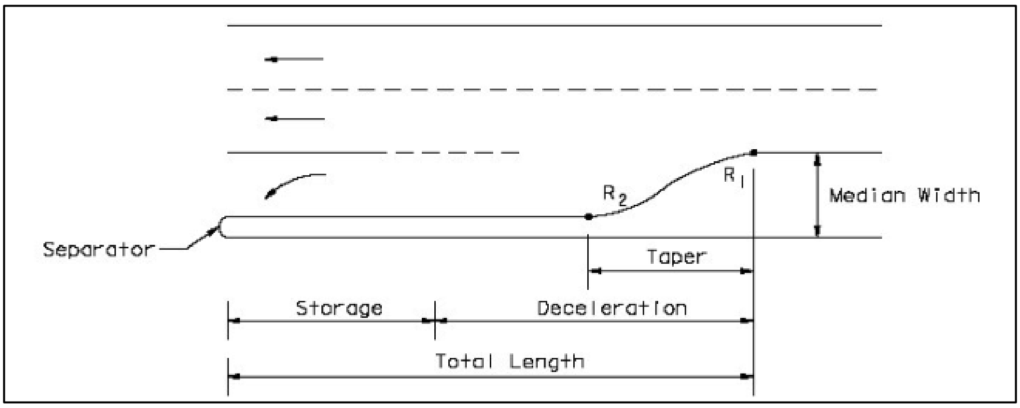

Figure (2.6): Single left turn lane, deceleration, storage and taper lengths. [TX RDM , 2020]

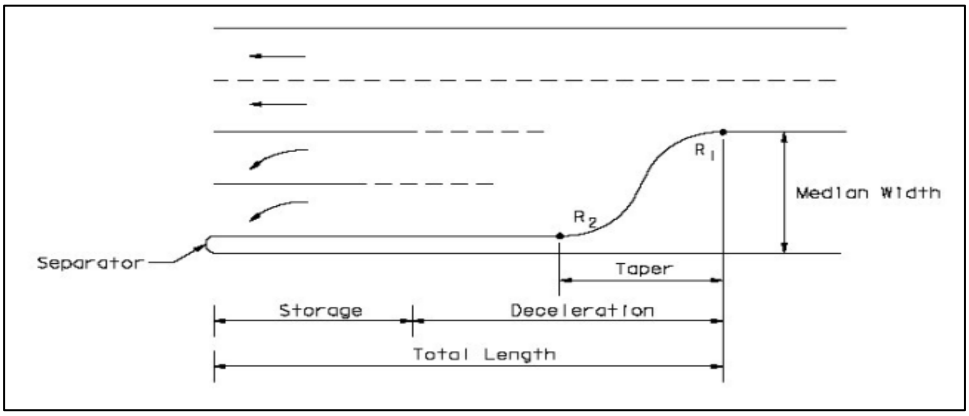

Figure (2.7): Dual left turn lane, deceleration, storage and taper lengths. [TX RDM , 2020]

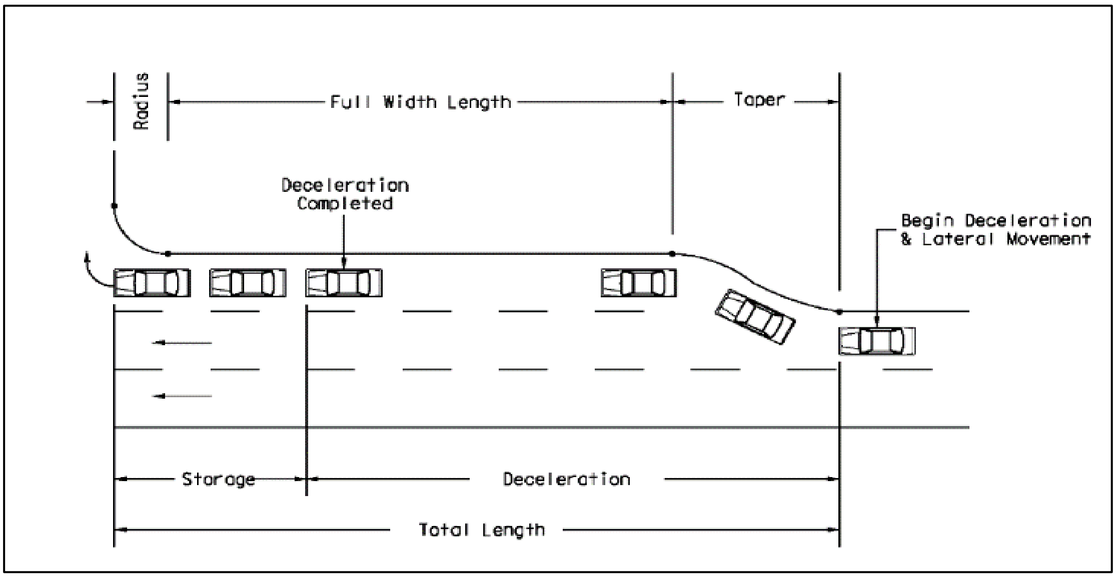

Figure (2.8): Right turn deceleration lane, deceleration, storage and taper lengths. [TX RDM , 2020]

1- Deceleration Length (Including Taper):

Deceleration length theory adopts the idea that reasonable deceleration is going to happen in through flow lane with vehicles entering left-turn lane at a speed of 10 mph (15 km/h) less than the speed entering through flow. **[TXDOT, 2020]**

On several urban roadways, it is inconvenient to supply an entire auxiliary lane length projected for deceleration, often; the length of storage overruns the deceleration length. In these situations, a part of deceleration should be achieved before incoming to the auxiliary lane. **[AASHTO, 2001]**

The presence of taper length as portion of deceleration length on auxiliary lanes presumes a possibility that a turning vehicle could slow down conveniently up until [10 mph] in through lane ahead of arriving at the auxiliary lane. Tables (2.5) and (2.6) shows the recommended deceleration lengths in feet.

Taper lengths were initially created by the means of a ratio or an equation grounded on design speed and presumed amount of adjacent movements of vehicles turning from through stream. **[Stover & Dixon, 2015]**

According to AASHTO the recommended taper ratio for speed change lanes range from (8:1) to (15:1) (Longitudinal: Transverse).

Table (2.5): Right turn deceleration lengths. [Traffic Engineering Handbook, 1999] & [AASHTO, 2004]

Design Speed (mph)	Deceleration Length (ft)		
	Traffic Engineering Handbook		AASHTO
	Desirable Circumstances	Limiting Circumstances	Limiting Circumstances
30	225	170	170
35	295	220	----
40	375	275	275
45	465	340	340
50	565	410	410
55	675	485	485
60	785	565	----

Table (2.6): Left turn deceleration lengths. [Traffic Engineering Handbook, 1999] & [AASHTO, 2004]

Design Speed (mph)	Deceleration Length (ft)	
	Traffic Engineering Handbook	AASHTO
30	170	170
40	275	275
45	340	340
50	410	410
55	485	485

2- Storage Length:

Auxiliary lanes must have adequate storage length for vehicles expected to gather through peak times. There is a probability that vehicles doing left turns stops when entering through stream while waiting for a gap or a traffic signal alteration in the opposite traffic stream. The storage length must be enough to escape this probability. Equation (2.8) determines storage length **[Preston, 2010]**

$$storage\ length\ (ft) = \left(\frac{Turn\ lane\ peak\ hour\ volume}{60}\right) \times (Pc\% \times 25) + (Hv\% \times 75) \times 2 \ \ldots\ldots (2.8)$$

Where:

Hv % = Percentage of heavy vehicles.

Pc % = Percentage of passenger cars.

2.6: Definition of Congestion:

Congestion is a condition where roadway traffic space requirements surpass the existing provided roadway space. It is the resistance that vehicles carry out on one another, when the utilization of a transportation facility come close to capacity. Congestion is basically a comparative occurrence that is connected to the variance between how users expect the transportation facility to perform and the actual facility performance. **[Chakrabarty & Gupta, 2015]**

There are two main forms of traffic congestion:

1- Recurring Congestion: this type of congestion can be predicted to happen at an identical period each day as a outcome of large traffic demand of travelers using roadways which are at or close to their roof capacity.

2- Non-Recurring Congestion: this type of congestion happens as a consequence of an unpredicted or unusual incident. Some sources of a congestion of this type involves: vehicle accidents, vehicle collapses, road construction, Security points checks, unplanned pedestrian passing, climate changes, and extra volumes consequential to special events or holidays. **[PVPC, 2019].**

2.7: Measures of Congestion:

There are two overall methods to indicate traffic congestion; an operative method which is favored by road networks constructers and managers. and an economical method that gives priority to public transportation costs. The first method has to do with the evident parameters of highway performance like (speed, flow rate and density, etc..), while the second one usually focuses on inducing physical features into economic standards which can aid the cost-benefit analysis.

2.7.1: Level Of Service (LOS):

“LOS represents the quality of service so it’s a vital measure of traffic congestion. An alteration of LOS point out that the highway traveling conditions has transformed from one specified variety of passenger-recognizable circumstances to another, whereas no alteration in level of service shows that circumstances have stayed inside the previous operational variety. **[HCM, 2010]**

2.7.2: Average Traffic Speed:

Average speed of vehicles traveling on a specified roadway during peak periods. the average speed of traffic is an important factor in measuring congestion, average traffic speed is equal to space mean speed (SMS), it can be calculated by finding the average of all individual speeds of vehicles passing on a specified segment of a roadway**. [Transportation Online Lab Manual, 2003].** As shown in Eqation (2.9):

$$V_{SMS} = \frac{length\ of\ roadway\ segment}{Avg.travel\ time} = \frac{d}{\frac{\sum t_i}{n}} = \frac{n \times d}{\sum t_i} \ldots . (2.9)$$

Where:

d = length of roadway segment;

n = number of observations;

V = speed of the vehicle;

t = travel time of the ith vehicle.

2.7.3: Travel Delay:

Travel delay is the extra travel time experienced by individuals using the roadway, due to conditions that block the wanted movements of traffic flow. It is the variance between actual travel time and travel time at free-flow conditions. **[AASHTO, 2011].**

Trip delays caused by the repeated traffic congestion is calculated approximately by formulas linking traffic volume and speed. The other type of delay that comes across by road users is the one that occurs due to non-current events. This delay is associated with the regularity of vehicle accidents or collapses, how difficult to get rid of those incidents' remnants from road lanes and sidewalks and the ordinary quantity of repeated congestion. Federal Highway Administration (FHWA) established a procedure to demonstrate the result of accidents grounded on the road geometric design features and projected traffic volumes. **[ECORYS & SETS, 2010].**

2.7.4: Cost of Congestion:

Congestion costs are the extra fuel costs the drivers has to pay to operate their vehicles due to congestion. As the most remarkable influence of congestion is the increase of travel time, the cost of congestion can be calculated by quantifying the wasted travel time and estimating the cost of wasted fuel during it.

The total delay cost is the yearly repeated and non-repeated delay expenses for each type of transportation., **[Mir Shabbar Ali et al., 2014]** studied the congestion cost at an arterial road in Karachi City and presented Equations (2.16) that is used to estimate opportunity cost of traffic congestion and vehicle operation cost

$$OC = \sum_{m=1}^{m} (VOT_m \times D_m \times V_m \times Vocc_m) \ldots\ldots\ldots (2.16)$$

Where:

OC = Opportunity Cost of traffic congestion, ID.

VOT_m = Value of time for mode m. (ID/hr).

D_m= Travel delay for mode m, (min/veh).

V_m = Number of vehicles, veh/day.

$Vocc_m$ = Vehicle occupancy factor for mode m.

Table (2.7) shows the value of time (VOT) in Iraq for both passenger and cargo transportation according to the 2005 Italian consortium for Iraqi transport infrastructure study.

Table (2.7): Values of Time (VOT) in Iraq for both Passenger and Cargo Transportation. [Iraq Transport Masterplan, 2005]

Year	Time Value (ID/hr.)	
	Passenger Transport	Cargo Transport
2020	1,527.66	27.15
2025	1,861.15	26.85
2030	2,119.05	25.54
2035	2,437.51	24.08
2040	2,821.51	22.48

2.7.5.1: Wasted Fuel Cost Estimation:

So as to estimate additional fuel use resulting from traffic congestion, average fuel efficiency and total additional fuel must be calculated. The average fuel economy is used to evaluate the wasted fuel cost for vehicles traveling in congestion circumstances. It can be computed from Equation (2.17).

$$FC = \sum_{Ft=1}^{3}(Fcq_m^{Ft} \times Fp^{Ft} \times \mu^{Ft}) \dots\dots\dots \quad (2.17)$$

Where:

Fcq_m^{Ft} = Fuel consumption quantity, (litr/km)

Fp^{Ft} = Fuel price of certain fuel type.

Ft = Fuel types (1 for CNG, 2 for Gasoline and 3 for Diesel).

μ^{Ft} = proportion of particular mode (m) using that road segment.

Passenger car , buses and trucks percentage of the collected traffic volume is used for μ^{Ft} , for Fp Table (2.8) presents fuel prices in Iraq for different types of fuel.

Table (2.8): Different Fuel Prices in Iraq. [Iraq Transport Masterplan, 2005]

Cost of the Fuel (ID/L.)		
Passenger Cars/buses	**Small Trucks**	**Large Trucks**
500	500	500

2.7.5.1: Vehicle Operating Cost Estimation:

Vehicle operating cost is the overall expenses experienced by highway travelers using vehicles from origin to destination. [**E. Kadarsa et al., 2019].** Equation (2.18) is used to calculate vehicle operating cost for different

$$VOC = L \times \sum_{m=1}^{m} (FC_m \times D_m \times V_m) \ldots \ldots \ldots \quad (2.18)$$

Where:

VOC = Vehicle operating cost, ID.

L = Length of congested segment (km).

2.7: Congestion Problems in Urban Areas:

Big cities are always the center of many economic activities; these activities generate many trips and help in creating more traffic demand on the city roadways. There are many problems associated with traffic especially on urban roadway systems; the following segment will present the most prominent traffic problems in urban locations in details:

Traffic congestion is one of the most common urban transportation problem, as drivers are frequently exposed to traffic jams, especially when going to work in the morning, which causes them discomfort due to congestion in the roadways. This problem climaxes in public holidays and holiday seasons.

Since the city is the main commercial center in urban area, the number of its residents and visitors doubles during working hours. Thus, the entrance points to the city would witness a huge traffic flow at peak hours, which will minimize the capacity of internal roadways.

This problem occurs because the roadway capacity is not enough to take in traffic flow at peak hours. In Iraq, generally and in Al-Hillah City specifically there are two main peak periods on workdays: morning and afternoon peak hours. Morning peak goes on from (6 AM to 9 AM) as most people go to their jobs, schools, universities. Etc. In addition, afternoon peak goes on from (12 PM to 3 PM) as people return from their jobs, schools... etc. The main sources of traffic congestion in urban areas are:

1- The uncontrollable rapid increase in the number of vehicles.

2- The lack of public transportation system, or the complete absence of it.

3- Narrow roadways, asymmetry and poor planning of city roadways, lack of roadway networks and alternative roadways, in addition to poor design of buildings, intersections, entrances and major exits.

4- Drivers not obeying traffic laws, also the bad behavior and habits of some drivers that cause severe confusion to traffic

5- The shortage of parking lots.

Although countries try to find a solutions that may reduce traffic congestion like expanding roadways and constructing more of them, these solutions has not met the desired success, due to the enormous increase in number of vehicle by a rate that exceeds the capacity of these roadways.

Traffic congestion has been defined as a condition where a number of vehicles trying to use a specific roadway at any time period surpasses the capability of the roadway to carry that number of vehicles at an acceptable level of service. This term also can be described as "an extra number of vehicles on a roadway section at a certain time inducing flow speeds slower than ordinary speeds" **[FHWA, 2020]**

2.7.1: Environmental Impacts of Congestion:

Traffic congestion participates to air and noise pollution largely, which has negative influences on the climate and the city people health. Air pollution causes damages to the lungs, heart and brain; air pollution causes irritation of eyes, nose and throat, coughing and chest tightness, in addition to that, the prolonged exposure to polluted air may cause cancer, damage to the human nervous, immune and reproductive systems.

Noise pollution on the other hand, causes sleep disturbances for people exposed to it, which in turn affects their health and general mood, as it causes fatigue. Noise pollution also leads to hearing impairment, as it's one of the acute effects of being constantly exposed to noise, as exposure to long periods of noise leads to damage to the human eardrum that may in turn lead to permanent impairment or loss of hearing. Figure (2.9) shows the Carbon Dioxide (CO2) emissions in Kiloton (kt) from liquid fuel consumption in Iraq over years from (1960-2016).

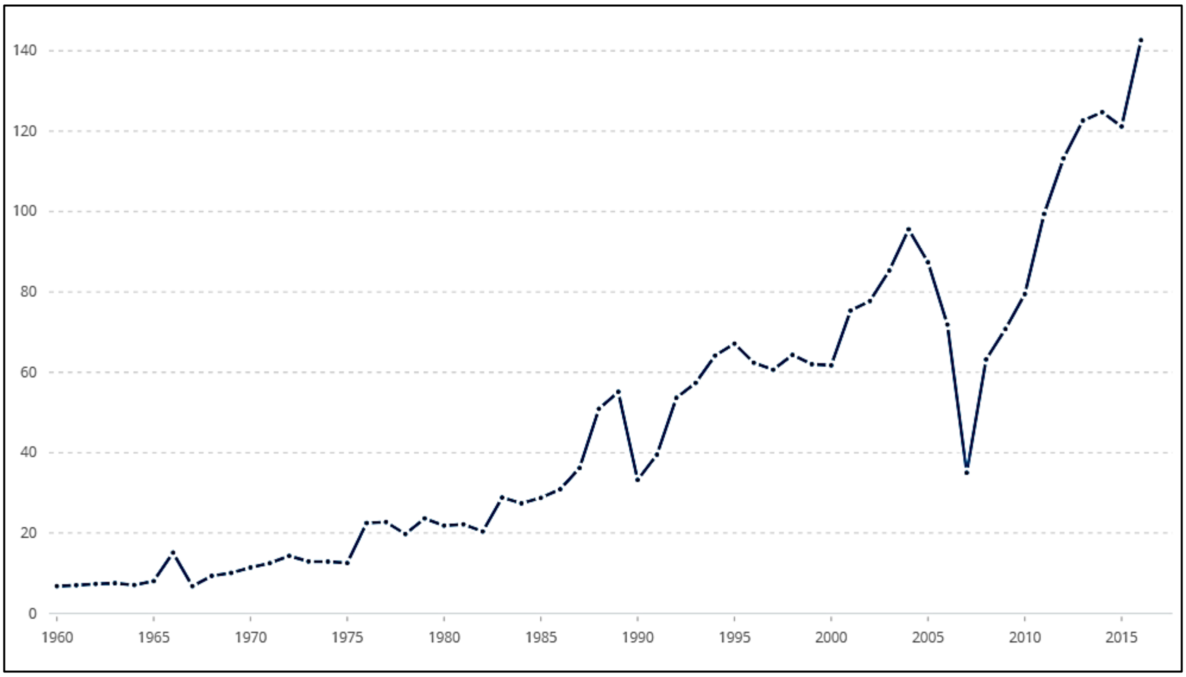

Figure (2.9): (CO_2) emissions in Kiloton (kt) in Iraq. [The World Bank, 2019]

2.8: Public Transport VS. Private Transport:

Public transportation systems convey countless benefits to people, society, and economy. There are many advantages these systems have over private vehicles. The main advantages are:

1- It supports the public's economy, by generating revenues, creating different jobs, opening doors for local investments, saving fuel, and maintenance money, which is usually, spent on private vehicles.

2- It produces much less air pollutants than private vehicles. A passenger car with a single occupant produces 89 lbs. of Carbon Dioxide (**CO_2**) per 100 passenger-miles, while a full bus with (50-70) travelers produces merely 14 lbs. **[Thomas Rubin, 2010]**

3- Public transportation system is much more fuel-efficient, this feature participates in the reduction of energy required for transportation per passenger-mile, by saving considerably more fuel than private transportation. **[NET, 2017]**.

4- It decreases traffic congestion, as these systems are able to carry more passengers in a much smaller space than separate vehicles, which sequentially decreases air contamination from lounging automobiles, and relief drivers from the stress that originates from driving every day in extremely congested roads. The huge difference in road space occupation is shown in Figure (2.10) **[NET, 2017]**.

5- Public transportation is safer than driving a private vehicle, the studies shows that public transportation is 10 times safer than using private cars, while traveling by express railways is 18 times safer. [**APTA, 2016].**

Figure (2.10): comparison between the road space occupied by a bus vs by individual vehicles. [Reddit, 2019]

2.9: Congestion Studies In Iraq:

Due to the vital importance that traffic congestion studies has, a fair number of transportation studies has been done in Iraq on this specific topic, in hopes of enhancing roads and reducing the increasing congestion problem, yet, there is a significant need for more studies that suggest appliable improvements and enhancements. The following section present a number of earlier studies:

► Al-Hillah City:

[**Ameerah Al- Hameed & Firas Alqatrani, 2020]** studied traffic congestions on urban transport system in Al-Hillah City. The study demonstrated that many causes have participated in increasing congestion in study locations, involving straight causes embodied by the enlarged urban growth of population and the increased standard. While the secondary causes were the small region of urban transportation system use in the original city plan as well as some technical and social aspects for the managerial establishments and population. The study located three sites where traffic congestions intensifies in the north, northeastern and southern entrance of Al-Hillah city. It also presented the recurrent times when traffic congestions intensifies in the times of religious occasions due to their geographic location. The study has come up with a set of conclusions and alternatives.

► Baghdad City:

[Ahmed Al-Jabbar , Ammar Shubber & Hussein Aziz, 2011] distributed public questionnaire on the staff of one of Baghdad's universities in order to collect information on the reasons of traffic congestion in the area, time waste in traffic jams, most congested areas and the possibility of constructing new facilities to relieve congestion. After analyzing the results a number of solutions were suggested, for example reducing police checkpoints and re-opening closed roadways and bridges.

[Ali Ahmed & Alaa Ahmed , 2017] analyzed the traffic congestion at Jordan's junction in Baghdad city using Sidra Software. The collected data involved delay time, traffic saturation , LOS, travel time and speed. The analysis of data showed that the intersection needed some major developments, like using an intelligent transportation system (ITS) To control traffic signals, or utilizing Closed-Circuit Television (CCTV) To help traffic offices in locating congestion points and eventually minimizing traffic jams and congestion.

[Humam Hasan, 2019] worked to analyze, evaluate and improve traffic operations for Al-Faris/Al-Arabee intersection in Baghdad City. The key outcomes of the study signified that this intersection functions with F level of service. Building of an under-pass at Al-Mansour Street will help in freeing Al-Faris/Al-Arabee intersection from about 50 % extra volume. After embracing the proposed geometrical design, the intersection was projected to function at LOS B and LOS D in the design year (2039).

[**Areej M. Abdulwahab & Muntathar A. Bader, 2020]** Studied Shaab - Selekh intersection in Baghdad city, a significant intersection that connects the heart of Baghdad City with the northern governorates. The study worked to identify the intersection level of service and suggest suitable improvements which embrace maintainable transportation plans, in order to develop the level of service and diminish traffic congestion.

[Farah S. Attab, Qais S. Banyhussan, 2020] studied the traffic network at AL-Karkh area in Baghdad City. This area located amid numerous streets; 14th July Street, Dimaishq Street, Mansour Street and 14th Ramadan Street. And their border intersections that included; Shaljia Intersection, Dimaishq Intersection, Deilal Intersection, Gailani intersection, and Topaji Intersection. The key outcome of this study is creating a new roadway to decrease the congestion impacts on the environment and on the transport system at the chosen streets. The proportions of traffic after constructing the suggested road was only 23% and 52 % from the original peak hour volume in study locations.

[Mohammed Zuhair Meki, and Maha Al-Mumaiz, 2021] worked to create a maintainable transport network in Baghdad City to operate a large traffic volumes with the least possible environmental impact. A railway transport system was proposed as it was found to be the best maintainable scheme, with recommended path and station locations planned to guarantee effective connections with the present road system. To evaluate the suggested system, the city was segmented into 15 sectors. The outcomes shown that the construction of such system would cause a significant decrease in travel time among most sectors. Moreover, the suggested system would alter the land-use next to stations, enhancing investment in housing and motivating the public to move from the congested city center.

► Basrah City:

[Wael Qasim Rashid, 2012] debated the factors and reasons that contributed to the escalation of bottlenecks and Traffic congestion in Basra City. It focused on economic factors mainly, as city people prefer private over public vehicle due to its advantages and low cost compared to the public transportation. The study had indicated the economic and social impacts and damages of congestion phenomenon , it also developed appropriate treatments and solutions to reduce congestion in the city in order to help decision-makers and specialists in facing this problem, as this study would contribute in increasing awareness and understanding of society to this problem.

► Karbala' City:

[Gandhi Sofia, Abdulhaq Al-Haddad & Israa Al-Haydari, 2018] made a study that worked on the estimation of traffic performance at the southern side of Karbala City road network, by studying Al-Tarbyia Street and Fatimah Al-Zahraa' Street, and evaluating their intersections operational performance. After completing the evaluation a number of proposals and improvements were presented. These improvements varied from altering signal timing strategy, geometric design, and changing intersections type.

The study area involved seven intersections. Video footage method was used to gather the traffic data of 27 approaches. Data was gathered from video recordings by EVENT computer program, and estimation and analysis of intersections was done by SYNCHRO program. While, estimation and analysis of both intersections and roundabouts was done using SIDRA INTERSECTIONS program. The best improvement was estimated for the goal year.

► Al-Kut City:

[Ihsan A. Jasim, Thaer Sh. Mahmood, Sohaib K. Al-Mamoori and Laheab A. Al-Maliki, 2021] Studied traffic congestion on urban roads in Al-Kut City in Wasit governorate**,** and worked to prove the link between congestion and urban land use. A mathematical model was created to demonstrate the connection among the land use distribution and traffic congestion in Al-Kut city, signifying that land use organization could reflect a substantial influence on congestion stages on urban roads in the short and long term.

► Erbil City:

[P. J. Muhammad Ali and R. H. Faraj, 2013] studied traffic congestion on the highway linking Sawaz district and Shaheedan district in Koya city in Erbil governorate. Congestion was measured by calculating the highway level of service. LOS of the studied road was found to be D. The study presented the actual sources of traffic congestion on this particular highway in Koya city and suggested a number of solutions and alternatives to eliminate the problem.

Summary:

This chapter specified traffic flow characteristics for urban roads, urban roads functional classification, two-way stop-controlled intersections and median U-Turns characteristics, which are chosen as study segments as addressed in the next chapter. Congestion problems in Urban areas were also presented in this chapter along with some of traffic congestion studies in Iraq. Study location characteristics and data collection are the topics of the chapter three.

CHAPTER THREE

METHODOLOGY & DATA COLLECTION

3.1: Introduction:

Technology evolution have made a boundless expanse of traffic data available, as it offered new methods of assembling different traffic data. With the fast urban expansion, gathering and evaluating traffic information is substantial to construct modern cities.

Traffic flow features must be gathered exclusively from the roadway. There are several methods of data assembly dependent on the requirement of the study. Several fundamentals controls data quality, every one of them can be arranged in a different way to achieve the required goals. This chapter presents study area characteristics, methodology, methods used for data collection and collected data.

3.2: Al-Hillah City Characteristics:

Babylon was the capital of the ancient Babylonian kingdom founded in Mesopotamia. Today, Babylon governorate still stands in the center of Iraq with an area of 5,119 Km^2. Whereas Al-Hillah city is the center of Babylon governorate. It is situated on a division of the Euphrates River, 100 km south of Baghdad and is adjacent to the historical city of Babylon. The population of Hillah City is now estimated at 615,000 people. **[Iraqi Central Statistical organization, 2021].**

Al-Hillah City is located in a mainly agrarian area, that is widely irrigated by Hillah water canal. The city embodies the principal connection point among the northern and southern governorates. Thus, there is an actual necessity to study the existing condition of Hillah urban roadway segments to deliver precise data, which is essential for its improvement. The study locations were chosen carefully due to many reasons.

Al-Hillah City roadways have experienced a lot of challenging circumstances, especially in the last decades, due to the huge increase in private vehicles ownership, and the fast growth of city population. On the other hand, the city experienced lack of roads maintenance, and roadways projects development. The studied locations are located within the urban area, which is distinguished by a great number of access points, conflicted movements, and random maneuvers, in addition to the diverse activities and land uses in these areas, such as commercial, governmental offices.

3.3: Study Sites:

There is an actual necessity to study the existing condition of Al-hillah urban roadway segments to deliver precise traffic volume data, which is essential for its improvement. The study segments were chosen carefully to represent some of urban roadways congestion problems in the city. Figure (A-1) in (Appendix A) shows the study locations on Al-Hillah City Masterplan. Figure (3.1) shows the full study area.

❖ ***The study location includes:***

- Al-Tuhmazia at grade-intersection.
- Street 60 Approach.
- Street 60 U-Turn.
- Al-Tuhmazia Approach.
- Al-Jamaa'ia Approach.
- Street 60 / Al-Taqah junction.

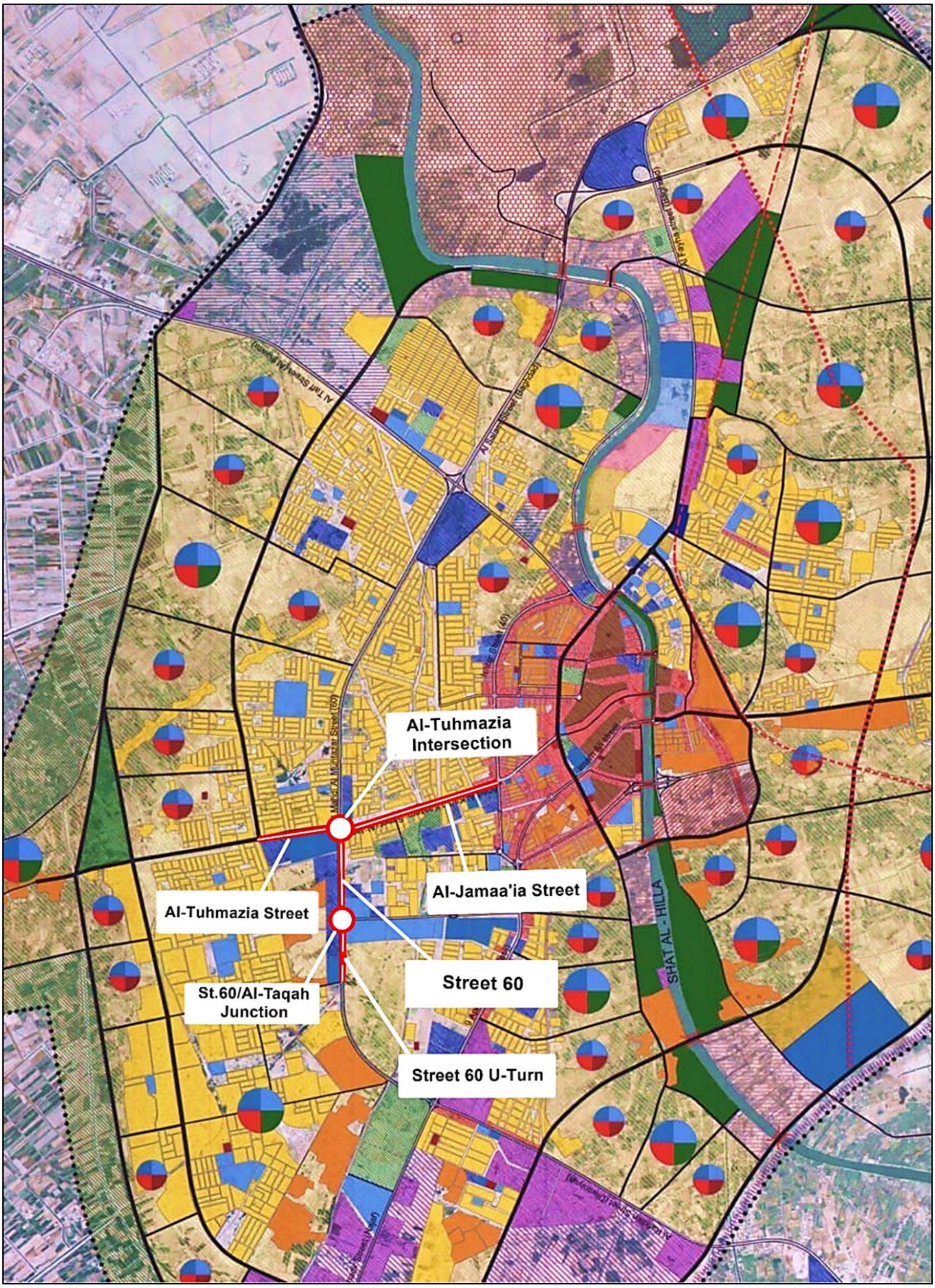

Figure (3.1): Al-Hillah City Masterplan. [Urban Planning Directorate, 2009]

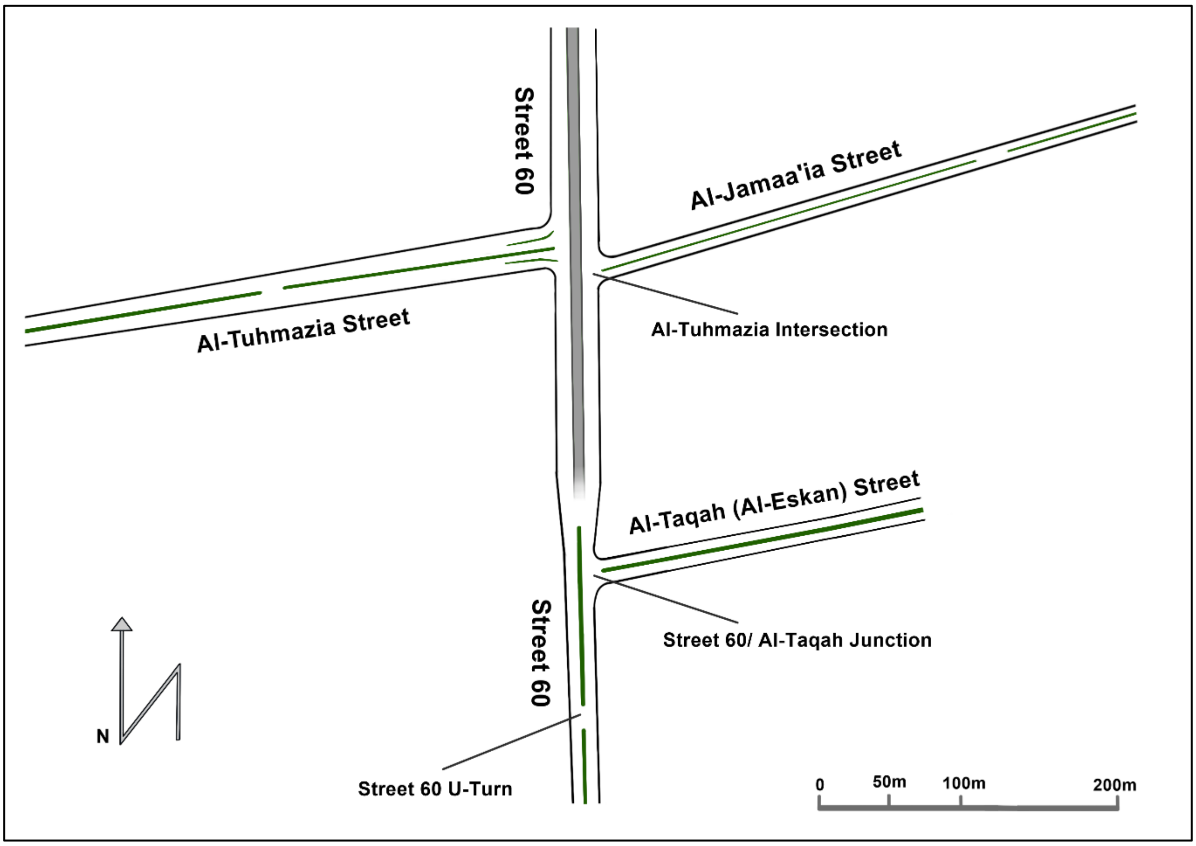

Figure (3.2): An illustration of Study Locations.

The following segment demonstrates study locations in detail.

3.3.1: Al-Tuhmazia At-Grade Intersection:

Al-Tuhmazia intersection is one of the major intersections in Hillah City; this four-leg at-grade intersection is located under Al-Tuhmazia intersection. It connects Street 60 with Al-Tuhmazia and Al-Jamaa'ia Streets, some of the most congested streets in Hillah City center. It is known by it high traffic density as it surrounded by a big commercial area that draws more traffic each day as many shops and small malls is located in this area. In addition to that, the surrounding neighborhoods has extended largely during the last five years as population largely increased.

The existence of the (Imam Al-Sadeq Hospital) right by the intersection is a good reason for the traffic congestion, not to mention having no parking lots for vehicles outside the hospital. This road is also near Al-Jamaa'ia, which is a ig commercial area that draws a lot of traffic. Figure (3.3) shows the current design of Al-Tuhmazia intersection.

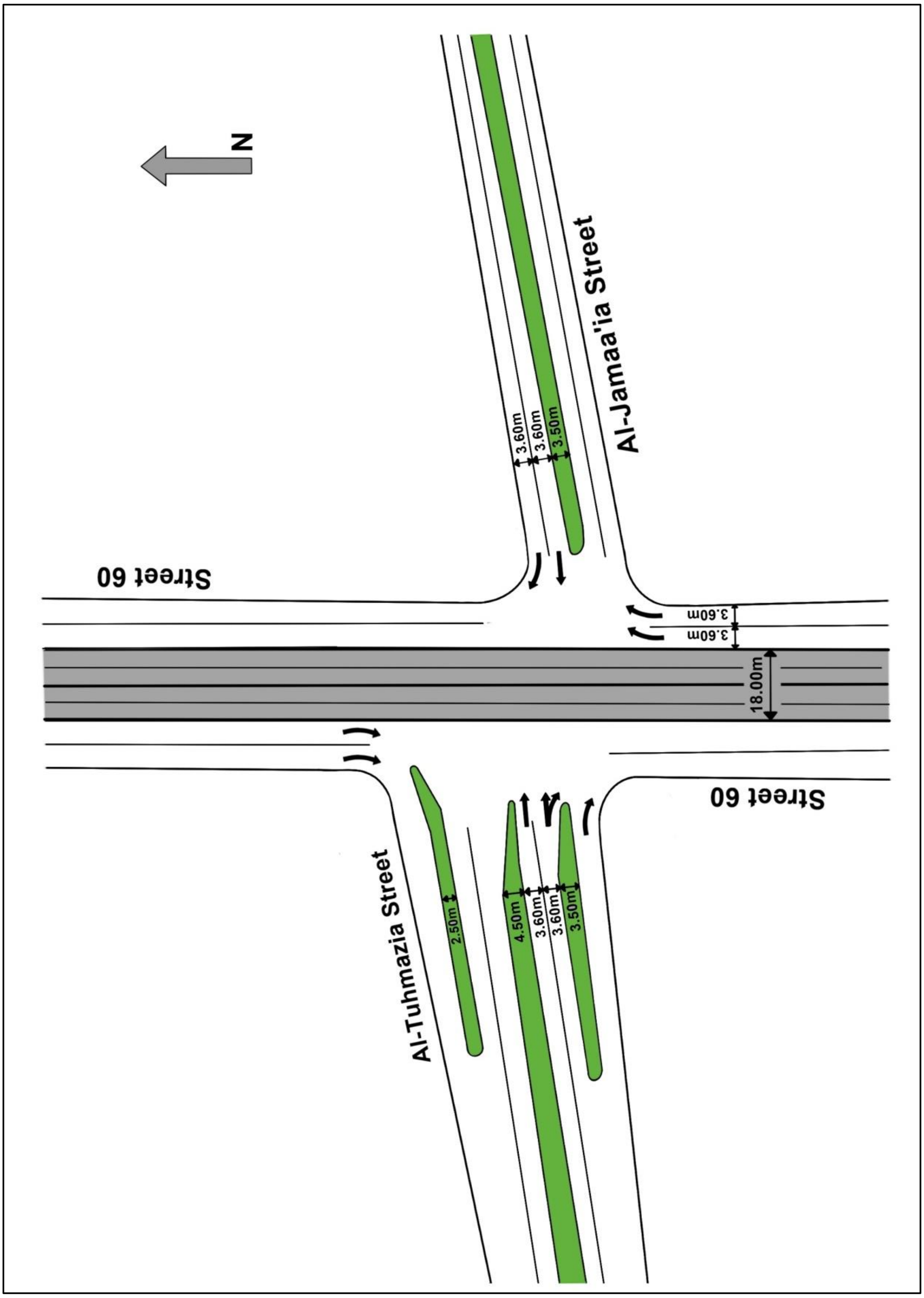

Figure (3.3): The Existing Design of Al-Tuhmazia at grade-intersection.

- **Main operational and design problems in Al-Tuhmazia at grade-intersection is:**

1- The intersection area suffers from a random overlapping traffic movements. The absence of traffic signals is one of the reasons that led to the chaotic traffic flow at this important intersection. Although placing traffic signals might increase delays, maintaining an intersection of this size without signalization is partially responsible of the current problem.

2- Currently, the turning movement from Street 60 to Al-Jamaa'ia Street is separated from the through movement from Al-Jamaa'ia Street to Al-Tuhmazia Street on both sides using plastic barriers. Therefore, a real separation islands could be designed to separate the two traffic movements.

3- The interference of pedestrians with vehicles that use the intersection. As pedestrians cross the intersection with a very random pattern and needs to be organized using a pedestrian crosswalk or traffic signals that gives pedestrians the right of the way to pass.

4- Heavy vehicles passing through this intersection crowds passenger cars and minibuses, which worsens congestion and delay problems.

Table (3.1) and (3.2) shows the collected traffic volume data for each approach.

❖ Al-Tuhmazia Intersection Traffic Volume Data:

Table (3.1): Al-Tuhmazia Intersection Traffic Data. (Passenger Cars + Buses+ Trucks)

Time		Al-Tuhmazia ST			Al-Jamaa'ia ST			ST 60 to Al-Tuhmazia			ST 60 to Al-Jamaa'ia		
		TH	LT	RT	TH	LT	RT	TH	LT	RT	TH	LT	RT
A.M	7:45-8:00	306	-	187	234	-	154	-	-	156	-	-	214
	8:00-8:15	294	-	209	355	-	146	-	-	144	-	-	247
	8:15-8:30	331	-	215	332	-	197	-	-	154	-	-	209
	8:30-8:45	357	-	263	397	-	158	-	-	166	-	-	183
Sum		1288		874	1318		655			620			853
P.M	12:00-12:15	292	-	63	236	-	96	-	-	127	-	-	106
	12:15-12:30	339	-	94	389	-	71	-	-	82	-	-	173
	12:30-12:45	357	-	125	438	-	144	-	-	153	-	-	284
	12:45-1:00	239	-	87	240	-	115	-	-	118	-	-	163
Sum		1227		369	1303		426			480			560

Table (3.2): Al-Tuhmazia Intersection Percentage of Heavy Vehicles.

Approach	Movements	Ave. Percentage of Heavy Vehicles HV%
From Al-Tuhmazia St.	Right Turn	10%
	Through	11%
From Al-Jamaa'ia St.	Right Turn	6%
	Through	7%

Street 60 to Al-Tuhmazia	**Right Turn**	9%
Street 60 to Al-Jamaa'ia	**Right Turn**	10%

3.3.2: Street 60 Approach:

This road is classified as urban multilane, it has 3 lanes in each direction with length of (8.622 Km) it is a divided with sidewalk. This street is one of the most important streets in Hillah City. As it is located in the city center, it overlooks the most important neighborhoods, like Al-Muharibeen neighborhood and Al-Karama neighborhood, which are two of the largest neighborhoods in the city of Hillah. This street is important and vital, as it is considered one of the commercial streets, and this street connects the areas north of Babil and Baghdad from the northern side. From the southern side, it connects the southern provinces with the holy city of Karbala. Al-Tuhmazia intersection being the center intersection on this street, located opposite of Al-Fayhaa National Hospital and Imam Al-Sadeq Hospital. In addition, on both sides of 60th Street, there are the most important public services departments.

- **Main operational and design problems in this selected section of Street 60 is:**

1- The presence of many government and private work offices has led to taking some of the original width of the street as a parking place for vehicles.

2- The width in the original design of this street is supposed to be no less than 60 meters from the property to the property on the opposite side. Including median islands and sidewalks. Still, the infringement of the adjacent property on the width of the street led to the reduction of the roadway width from about 20 meters to maximum 12 meters. Which affected the road and reduced the capacity of the road.

3- The constant random conflicts between traffic movements had led to an increase in the possibility of traffic accidents, and according to traffic police yearly reports, this section has a high rate of traffic accidents. **[Babylon Traffic Police Office, 2021]**

❖ **Street 60 Traffic Volume Data:**

Table (3.3) and (3.4) shows the collected traffic volume and speed data for Street 60 approach.

Table (3.3): Street 60 Traffic Volume Data and Heavy Vehicles Percentage.

Time (15 min)		PC	Bus	Trucks	Average HV%
Northbound Direction					
AM	7:45 – 8:00	583	47	16	11%
	8:00 – 8:15	686	63	23	
	8:15 – 8:30	710	61	29	
	8:30 – 8:45	536	52	20	
Sum		2515	223	88	
PM	12:45 - 1:00	433	33	11	12%
	1:00 - 1:15	575	48	18	
	1:15 - 1:30	523	49	21	
	1:30 - 1:45	395	42	13	
Sum		1926	172	63	
Southbound Direction					
AM	7:45 – 8:00	665	74	21	
	8:00 – 8:15	782	81	37	

	8:15 – 8:30	795	97	28	13%
	8:30 – 8:45	678	69	29	
Sum		2920	321	115	
PM	12:45 - 1:00	533	40	7	12%
	1:00 - 1:15	421	34	14	
	1:15 - 1:30	548	51	16	
	1:30 - 1:45	411	49	19	
Sum		1913	174	56	

Table (3.4): Average speed and delay for Street 60 segment.

Time	Average Travel Speed (mph)			Average Delay Under Posted Speed (hr/veh)		
	Passenger Cars	Buses	Trucks	Passenger Cars	Buses	Trucks
7:45 – 8:00	36.3	32.6	29.4	0.129	0.228	0.345
8:00 – 8:15	36.8	33.4	31.3			
8:15 – 8:30	36.5	33.2	29.5			
8:30 – 8:45	37.1	32.9	30.8			
12:45 - 1:00	43.7	38.1	35.2	0.125	0.207	0.312
1:00 - 1:15	44.0	39.8	34.1			
1:15 - 1:30	43.7	38.2	34.6			
1:30 - 1:45	43.9	39.7	35.5			

3.3.3: Street 60 Median U-turn:

This U-turn is a severely congested point. As it is near (Al-Moahad Garage) which is a garage for vehicles coming from and going to Baghdad City. In addition to that, through traffic from street 60 clashes with the left turning traffic coming from Al-Tuhmazia intersection and heading to Al-Jamaa'ia street or Al-Tuhmazia street. This conflict causes a lot of traffic accidents, so working to decrease conflict points at this U-turn could have a great effect on minimizing traffic accidents. Figure (3.4) shows the current design of Street 60 U-Turn.

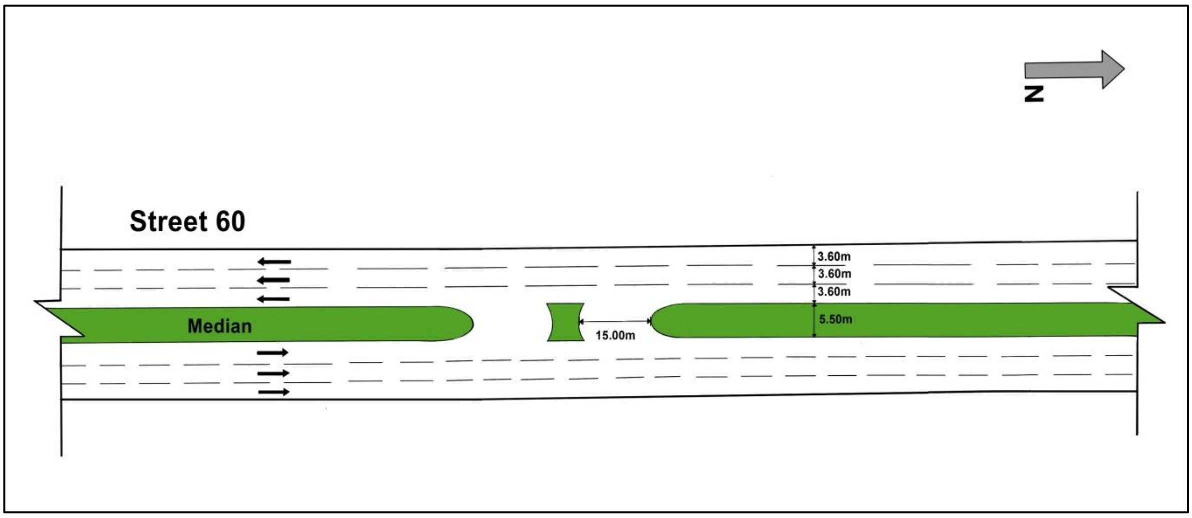

Figure (3.4): The Existing Design of Street 60 U-Turn.

- **Main operational and design problems in this selected section of Street 60 is:**

1- Street 60 through movements conflicts with the usual turning movements, as the turning traffic moves at a lower speed than the through traffic.. Therefore, it necessary to separate the turning movements from street 60 through movement to reduce accidents and traffic congestion and delay problems that actively reduces the average travel speed of on this street.

2- Due to the large traffic that travels on this street and the basic design of this u-turn. The possibility of traffic accidents is as high as ever be on this specific section, therefore, a new design that support high safety levels must be adopted to ensure safe traveling on this section of the road.

❖ **Street 60 U-Turn Traffic Volume Data:**

Table (3.5) shows the collected traffic volume for Street 60 U-Turn.

Table (3.5): Street 60 U-Turn Traffic Volume Data and Heavy Vehicles Percentage.

Time (15 min)		PC	Bus	Trucks	Average HV%
AM	7:45 – 8:00	351	21	15	10%
	8:00 – 8:15	340	44	9	
	8:15 – 8:30	491	38	18	
	8:30 – 8:45	462	35	12	
Sum		1644	138	54	
PM	12:45 - 1:00	296	21	11	10%
	1:00 - 1:15	285	37	12	
	1:15 - 1:30	379	18	15	
	1:30 - 1:45	285	17	9	
Sum		1245	93	47	

3.3.4: Al-Tuhmazia Approach:

This road is classified as an urban multilane, with 3 lanes in each direction, and a length of 1.850 Km, it is a divided with sidewalk. This street is located in the center of the city and is one of the streets that connects Street 60 with Street 80. It overlooks Imam Al-Sadeq Hospital, and is surrounded by many commercial shops and workplaces. This street attracts great traffic demand due to its important location.

❖ **Main operational and design problems in Al-Tuhmazia Street is:**

1- The parking area next to the Imam Al-Sadeq Hospital (Turkish Hospital) usually occupies a big portion of the street and reduces the actual usable width of the street. A parking lot is ideal to help relieving this problem.

2- The presence of pavements depressions and other distresses along the street makes drivers compelled to reduce vehicle speed in order to cross it, this problem led to an increase in the average travel time on this street and reduced the levels of travel safety.

❖ **Al-Tuhmazia Street Traffic Volume Data:**

Table (3.6) and (3.7) shows the collected traffic volume and speed data for Al-Tuhmazia Street approach.

Table (3.6): Al-Tuhmazia Street Traffic Volume Data and Heavy Vehicles Percentage.

Time (15 min)		PC	Bus	Trucks	Average HV%
Northbound Direction					
AM	**7:45 – 8:00**	432	43	26	12%
	8:00 – 8:15	673	48	19	
	8:15 – 8:30	559	59	27	
	8:30 – 8:45	519	51	22	
Sum		2183	201	94	
PM	**12:45 - 1:00**	417	34	12	10%
	1:00 - 1:15	585	45	13	
	1:15 - 1:30	461	40	10	
	1:30 - 1:45	388	49	14	
Sum		1851	168	49	

Southbound Direction					
AM	7:45 – 8:00	658	49	18	10%
	8:00 – 8:15	593	45	27	
	8:15 – 8:30	578	59	19	
	8:30 – 8:45	642	44	13	
Sum		2471	197	77	
PM	12:45 - 1:00	474	45	10	10%
	1:00 - 1:15	395	39	9	
	1:15 - 1:30	493	33	13	
	1:30 - 1:45	367	47	11	
Sum		1729	164	43	

Table (3.7): Average speed and delay for Al-Tuhmazia Street.

Time	Average Travel Speed (mph)			Average Delay Under Posted Speed (hr/veh)		
	Passenger Cars	Buses	Trucks	Passenger Cars	Buses	Trucks
7:45 – 8:00	41.7	37.1	34.8	0.134	0.238	0.380
8:00 – 8:15	41.9	38.0	34.3			
8:15 – 8:30	40.1	38.2	35.0			
8:30 – 8:45	42.8	39.9	34.9			
12:45 - 1:00	44.2	40.5	37.2	0.123	0.177	0.317
1:00 - 1:15	43.8	41.8	37.7			
1:15 - 1:30	43.1	41.2	38.6			

1:30 - 1:45	43.3	40.9	38.1			

3.3.5: Al-Jamaa'ia Approach:

This road is classified as urban multilane, with 2 lanes in each direction, and a length of 0.740 Km, it is a divided two-lane with sidewalk. It is one of the most important streets in city center, as it connects Street 60 with Street 40. This street passes through Al-Jamaa'ia district, which is one of the central commercial areas that is usually crowded with shoppers, as it surrounded by many commercial shops, restaurants and supermarkets, not to mention that this street overlooks Al-Jamaa'ia Park.

❖ **Main operational and design problems in Al-Jamaa'ia Street is:**

1- Al-Jamaa'ia Street is a relatively narrow street, as the width of the street is not adequate for traffic volumes traveling on it, which are usually large, considering this street includes a large number of shopping centers and restaurants, in addition to the presence of a public park. Congestion occurs frequently at many times of the day, at morning, evening and even at night peak periods, which led to frequent queues of vehicles.

2- The presence of a large number of shopping centers, restaurants, pharmacies, etc., and the lack of parking lots, vehicles usually park in the street, even double-parking. which reduces the usable width of the road and decreases road capacity, which in turn worsens the current congestion problem.

3- The median is relatively wide on this street, with width that is nearly 60% of street lanes width in one direction, so the median width should be reduced to provide more space for street lanes.

4- Shops and sellers occupying a large area of the sidewalk, has led pedestrians to walk on street lanes instead of the sidewalk, which affected flow of traffic and created conflicts between pedestrians and vehicles, all that increased the possibility of traffic accidents and reduced safety levels for pedestrians.

❖ **Al-Jamaa'ia Street Traffic Volume Data:**

Table (3.8) and (3.9) shows the collected traffic volume and speed data for Al-Jamaa'ia Street approach.

Table (3.8): Al-Jamaa'ia Street Traffic Volume Data and Heavy Vehicles Percentage.

Time (15 min)		PC	Bus	Trucks	Average HV%
Northbound Direction					
AM	**7:45 – 8:00**	594	31	12	7%
	8:00 – 8:15	671	23	11	
	8:15 – 8:30	566	42	13	
	8:30 – 8:45	647	39	15	
Sum		2478	135	51	
PM	**12:45 - 1:00**	461	29	8	7%
	1:00 - 1:15	354	22	7	
	1:15 - 1:30	557	31	9	
	1:30 - 1:45	483	25	10	
Sum		1855	107	34	
Southbound Direction					
AM	**7:45 – 8:00**	493	18	10	6%
	8:00 – 8:15	547	23	10	
	8:15 – 8:30	608	37	15	
	8:30 – 8:45	590	23	13	
Sum		2338	101	48	

PM	12:45 - 1:00	491	21	8	6%
	1:00 - 1:15	429	29	9	
	1:15 - 1:30	536	28	12	
	1:30 - 1:45	480	20	11	
Sum		1936	98	40	

Table (3.9): Average speed and delay for Al-Jamaa'ia Street.

Time	Average Travel Speed (mph)			Average Delay Under Posted Speed (hr/veh)		
	Passenger Cars	Buses	Trucks	Passenger Cars	Buses	Trucks
7:45 – 8:00	40.3	38.2	31.4	0.152	0.257	0.315
8:00 – 8:15	39.1	37.8	32.8			
8:15 – 8:30	40.8	38.7	30.5			
8:30 – 8:45	40.0	37.1	30.1			
12:45 - 1:00	44.1	41.1	34.5	0.144	0.239	0.368
1:00 - 1:15	43.7	41.9	35.1			
1:15 - 1:30	43.4	40.8	35.8			
1:30 - 1:45	42.3	40.7	35.9			

3.3.6: Street 60 / Al-Taqah Junction:

This three legs intersection is located next to Al-Tuhmazia intersection, it is a congested point, traffic volumes coming from Al-Jamaa'ia street, Al-Tuhmazia street and Street 60 and heading to Al-Taqah street is what causes the congestion at the junction. Figure (3.5) shows the current design of Street 60/Al-Taqah T-Intersection.

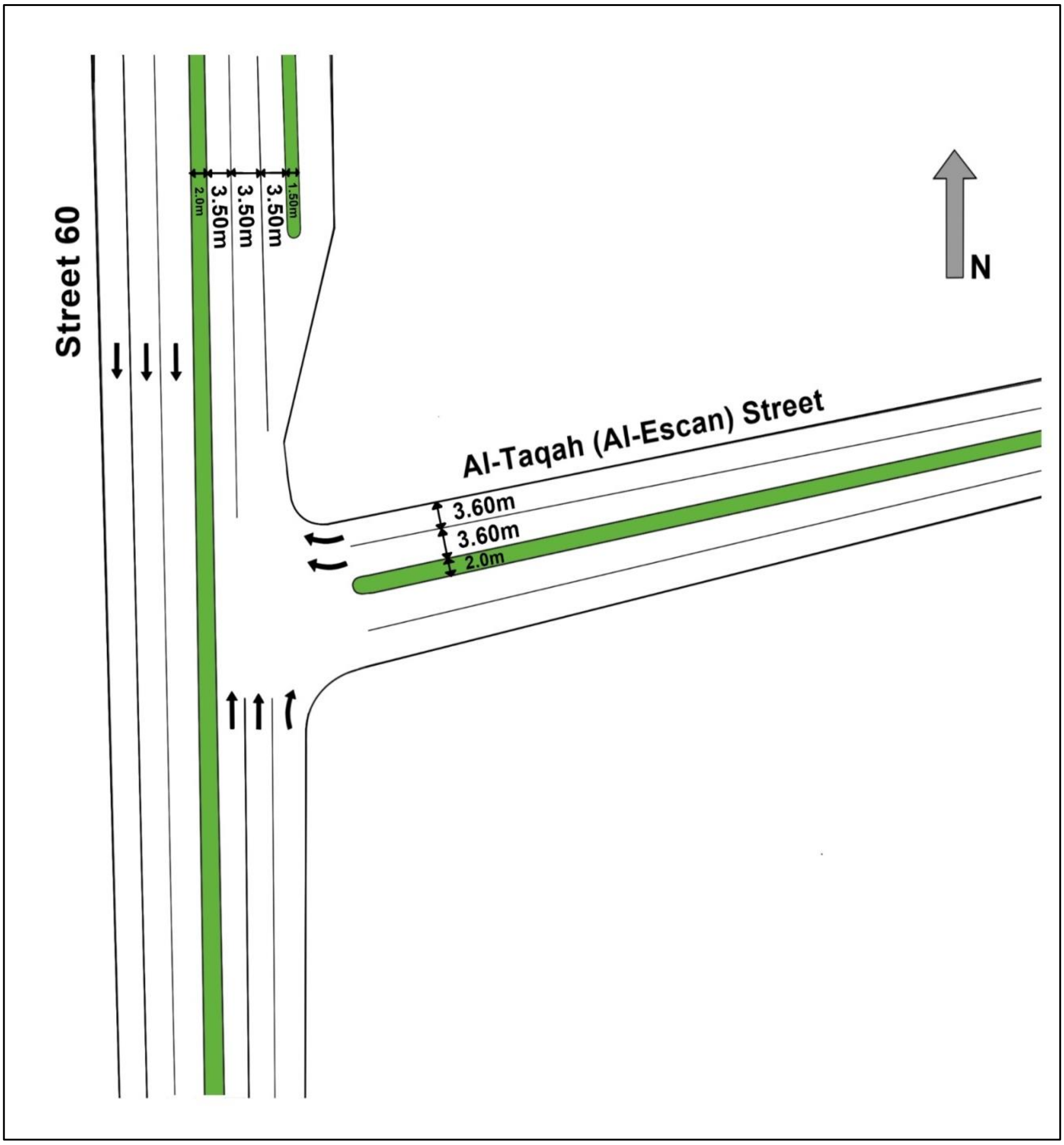

Figure (3.5): The Existing Design of Street 60 / Al-Taqah intersection.

❖ **Main operational and design problems in Street 60/ Al-Taqah T-Junction is:**

1- This location suffers from the repeated vehicles gatherings right in front of the junction due to the overlapping through and right turning movements, which actively delays the passage of vehicles that want to enter Al-Taqah Street from Street 60. Therefore, the turning traffic that wants to enter Al-Taqah Street must be separated from the through traffic of Street 60.

2- The existence of a road bottleneck just before this junction, has led to a typical and expected vehicle queues. Therefore, a new design that eliminates the existing bottleneck could partially relief the current problem.

❖ **Street 60/ Al-Taqah Junction Traffic Volume Data:**

Table (3.10) shows the collected traffic volume for Street 60/ Al-Taqah Junction.

Table (3.10): Street 60/ Al-Taqah Junction Traffic Volume Data and Heavy Vehicles Percentage.

Time (15 min)		PC	Bus	Trucks	Average HV%
Street 60 Through Movement					
AM	**7:45 – 8:00**	245	26	11	12%
	8:00 – 8:15	383	34	10	
	8:15 – 8:30	267	39	16	
	8:30 – 8:45	338	25	9	
Sum		1233	124	46	
PM	**12:45 - 1:00**	276	34	11	13%
	1:00 - 1:15	347	25	9	
	1:15 - 1:30	299	47	14	
	1:30 - 1:45	263	31	8	
Sum		1185	137	42	
Street 60 Right Turning Movement					
AM	**7:45 – 8:00**	132	8	-	9%
	8:00 – 8:15	112	13	-	
	8:15 – 8:30	92	10	-	
	8:30 – 8:45	107	14	-	

Sum		443	45	-	
PM	**12:45 - 1:00**	97	7	-	8%
	1:00 - 1:15	106	13	-	
	1:15 - 1:30	123	8	-	
	1:30 - 1:45	93	11	-	
Sum		419	39	-	
Al-Taqah Street Right Turning Movement					
AM	**7:45 – 8:00**	102	6	-	5%
	8:00 – 8:15	95	3	-	
	8:15 – 8:30	82	7	-	
	8:30 – 8:45	124	7	-	
Sum		403	23	-	
PM	**12:45 - 1:00**	84	5	-	8%
	1:00 - 1:15	96	8	-	
	1:15 - 1:30	119	13	-	
	1:30 - 1:45	90	10	-	
Sum		389	36	-	

3.4: General Causes of Congestion in Study Area:

After initial investigation at study area a number of design and traffic operations issues were spotted, these issues strongly contributes in the congestion problem at these locations, the detected issues for each study location summarized in the following points:

1- The Lack of Public Transportation Systems:

Many factors led to the current poor public transportation system in Iraq, including:

1- Neglecting the transport file and the laws that regulate the movement of transport and communications, and passing the crisis from previous generations to succeeding generations in successive governments.

2 - Unavailability of public transport systems, such as metros, subway trains, trams, and others due to economic and political reasons.

3 - The shortage of public buses, and not facilitating the usage of this mean of transportation to the public.

4 - Randomness and absence of thoughtful and organized urban and engineering planning.

2- Parking Difficulties:

Al-Hillah City suffers from serious parking problems. On daily basis, people waste a lot of time searching for a place to park their vehicles, resorting to park in prohibited places, sidewalks and street corners, which made the sidewalks of Al-Hillah City turn into parking lots and car stations. These problems led to vehicle owners suffering and discontent of residents and pedestrians.

2- Bad Traffic Management:

Roadway mismanagement is one of the important problems that affect the quality of traffic flow in the city. The main reason for this problem is the lack of commitment and qualification of local traffic police in organizing traffic and holding violators accountable, especially in congestion areas. Not to mention the government’s lack of interest in legislating laws that emphasize obligation roadways rules.

3.5: Study Period:

Several inspections has been done to decide on the most suitable time to collect data. Peak hours were decided by inspecting the traffic volumes at different hours of the day, roadway segments were inspected and police officers were interviewed to collect the needed data for study. Peak hours were found to be between (7:45 – 8:45) A.M and between (1:45-2:45) P.M. Video records of each segment during a regular workdays (Mondays, Tuesdays and Wednesdays) were inspected. The surveys and data collection were done in January, February and March of 2021, with video recordings for volume data collection. The peak hour data was divided into (15 Minutes) intervals. Table (3.11) shows volume data collection dates for each study location.

Table (3.11): Volume Data Collection dates for each study location.

Study Location	Date	Day	Data collection period
Al-Jamaa'ia Street	20/1/2021	Wednesday	7:45-8:45 AM 1:45- 2:45 PM
Al-Tuhmazia at-grade Intersection	25/1/2021	Monday	7:45-8:45 AM 1:45- 2:45 PM
Street 60	26/1/2021	Tuesday	7:45-8:45 AM 1:45- 2:45 PM
Al-Tuhmazia Street	27/1/2021	Wednesday	7:45-8:45 AM 1:45- 2:45 PM
Street 60 / Al-Taqah Junction	1/2/2021	Monday	7:45-8:45 AM 1:45- 2:45 PM

3.6: Segmentation of Study Locations:

To make the process of data collection and analysis easier, the study locations were divided into segments. A segment is "A portion of road which capacity analysis is executed, it is one directional distance with two end points" **[HCM, 2010]**

In order to analyze a roadway or a traffic facility, it must be divided to separate units which are next to each other and work as one facility. For multilane arterials points and links are the usual divisions. A point embodies the frontier among links, an intersection or a junction usually characterizes it. A link on the other hand embodies a roadway section between two points. A segment is the link with its two border points.

3.7: Data Collection Methods:

In this study, data was collected after a detailed investigation of the selected study segments. First, geometric data was obtained by measuring Lane widths, Sidewalk with median island widths. Dimensions were collected by hand using measuring tape with aid of information obtained from Hillah Resident Engineer Department.

Then, traffic volume data was collected by using video recordings, with the aid of CCTV (Closed-circuit television) footage from Hillah City Hall office.

3.7.1: Geometric Data Collection:

Geometric data is essential for design and analysis of different traffic facilities; this kind of data do not fluctuate daily. On the other hand, traffic data fluctuates on daily basis. **[FHWA, 2017]**

Geometric data for all roadway segments, junctions and intersections were collected from Al-Hillah City municipality office. With the aid of the collected geometric data, junctions and intersection included in the study area were illustrated with details and accurate dimensions. The geometric features of Multilane Segments are demonstrated in Table (3.12). while Street 60 / Al-

Taqah Junction, and Al-Tuhmazia Intersection are demonstrated in Table (3.13).

Table (3.12): Geometric features of Multilane Segments at study area.

Multilane Name	From	To	Segment Length (km)	No. of lanes	Approach Width (m)	Lane Width (m)	Median Width (m)
Street 60	Street 60 U-Turn	Tuhmazia Intersection	0.83	3	10.75	3.60	4.5
Al-Tuhmazia Street	Tuhmazia Intersection	Street.80/ Tuhmazia Intersection.	1.85	3	10.5	3.60	5
Al-Jamaa'ia Street	Jamaa'ia Intersection	Tuhmazia Intersection.	1.42	2	8.5	3.60	5.5

Table (3.13): Geometric features of Junctions/ Intersections at study area.

Intersection/Junction	Approach	No. of lanes	Approach Width (m)	Lane Width (m)	Median Width (m)
Street 60 / Al-Taqah Junction.	N	3	10.5	3.5	4.5
	NE	2	9.75	3.75	5
	S	3	10.5	3.5	17.5*

Al-Tuhmazia Intersection	E	2	8.5	3.6	5
	N	3	10.5	3.5	17.5*
	W	3	10.2	3.5	4.5
* Broad median due to the existence of Al-Tuhmazia intersection over-pass.					

3.7.2: Volume Data Collection:

Collecting data of traffic volumes is one of the fundamental necessities for the analysis and management of roads. Volume Count is calculating the number of vehicles traveling over a roadway during a specified time interval. It's utilized to compute the roadway capacity, Level of Service (LOS) and other essential measures of effectiveness.

Traffic volume count was obtained from video recordings of study segments, and categorized into three groups, passenger cars (PC), buses and trucks (HV), Heavy vehicles are described as "heavy vehicles are defined as any vehicle that has more than four tires touching the pavement" **[HCM, 2010]**

It is essential to convert heavy vehicles to their passenger car equivalent units (PCU), in order to carry on the required analysis accurately. Traffic volume videos used for analysis were divided into 15-minutes periods throughout the peak hour. Collected traffic volume data and heavy vehicles percentage for each multilane segment and intersection are presented in Tables (3.1) to (3.6).

3.7.3: Speed Data Collection:

Spot speed is the immediate velocity of an automobile at a certain position. It can be used for congestion and incidents analysis. The average spot travel speed of a roadway segment is the (Time Mean Speed) as the spot travel speed collection requires collecting travel time over a specified section length. **[Tom Mathew, 2017]**

Travel speed data was collected manually using a stopwatch and a measuring tape, this method was used as the study sections were surveyed over a relatively short time period. The stopwatch technique is a fast and low-cost way to gather fairly accurate travel time data. **[A. Abushaban & S. Elaish, 2011]**

This method has two restrictions, first; the total of automobiles on the section must be 100 veh or more, second; length between the two border points must be at least 100 m. In this study section length of (100 m) was chosen for each segment of the studied urban streets in order to satisfy the minimum requirements of this method.

To measure travel time with stopwatch method, the length of road section (AB) must be measured using measuring tape, assuming the section length is (X) in (mile), a vehicle passes the road section from point A to point B in a (T) period of time, where (T) is the travel time in (hr). Spot travel speed (mph) can be calculated from Equation (3.1).

$$\boldsymbol{Spot\ Speed\ (S) = \frac{Section\ Length\ (L)}{Travel\ Time\ (T)}} \ldots\ldots..(\mathbf{3.1})$$

The watch should be started as soon as the front wheels of the specified vehicle passes on point A, and stopped immediately when the front wheels of same vehicle passes on point B. Figure (3.2) shows the methodology of speed data collection.

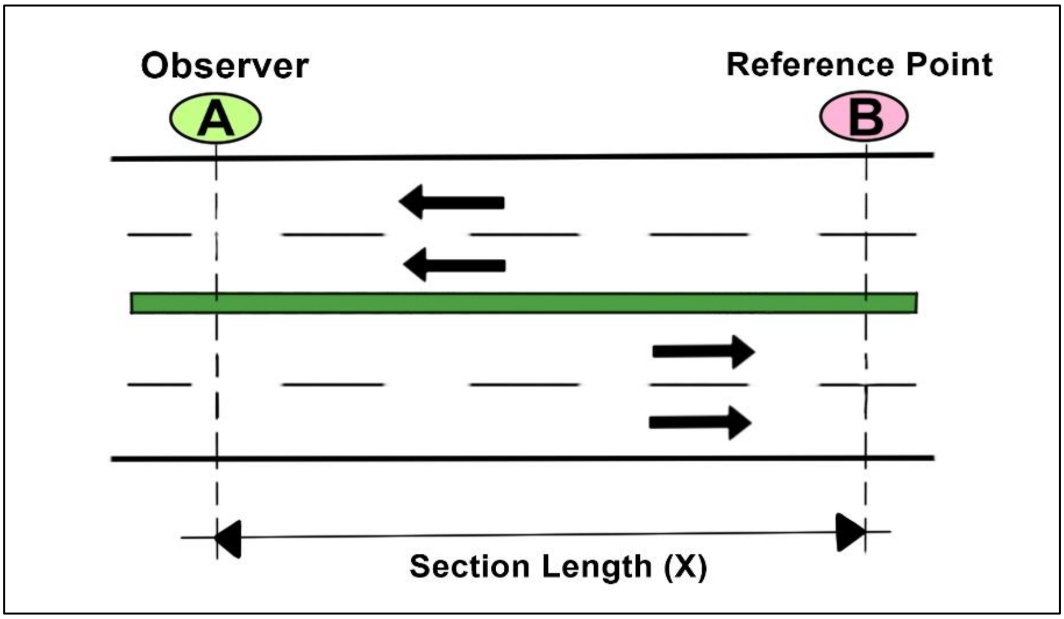

Figure (3.6): Spot Speed Data Collection by Stopwatch Method.

3.8: Traffic Operations Analysis Software:

Computer software of traffic analysis delivers a calculated demonstration of traffic data on diverse transportation systems. To accomplish a better breakdown and exact details of the operational performance of the investigated facility. These ready traffic simulations can calculate the impact of traffic controls.

software that were used in this research to study data and achieve outcomes, beside additional supporting programs are:

3.8.1: Smart Traffic Analyzer (STA) Program:

Traffic volume count was acquired from the recorded video clips using this (Smart Traffic Analyzer (STA)) computer program. This program was developed by (Picomixer) Technology Company.

It is capable of analyzing traffic using artificial intelligence and video processing, detecting, counting and categorizing vehicles in different classes, calculating average traffic volume, calculating the average speed of vehicles, detecting traffic incidents, providing applicable reports in different forms, including tables, charts and EXCEL files. Not to mention that this program is able to operate in two modes: online (real-time connection to the camera) and offline (video files).

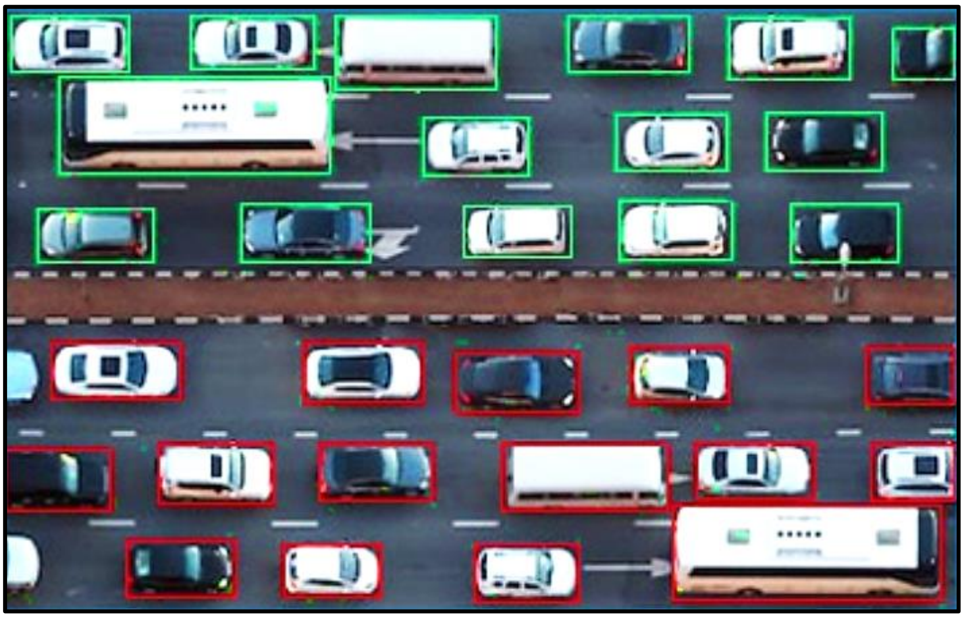

Figure (3.7): (STA) Program vehicle detecting process.

STA is a specialized tool for urban road/streets Traffic Administration to detect traffic accidents, volume count and speed data collection, based on artificial visualization (artificial intelligence and video handling). This program have been tested and set up in diverse ecological and climate settings, so in the circumstance of suitable sets and least practical requirements, this program will offer great performance and effectiveness.

Figure (3.3) and (3.4) shows a screenshot of (STA) program volume counts and classification of video records.

Figure (3.8): Screenshot from the (STA) Program.

3.8.2: Highway Capacity Software (HCS+ T7F):

The Highway Capacity Software (HCS 2010) executes the procedures specified in the Highway Capacity Manual (HCM 2010) for evaluating capacity and calculating levels of service for Arterials, Un-signalized and Signalized Intersections and, Freeway sections, Weaving segments, Ramps and junctions, Two-Lane Highways and Multilane Highways. Highway Capacity Manual (HCM) Model is widely used for the operational analysis of traffic conditions on various transportation facilities as many traffic analysis software tools uses the HCM delay model. Figure (3.5) methodology to decide multilane level of service. Figure (3.6) shows (HCS+T7F) program data input process.

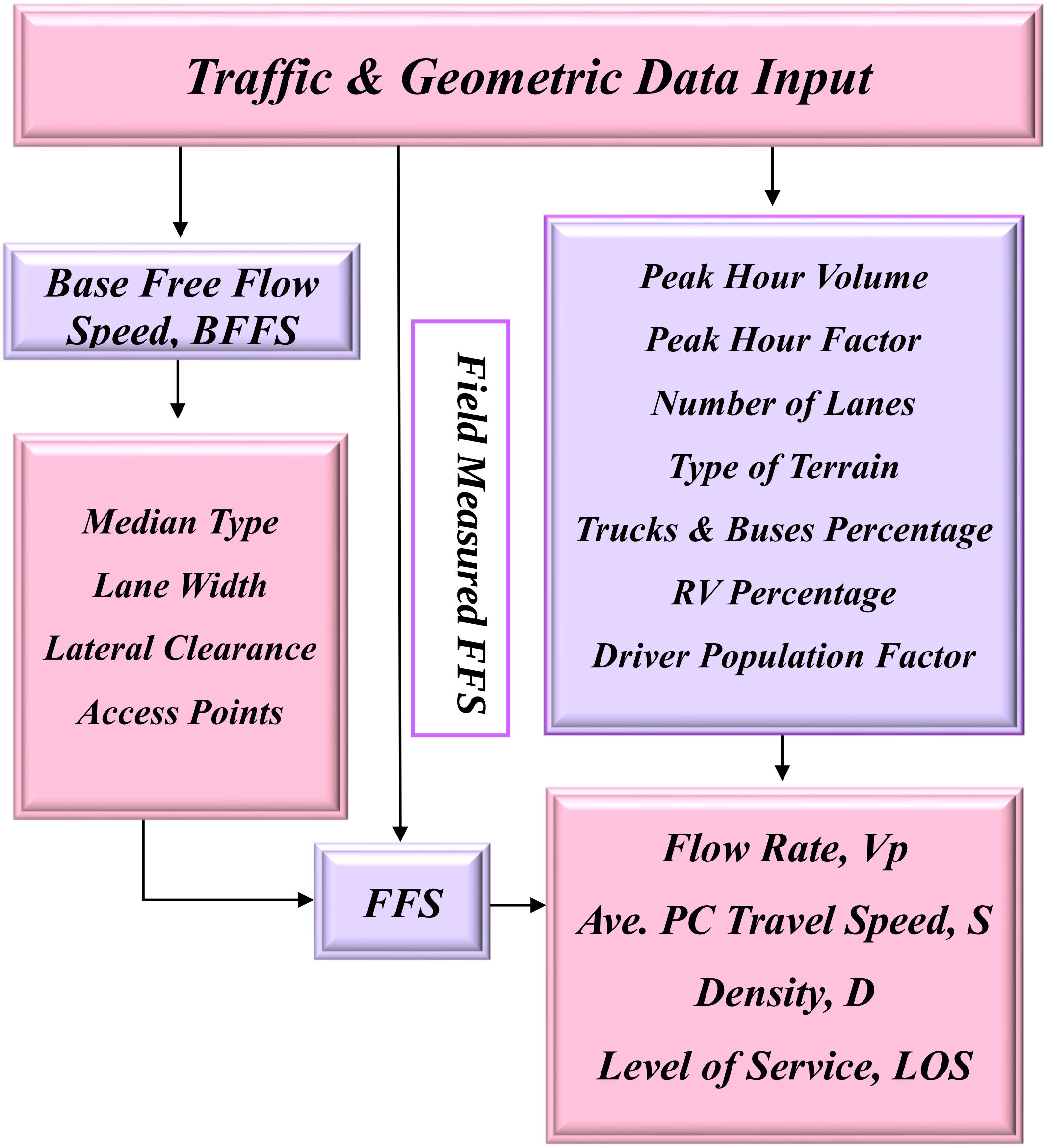

Figure (3.9): (HCS+T7F) Methodology for Calculating Multilane Segments LOS.

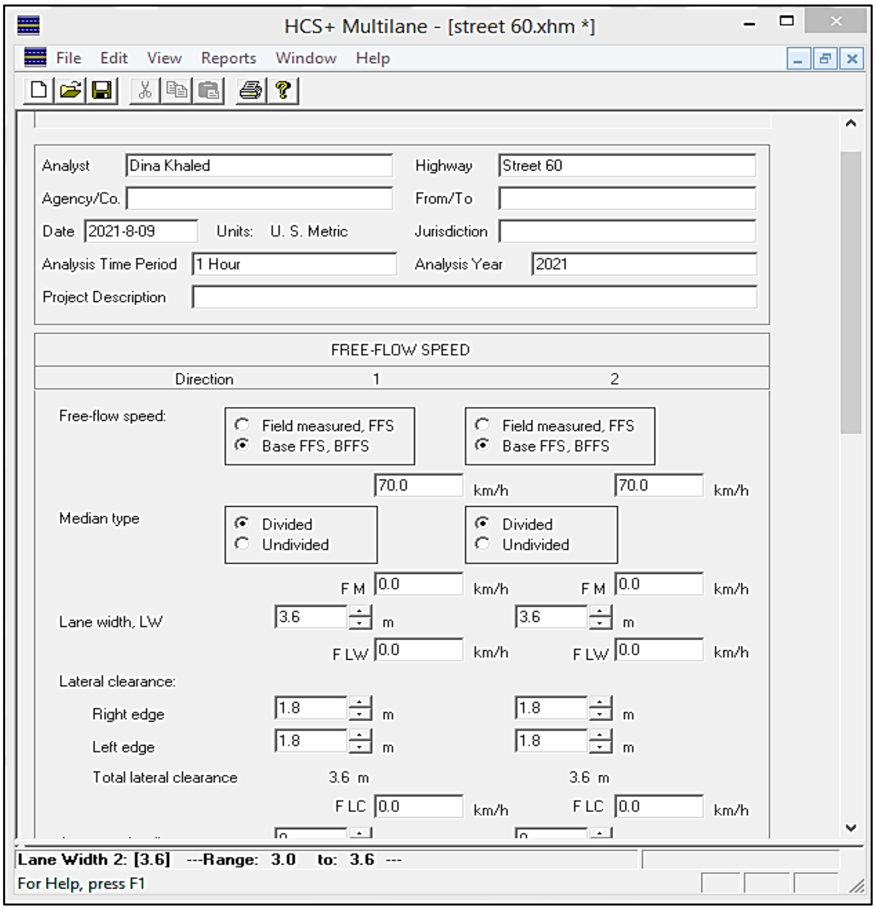

Figure (3.10): (HCS+T7F) Software Multilane Analysis Data Input.

3.8.3: Synchro 6.0:

Synchro is traffic analysis and enhancement computer program. This program works with assessment of the 2010 & 2000 Highway Capacity Manual's (HCM), for signalized, unsignalized intersections and roundabouts. This program provides several set-ups for each file. Since the program is simple and convenient, any project analysis and modeling can be done in few days. Figure (3.7) shows (Synchro) program methodology to decide level of service of stop-controlled intersections.

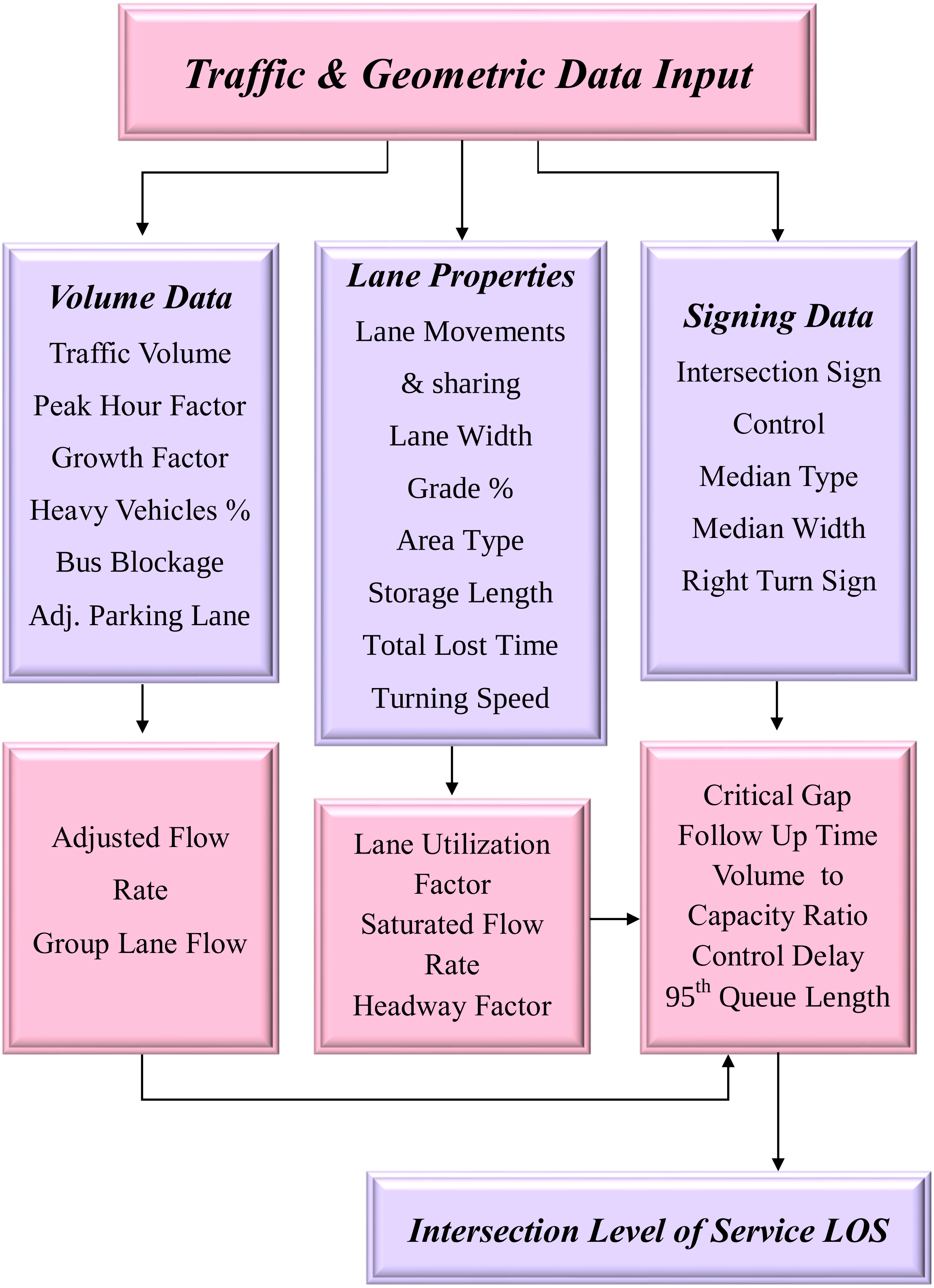

Figure (3.11): (Synchro 6.0) Software Methodology for Calculating Stop Controlled Intersections LOS.

Summary

The fundamental concept this chapter focused on; is the techniques used for data collection. Traffic volume data was gathered from video footages. Collected data were then organized and categorized by (STA) computer software. Initial investigation data shown that the peak period was ranging between (7:45-8:45 A.M.). this chapter also presented different computer software used in this study. Data analysis, assessment and presentation of study segments enhancements are the topics of the following chapter.

CHAPTER FOUR

ANALYSIS AND RESULTS

4.1: Introduction:

The rising traffic congestion in urban areas is a main reason of many issues that affects passengers and pedestrians. The expansion of urbanism goes together with the regional development of the city as the residents emigrate further and further from city's center, therefore spaces are constantly growing among residential and work areas. This marks in more use of the existing transportation services, and a more journeys per resident per year. The capacity of cargo transportation likewise, escalates rapidly. The growth of urban transportation systems and the advancement in civic facilities impacts public's time budget**.**

4.2: Data Reduction and Analysis:

Data reduction is the conversion of arithmetic or alphabetic data obtained experientially or experimentally to a modified, organized, and condensed format. The advantage of this process can be stated in two points: first, minimizing the quantity of data registers by disregarding inacceptable data and second, outputting a summarized information at diverse stages for several uses.

Different kinds of vehicles require different areas on the roadway since there are variances in dimensions and pace. Therefore, in order to measure traffic capacity, flow rates are usually specified in terms of passenger car units (PCU's) as traffic volumes are converted by analysis programs.

Data analysis is the applied clarification of the collected data for the purpose of comprehending the acknowledged situation and to plot enhancements, subject to the condition being considered, this process can range from being easy and direct to being multifaceted and complicated. **[Mc shane & Roess, 1990].**

4.3: Study Segments Evaluation (Existing State):

4.3.1: Multilane Segments Evaluation by (HCS+T7F) Software:

(Highway Capacity Software (HCS+T7F) software was used to analyze multilane segments at the study locations. Highway Capacity Manual (HCM 2010) analysis methodology was adopted by Highway Capacity Software **(HCS+T7F)** to evaluate the traffic operations at multilane and calculate the level of service of these segments. Table (4.1) shows (HCS+T7F) program analysis output for Street 60, Al-Tuhmazia Street and Al-Jamaa'ia Street segments.

Table (4.1): (HCS+7TF) program output for Each Street Segments at Study Area.

Street Name	Dir.	Length (mi)	Flow Rate Vp (pc/ln/hr)	Average Passenger Car Travel Speed (mph)	Density D (pc/mi/ln)	LOS
Street 60	SB	0.5	1341	43.9	19.2	**D**
	NB	0.5	1131	44.2	16.2	**D**
Tuhmazia Street	SB	1.14	1143	44.2	16.3	**D**
	NB	1.14	938	44.9	13.4	**C**
Jamaa'ia Street	SB	0.49	1543	43.3	22.2	**E**
	NB	0.49	1621	42.9	23.4	**E**

❖ **Street 60 U-Turn:**

For street 60 U-Turn **[Al-Masaeid, 1999]** U-turn equations was used to find capacity and total delay of U-turn movements, as the equation (2.5) and (2.7) was proposed in chapter 2, the conflicting flow q_c for this u-turn was found to be

548 pc/hr/ln, the following segment shows the calculations of Street 60 u-turn capacity.

$$C = 799 - 0.62\, q_{cp} \quad \ldots\ldots (2.5)$$

$$C = 799 - 0.62\,(548) = 459.24\, pc/ln/hr$$

$$TD = 6.6 \times e^{qc/1200} \quad \ldots\ldots (2.7)$$

$$TD = 6.6 \times e^{548/1200} = 10.42\, sec/veh/ln$$

Therefore Street 60 U-turn have a capacity of 459.24 pc/hr/ln and average total delay of 10.42 sec/veh/ln.

4.3.2: Junctions/ Intersections Evaluation by (Synchro) Software:

In order to enhance the traffic performance of study segments, main congestion points were located, and they were Al-Tuhmazia Intersection and St.60/ Al-Taqah Junction, traffic movements were analyzed at these locations, in order to find the main problem and suggest suitable improvements to solve the congestion problem.

(Synchro) computer software was used to analyze intersections and junctions at the study area. This computer software is a traffic analytical tool used for road intersections with different types of control. In the case of study area, both selected intersections were unsignalized and stop controlled. This software uses Highway Capacity Manual 2000 methodology to find level of service at both signalized and stop/yield-controlled intersections.

1- Al-Taqah Street / Street 60 T-Junction:

The junction was operating with an average Level of Service of (C), with movements in the major street having an average LOS of (D) which is considered a bad operational condition. Table (4.2) shows the summary of analysis.

Table (4.2): Movements, Approaches LOS for Al-Taqah Street / Street 60 Junction.

<table>
<tr><th>Approach</th><th>Movements</th><th>Movement Level of Service (LOS)</th><th>Approach Level of Service (LOS)</th><th>Intersection Capacity Utilization (ICU)</th><th>Intersection Capacity Utilization (ICU) Level of Service (LOS)</th></tr>
<tr><td>Taqah St. / St. 60 T-junction</td><td>Right Turn</td><td>-</td><td>-</td><td rowspan="3">68.6%</td><td rowspan="3">C</td></tr>
<tr><td rowspan="2">Street 60</td><td>Through</td><td>C</td><td rowspan="2">D</td></tr>
<tr><td>Right Turn</td><td>C</td></tr>
</table>

The following (Synchro) software report demonstrates the output of Street 60/ Al-Tuhmazia T-Junction analysis in details.

HCM Unsignalized Intersection Capacity Analysis

Al-Taqah Street / Street 60 2021-01-25

Movement	WBL	WBR	NBT	NBR	SBL	SBT
Lane Configurations						
Sign Control	Free		Stop			Yield
Grade	0%		0%			0 %
Volume (veh/h)	0	425	1403	461	0	0
Peak Hour Factor	0.25	0.87	0.88	0.76	0.92	0.92
Hourly flow rate (vph)	0	568	1592	607	0	0
Pedestrians						
Lane Width (m)						
Walking Speed (m/s)						
Percent Blockage						
Right turn flare (veh)						
Median type			Raised			Raised
Median storage veh)			1			1
vC, conflicting volume	0		0	0	797	0
vC1, stage 1 conf vol	0		0		0	0
vC2, stage 2 conf vol	0		0		797	0
vCu, unblocked vol	0		0	0	797	0
tC, single (s)	4.1		6.8	6.5	7.1	6.5
tC, 2 stage (s)	3.1		5.8		6.1	5.5
tF (s)	2.2		4.3	3.6	3.5	4.0
p0 queue free %	100		0	26	0	100
cM capacity (veh/h)	1636		843	1003	0	900

Direction, Lane #	WB 1	WB 2	NB 1	NB 2	NB 3
Volume Total	302	302	638	638	925
Volume Left	0	0	0	0	0
Volume Right	302	302	0	0	607
cSH	1700	1700	843	843	1003
Volume to Capacity	0.18	0.18	0.76	0.76	0.98
Queue Length 95th (m)	0.0	0.0	55.2	55.2	134.1
Control Delay (s)	0.0	0.0	21.2	21.2	46.2
Lane LOS			C	C	E
Approach Delay (s)	0.0		31.7		
Approach LOS			D		

Intersection Summary			
Average Delay	24.9		
Intersection Capacity Utilization	68.6%	ICU Level of Service	C
Analysis Period (min)	15		

5:00 pm Baseline Synchro 6 Light Report

2- Al-Tuhmazia Intersection:

The junction was operating with an average Level of Service of (E), with Intersection Capacity Utilization percentage of (90.9%) which is indicates a bad case of congestion at the intersection. Table (4.3) shows the summary of analysis.

Table (4.3): Movements, Approaches LOS for Al-Tuhmazia Intersection.

Approach	Movements	Movement Level of Service (LOS)	Approach Level Of Service (LOS)	Intersection Capacity Utilization (ICU)	Intersection Capacity Utilization (ICU) Level of Service (LOS)
WB	Right Turn	B	C	90.9%	E
	Through	D			
EB	Right Turn	F	F		
	Through	F			
NB	Right Turn	-	-		
SB	Right Turn	-	-		

The following (Synchro) software report demonstrates the output of Al-Tuhmazia Intersection capacity analysis in details.

HCM Unsignalized Intersection Capacity Analysis

Al-Tuhmazia Intersection 2021-06-23

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Sign Control		Stop			Stop			Free			Free	
Grade		0%			0%			0%			0 %	
Volume (veh/h)	0	1288	874	0	1318	655	0	0	620	0	0	768
Peak Hour Factor	0.92	0.87	0.77	0.92	0.88	0.89	0.92	0.92	0.89	0.92	0.92	0.90
Hourly flow rate (vph)	0	1480	1135	0	1498	736	0	0	697	0	0	853
Pedestrians												
Median type		Raised			Raised							
Median storage veh)		2			2							
vC, conflicting volume	749	0	0	740	0	0	0			0		
vC1, stage 1 conf vol	0	0		0	0		0			0		
vC2, stage 2 conf vol	749	0		740	0		0			0		
vCu, unblocked vol	749	0	0	740	0	0	0			0		
tC, single (s)	7.1	6.7	6.4	7.1	6.7	6.5	4.1			4.1		
tC, 2 stage (s)	6.1	5.7		6.1	5.7		3.1			3.1		
tF (s)	3.5	4.2	3.5	3.5	4.2	3.6	2.2			2.2		
p0 queue free %	0	0	0	0	0	26	100			100		
cM capacity (veh/h)	0	865	1032	0	858	1001	1623			1623		

Direction, Lane #	EB 1	EB 2	EB 3	EB 4	WB 1	WB 2	NB 1	NB 2	SB 1	SB 2
Volume Total	740	740	568	568	998	1235	348	348	427	427
Volume Left	0	0	0	0	0	0	0	0	0	0
Volume Right	0	0	568	568	0	736	348	348	427	427
cSH	865	865	1032	1032	858	938	1700	1700	1700	1700
Volume to Capacity	0.86	0.86	0.55	0.55	1.16	1.32	0.20	0.20	0.25	0.25
Queue Length 95th (ft)	265	265	87	87	752	1176	0	0	0	0
Control Delay (s)	28.2	28.2	12.7	12.7	105.9	166.2	0.0	0.0	0.0	0.0
Lane LOS	D	D	B	B	F	F				
Approach Delay (s)	21.5				139.2		0.0		0.0	
Approach LOS	C				F					

Intersection Summary			
Average Delay	57.4		
Intersection Capacity Utilization	90.9%	ICU Level of Service	E
Analysis Period (min)	15		

Synchro 6 Light Report Baseline

4.4: Congestion Cost Evaluation:

From multilane segments in study area the congestion cost can be calculated from the summation of opportunity cost, fuel cost, vehicle operation cost, wear and tear cost given in Equation (2.15) to (2.17).

$$OC = (VOT_m \times D_m \times V_m \times Vocc_m) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (2.15)$$

$$FC = \sum_{Ft=1}^{3}(Fcq_m^{Ft} \times Fp^{Ft} \times \mu^{Ft}) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (2.16)$$

$$VOC = L \times \sum_{m=1}^{m}(FC_m \times D_m \times V_m) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (2.17)$$

Congestion cost calculations and results are issued in Appendix (A).

4.4: Improvements:

In this study, most of the chosen study locations were found to be functioning with a low level of service, which is expected as these locations support high congestion, thus. The following changes and enhancement approaches are demonstrated to advance and enhance traffic operations at the selected locations:

4.4.1: Al-Tuhmazia intersection Improvements:

- Constructing a second overpass above Al-Tuhmazia current overpass dedicated for Al-Jamaa'ia through movement, to separate all through movements from turning movements as Street 60 through movement is already separated by Al-Tuhmazia overpass, reduce delay, eliminate conflict points to help increase safety levels, promote smooth flow and give through movement more space and freedom. This way the ground level of intersection will be employed only for turning movements.
- Widening Al-Jamaa'ia approach in order to create more space for the suggested overpass, and more space for the turning lanes.
- Installing a pedestrian crossway with pre-timed light signal, to reduce the conflicts between vehicles and pedestrians at the intersection and regulate the chaotic pattern of pedestrian crossing.

- ❖ Installing traffic signs and warrants to help and remind drivers by the road instructions and limitations.
- ❖ Improving traffic performance of connected approaches helps in reliving the climax of traffic congestion of the intersection, therefore geometric and planning developments must be done to ensure safer and smoother traffic flow.

- **Design of an overpass for through movement from Al-Jamaa'ia street to Al-Tuhmazia Street:**

1- Vertical Alignment Design:

In order to design the overpass two vertical curves should be designed; a sag vertical curve at the beginning of grade and a crest vertical curve at the peak of the grade, as sag and crest curve connects with 0% grade roadway segment, the main design essentials for vertical curves are stopping sight distance, maximum grade and critical curve length.

1- Stopping Sight Distance:

Sight distance is the road span that can be observed by the driver. It a chief design principle for highway vertical placements and is vital for safety and operational efficiency. This length depends on motorist's vision elevation, and location of view obstacles. Sight distance consists of two lengths: (break reaction time distance and breaking distance). **[Gregory J. Taylor, 2014]**

Equation (4.1) shows the formula of stopping sight distance:

$$\boldsymbol{SSD = 1.47Vt + 1.075\ \frac{V^2}{a}} \ldots\ldots\ldots(\boldsymbol{4.1})$$

Where:

SSD = Stopping sight distance, ft.

V = Design speed, (mph).

t = Break reaction time, (2.5 Seconds).

a = Deceleration rate, (ft$/sec^2$).

It was shown that the recommended deceleration rate (a) is **11.2 $\mathbf{ft}/\boldsymbol{sec^2}$**, as the vast majority of motorists decelerate at a higher rate. So, For a design speed of

(70 km/h or 45 mph) and a deceleration rate of (11.2 ft/sec^2) the stopping sight distance is (727.5 ft or 221.7 m) as follows:

$$SSD = 1.47\ (45\ \times 2.5) + 1.075\ \frac{(45)^2}{11.2}$$

$$SSD = 359.7\ ft\ \ or\ \ 109.6\ m$$

2- Maximum Grade:

Usually, vertical curves grades values are ought to be below than the highest allowed design grades. these grades must support smooth travel process through the projected highways. AASHTO procedures for grades depends on roadway class, design speed and terrain type. The majority of light/passenger vehicles is able to cross (4% - 5%) grades swiftly with no substantial shortage in regular travel speeds. But it is not the case for heavy vehicles as their travel speeds decline increasingly with grade. **[AASHTO, 2011].** Table (4.7) demonstrates the highest suggested grades in accordance with terrain and road types.

Table (4.7): Maximum Suggested Grades for Vertical Curves on Urban Arterials. [AASHTO, 2011]

Design Speed (mph)	Level	Rolling	Mountainous
30	8	9	11
35	7	8	10
40	7	8	10
45	**6**	7	9
50	6	7	9
55	5	6	8
60	5	6	8

Therefore, for a design speed of (70 km/h or 45 mph) the maximum vertical grade should be 6%.

3- Minimum Curve Length:

A vertical curve is dependent by the next four standards as a minimum requirement, these standards are:

- Sight distance.
- Traveler/Driver comfort.
- Drainage management.
- General appearance.

A sag curve should fulfil all of them, whereas a crest curve should fulfil sight distance requirement only. **[Duraid M Abd, 2019]**

A- Sag Curve Minimum Length:

1- Sight Distance Requirements:

Assuming that S>L , The minimum sag curve length can be calculated from equation (4.2):

$$\boldsymbol{L_{\min} = 2S - \frac{200(h_1 + S\,tan\beta)}{A}} \quad \dots\dots\dots (\mathbf{4.2})$$

Where:

$\boldsymbol{L_{\min}}$ = The minimum sag curve length, ft.

A = The absolute difference between grades connected by the curve. (A= |G1-G2|)

S = Stopping sight distance, ft.

$\boldsymbol{h_1}$ **=** Eyesight level over road surface, (assumed 2 ft).

$\boldsymbol{\beta}$ = Uphill deviation of stream of light from the vehicle longitudinal axis, (1^o)

Assuming that G1=0 and G2= 4.5%, $L_{\min}$ should be :

$$L_{\min} = 2 \times 359.7 - \frac{200(2 + 359.7 \times tan(1))}{4.5}$$

$$L_{\min} = 351.4\,ft \;\; or\; 107\, m$$

2- Traveler/Driver Comfort Requirements:

The minimum sag curve length can be calculated from equation (4.3):

$$\boldsymbol{L_{\min} = \frac{AV^2}{46.5}} \quad \dots\dots\dots (\mathbf{4.3})$$

$$L_{\min} = \frac{(4.5 \times (45)^2)}{46.5}$$

$$L_{\min} = 195.96\, ft \;\; or\; 59.7m$$

3- Drainage Requirements:

Drainage of roads with curbing should maintain a slop of at least 0.5% for the external ends of the road. **[TXTDOT, 2020]**

4- General Appearance Requirements:

The minimum sag curve length can be calculated from equation (4.4):

$$\boldsymbol{L_{\min} = K \times A} \;\; \dots\dots\dots (\mathbf{4.4})$$

Where:

K = Rate of vertical curvature. Table (4.8) shows K values according to design speeds.

Table (4.8): Rate of Curvature Values for Sag Vertical Curves. [AASHTO, 2011]

Design Speed (mph)	Stopping Sight Distance (ft)	Rate of Curvature, K	
		Calculated	Design
30	200	36.4	37
35	250	49.0	50
40	305	63.4	64
45	**360**	**78.1**	**79**
50	425	95.7	96
55	495	114.9	115
60	570	135.7	136

$$L_{\min} = 79 \times 4.5$$

$$L_{\min} = 355.5\, ft \;\; or\; 108m$$

B- Crest Curve Length:

Assuming that S>L , The minimum Crest curve length according to sight distance requirements can be calculated from equation (4.5):

$$\boldsymbol{L_{\min} = 2S - \frac{200(\sqrt{h_1}+\sqrt{h_2})^2}{A}} \quad \ldots\ldots\ldots (\mathbf{4.5})$$

Where:

$\boldsymbol{h_2}$ **=** obstacle level over road surface, (assumed 2 ft), h_1 assumed (3.5ft) for crest curves.

$$L_{\min} = (2 \times 359.7) - \frac{200(\sqrt{3.5}+\sqrt{2})^2}{A}$$

$$L_{\min} = \ 239.7\ ft\ \ or\ 73m$$

2- Cross Section Design:

For the cross-section design of the suggested overpass ranges for minimum vertical clearance for overpasses are given in Table (4.9).

Table (4.9): Minimum Suggested Values for Vertical Clearance on Urban Roads. [AASHTO, 2011]

Highway Type	Metric (m)	US Custom (ft)
Freeway	4.3 – 4.9	14 -16
Arterial	**4.3 – 4.9**	**14 -16**
Collector	4.3	14
Local	4.3	14

A Vertical clearance of (5m) will be chosen for design, with 0.225m pavement thickness, 1.453m concrete slab / girder thickness and 0.5m T-beam thickness.

Therefore, the full overpass height would be:

The Highest Vertical Curve Elevation (PVC) = Al Tuhmazia overpass height + (Al Jamaa'ia overpass vertical clearance + T-Beam thickness + Girders/Slab thickness + Pavement thickness).

The Highest Vertical Curve Elevation (PVC) = (6.8m + (5m + 0.5m +1.453m + 0.225m) = **13.975m ≈ 14m** as shown in Figure (4.1).

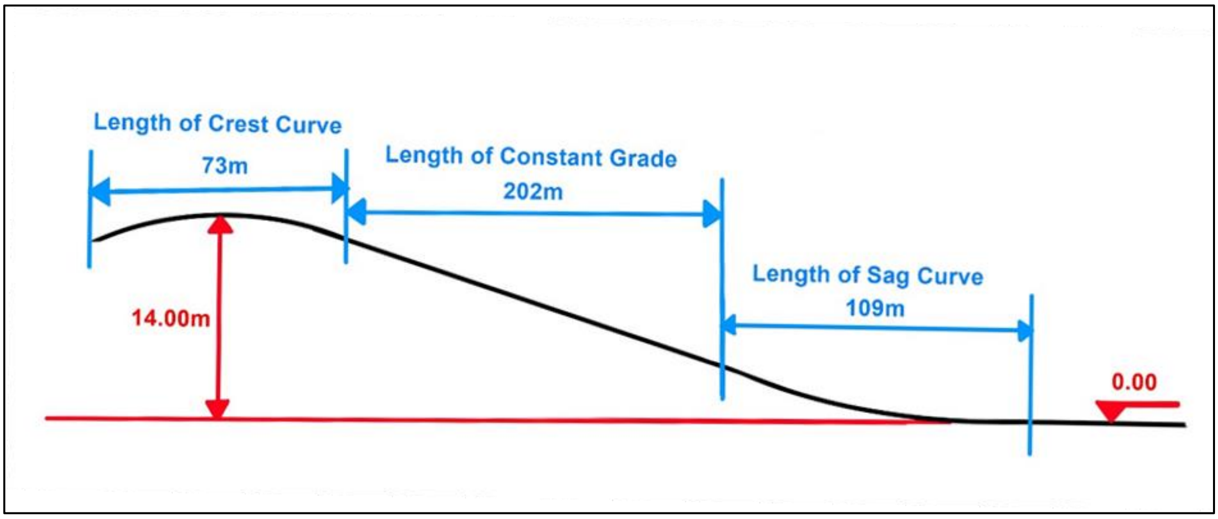

Figure (4.1): Vertical Alignment Design of the suggested overpass.

❖ **Overpass full Length:**

For a grade transition from G1=0% to G2=4.5% , the grade length is:

$$\text{Grade Length} = \frac{Highest\ Point\ Elevation}{|\ G1 - G2\ |} = \frac{14\ m}{|0 - 0.045|} = 311m$$

Therefore, the full overpass length would be:

Full length = Crest curve length + (2 × Grade length (Including Sag Curve Length 109m))

Full length $= 73 + (2 \times 311\ )$ = **695 m**

Figure (4.2) and (4.3) shows the proposed improvement.

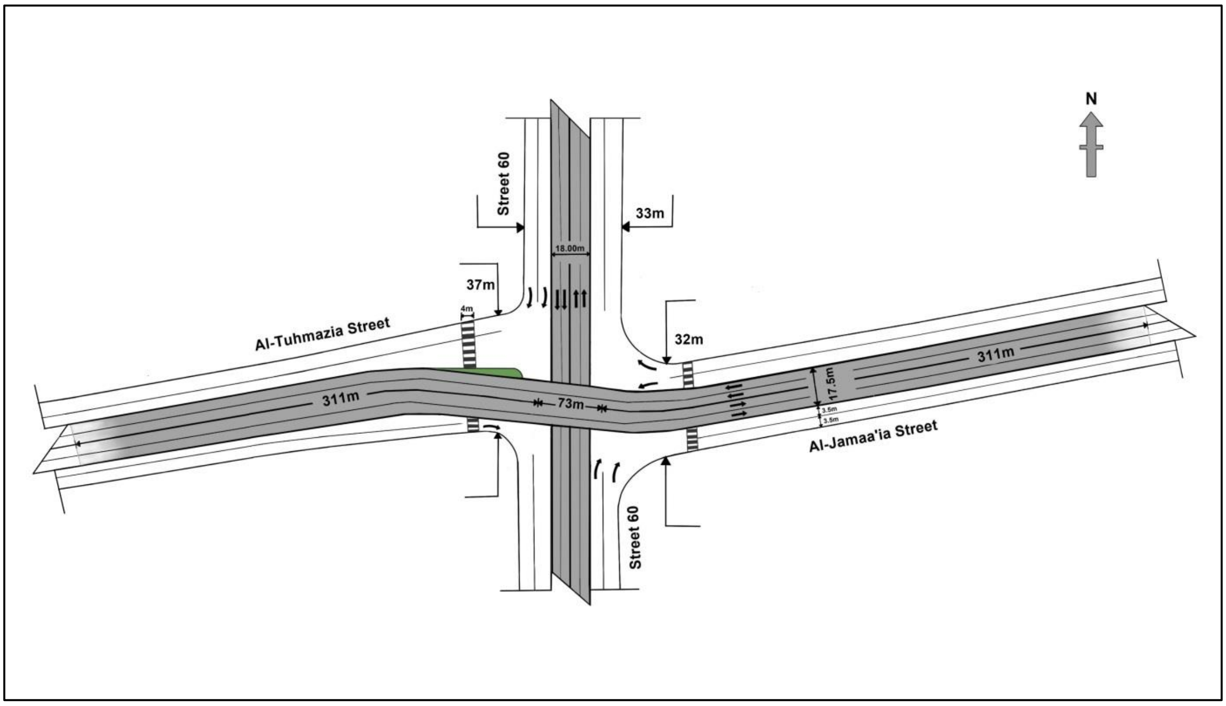

Figure (4.2): Suggested improvement of Al-Tuhmazia intersection (Top View).

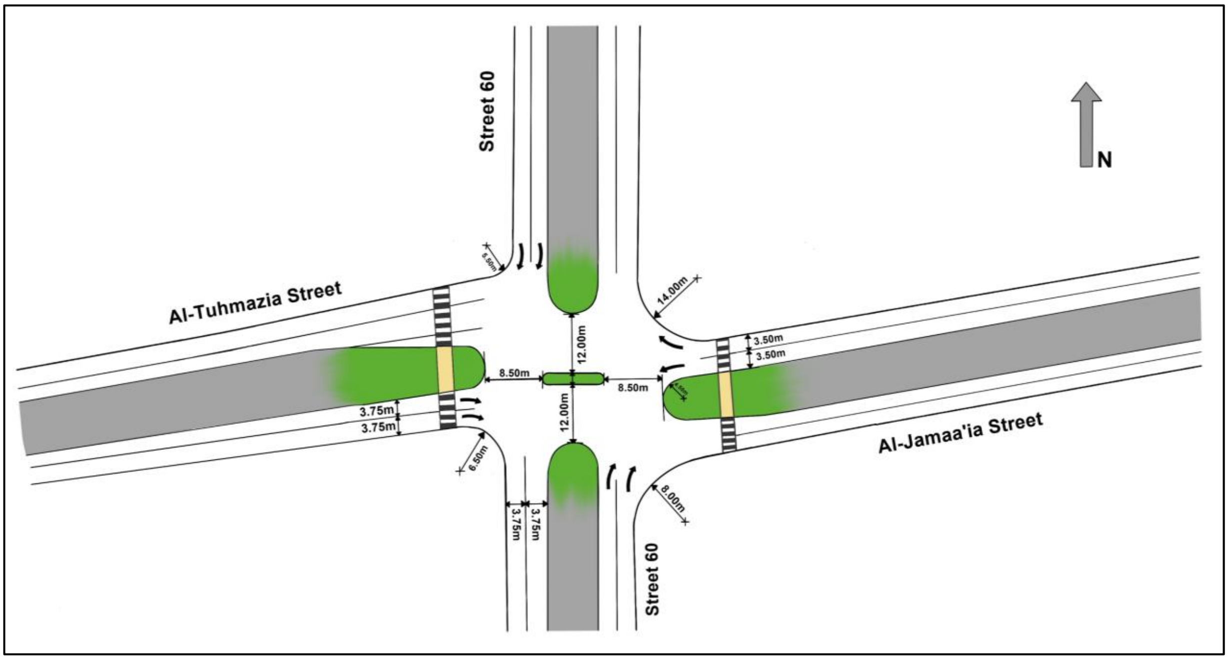

Figure (4.3): Suggested improvement of Al-Tuhmazia intersection (Ground level)

4.4.2: Street 60 Approach Improvements:

- ❖ Constructing parallel/frontage roads to street 60, by adding one lane in each direction of flow and separating through movement from access points merging and turning maneuvers by medians, hence, dedicating 2 exclusive lanes for through movement and 2 exclusive lanes for merging and turning movements from access points for each direction along the street, to give some congestion relief, reduce conflicts and increase accessibility without affecting the main through stream.
- ❖ Marking the street with white paint to define lanes, movement directions and pedestrian walkaways to aid both of drivers and pedestrian in committing to organized traffic flow.
- ❖ Paving and maintaining the street on constant basis for smoother and safer traveling experience with the placement of road fixtures like traffic signs and warrants.

2- Street 60 U-Turn:

I- Improvement No.1:

- ❖ Converting the current two-way left turn median cross-over into a median cross-over with dual turning lanes, directional left turn bays and flares, to prevent crossing traffic from driveways, minimize conflict points, separate through movements from turning movements, and give the driver enough space to execute turning maneuvers safely.

- o **Design Of Two-Way Dual Left Turn Speed Change Lanes (Deceleration /Acceleration Lane) At The Median U-Turn:**

The establishment of U-turns is applicable in a narrow amount of road circumstances, as safety concerns has a significant weight on the design process. The median must have enough width to support exclusive lanes for U-turn movements and an sufficient internal diameter to finish the movement safely. U-turning is often linked with weaving maneuvers. Therefore, capacity of weaving volumes must continuously be examined to find the needed weaving distance.

[Muhammad Bhatti, 2014]. The following segment shows the design calculations:

1- Geometric Design:

- The values used for the design off these lanes were taken from Table (2.3) for design speed of (60 Km/hr or 40 mph).
- AASHTO Specifications has been used and it recommended a deceleration length of (275ft or 85m) for the left turn lane of this divided multilane segment, as shown in Table (2.2).
- According to AASHTO the recommended taper ratio for speed change lanes range from (8:1) to (15:1) (Longitudinal: Transverse).
- For dual left turn lanes with (3.75m) width and (8:1) Taper ratio:

$$Taper\ Length = 2 \times (3.75) \times 8$$

$$Taper\ Length = 60\ m$$

- for Storage length, Turn lane peak hour volume is required, according to collected data from Street 60 U-Turn left turn peak volume was (396 pc/hr), it was calculated using equation (2.2):

$$storage\ length\ (ft) = \left(\frac{Turn\ lane\ peak\ hour\ volume}{60}\right) \times (Pc\% \times 25) + (Hv\% \times 75) \times 2 \ \ldots\ldots \text{(2.2)}$$

$$storage\ length\ = \left(\frac{396}{60}\right) \times (0.91 \times 25) + (0.09\ \times 75) \times 2$$

$$storage\ length\ = 389.4\ ft$$

$$storage\ length\ =\ 118.6\ \text{m}$$

2- Turning Speed:

Lowest values for the length required to suitably decelerate a vehicle and take it to median storage part, is called the deceleration length, this length is calculated from the taper starting point to the storage part ending point, a deceleration rate of 10mph of design speed is assumed to be the entry speed of the u-turning vehicles to ensure safety and adequate queue length. **[FDOT, 2014]**

Therefore, for a design speed of 45mph or 70 km/h, the entry speed is 35mph or 56.3 km/h. Figure (4.4) shows the design of improvement No.1 of Street 60 U-Turn.

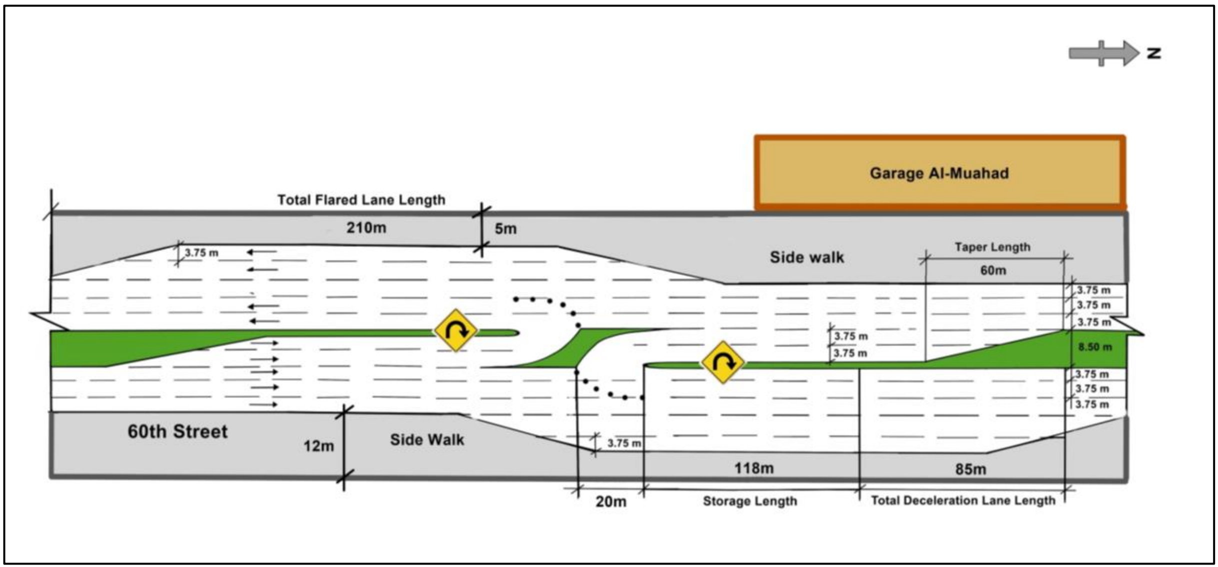

Figure (4.4): Improvement No.1 of Street 60 U-Turn.

II-Improvement No.2:

- ❖ Constructing a two-lane one-way frontage/parallel road with median openings to allow vehicles wanting to change travel direction to merge with street 60 through movement.
- ❖ Establishing a pedestrian bridge near the U-turn to help pedestrian cross over this segment of road safely, Figure (4.5) shows the design of improvement No.2 of Street 60 U-Turn.

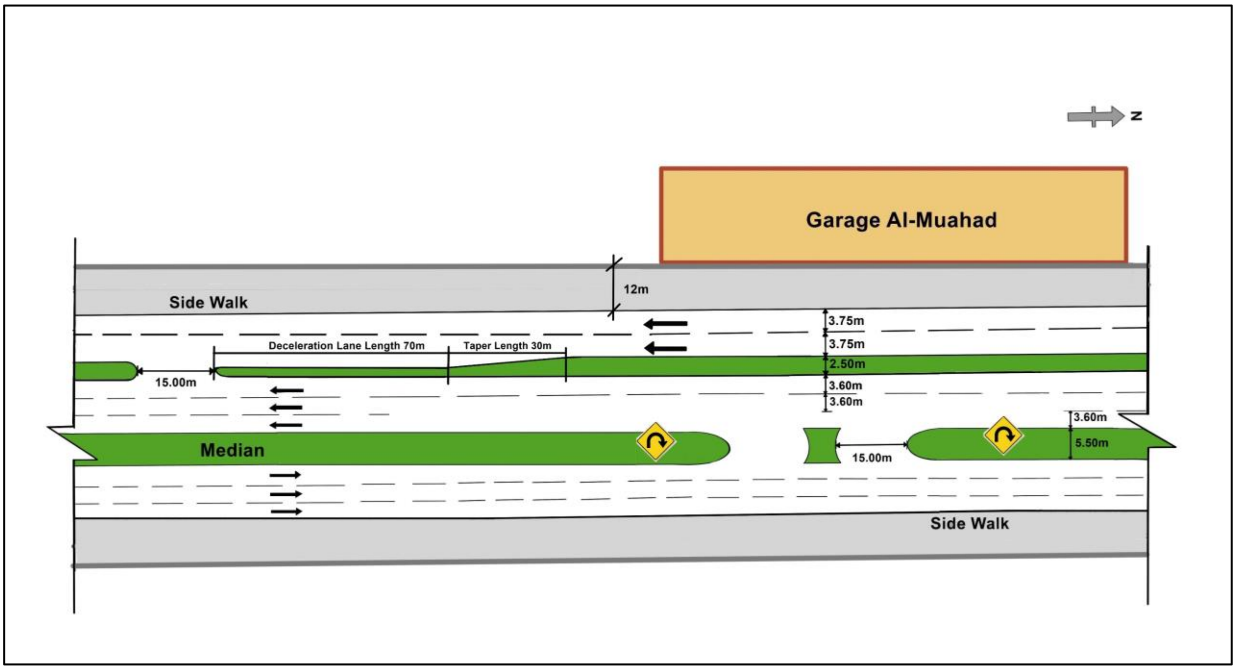

Figure (4.5): Improvement No.2 of Street 60 U-Turn.

4.4.3: Al- Jamaa'ia Street Approach Improvements:

- ❖ Reducing Al-Jamaa'ia Street median width from 4.5m to 1.25m, and reducing side walk width which creates more space for street widening.
- ❖ Adding two new lanes, one in each direction, in order to increase street capacity and give more space to complete all kinds of vehicle maneuvers.
- ❖ Preventing on-street parking and constructing a muli-story parking building, in order to solve the street parking/ double-parking issue and increase road capacity, operating speed, safety and establishing proper traffic signs to warn and assist drivers making trips on the roadway.
- ❖ Installing pedestrian crossways with pre-timed signal lights to regulate pedestrian crossing movement.
- ❖ Establishing strict instructions regarding storefronts borders, where a significant width of sidewalks is occupied by the adjacent storefronts, in order to give pedestrians their own space to walk in and not interfere with vehicular movements.

4.4.4: Al-Tuhmazia Street Approach :

- Constructing parallel/frontage roads to Al-Tuhmazia Street, by other means, separating through movement from access points merging and turning maneuvers by medians, hence, dedicating 2 exclusive lanes for through movement and 2 exclusive lanes for merging and turning movements from access points for each direction along the street, to give some decrease congestion, diminish conflicts and increase accessibility without affecting the main through stream.
- Preventing on-street parking and providing free parking area, to relief the parking/ double-parking issue and enhance road capacity, travel speed and safety levels, and adding suitable traffic signs to warn and guide drivers traveling on the roadway.
- Constructing a pedestrian bridge with proper design, using Energy efficient Escalators to save electrical energy, which would encourage pedestrians to use it instead of conflicting with vehicular traffic movements.
- Adding traffic signs and markings to road, and imposing traffic penalties for drivers violating traffic rules to get a smoother traffic flow.
- Paving and maintaining the street on constant basis for smoother and safer traveling experience.

4.4.5: Al-Taqah / Street 60 T-Junction:

- Adding deceleration / acceleration (speed change lanes) to separate right turning from through movement. These lanes would also give drivers enough space to decelerate / accelerate their speed before turning, which would decrease conflict points between movements and minimize traffic accidents in the future. Figure (4.6) shows the proposed improvement, while the following segment shows the design calculations.

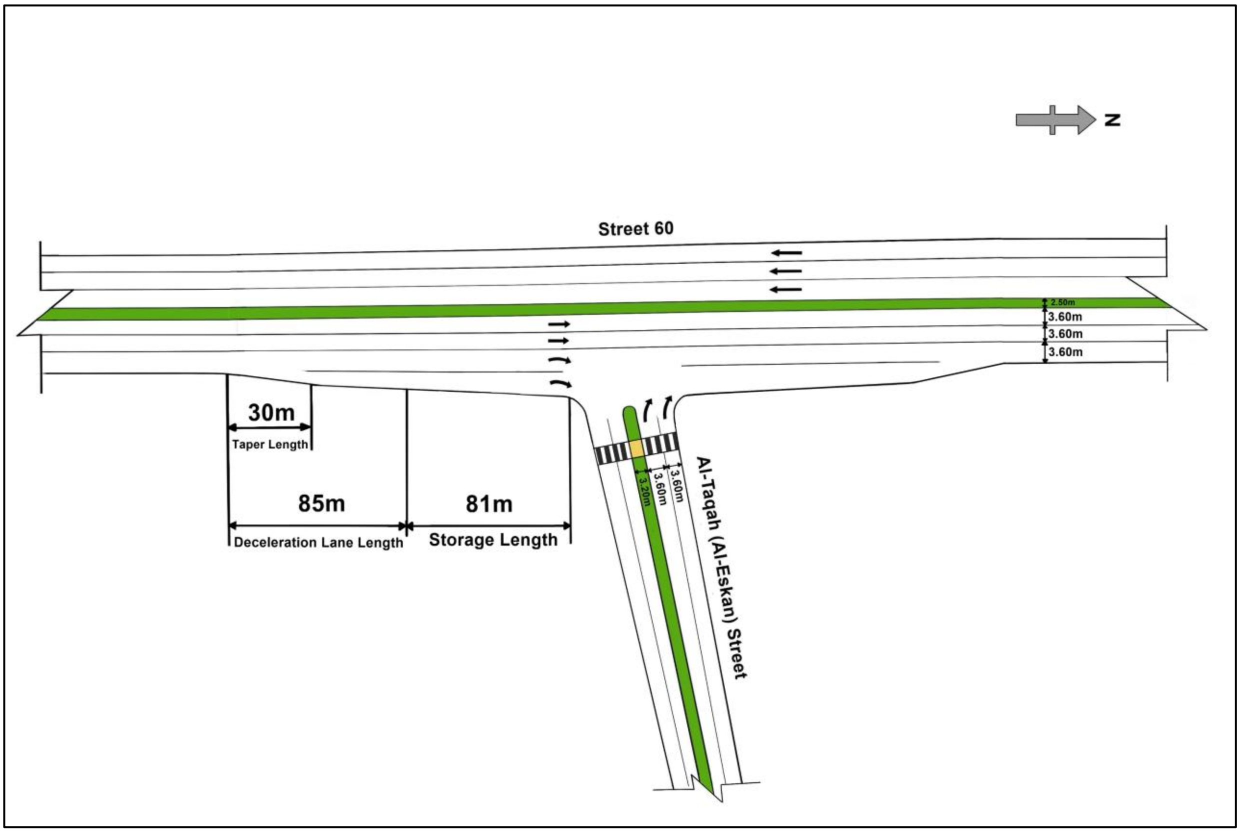

Figure (4.6): Suggested improvement of Street 60/Al-Taqah T-Junction.

- **Design of Right Turn Speed Change Lanes (deceleration /acceleration Lane) at 60th Street:**
- The values used for the design off these lanes were taken from Table (2.3) For design speed of (60 km/h or 40mph).
- AASHTO Specifications has been used and it recommended a total deceleration length of **(275 ft or 85 m)** For the right turn lane of this divided multilane segment.
- According to AASHTO the recommended taper ratio for speed change lanes range from (8:1) to (15:1) (Longitudinal: Transverse).
- for Storage length, Turn lane peak hour volume is required, according to collected data from St.60/Al-Taqah T-junction right turn peak volume was (285 veh/hr), it was calculated using equation (2.2):

$$storage\ length\ (ft) = \left(\frac{Turn\ lane\ peak\ hour\ volume}{60}\right) \times (Pc\% \times 25) +$$
$$(Hv\% \ \times 75) \times 2 \ldots\ldots (2.2)$$

$$storage\ length\ = \left(\frac{285}{60}\right) \times (0.94 \times 25) + (0.06\ \times 75) \times 2$$

$$storage\ length\ = 266\ \ ft$$

$$storage\ length\ =\ 81\ \mathrm{m}$$

Figure (4.5) shows the design of proposed improvement of Street 60/Al-Taqah T-Junction.

- Adding traffic signs at all approaches to assist the driver and assure smooth volume transition between approaches, and help out traffic officers at regulating traffic flow.

4.5: Study Segments Evaluation (After Improvements):

In order to testify the significance of the suggested improvements, traffic operational analysis was done after applying improvements, the following points summarize the enhancements that was made for each segment and intersection:

4.5.1- Al-Tuhmazia At-grade Intersection:

After separating through movements from turning movements entirely by the suggested overpass, only turning volumes should be using the at-grade intersection, which decreased delay and Intersection Capacity Utilization, as well as increased the intersection overall level of service. Table (4.10) Summarize the program output of Al-Tuhmazia At-Grade Intersection analysis.

Table (4.10): (SYNCHRO) Analysis Output for Al-Tuhmazia Intersection After Applying Improvements.

Approach	Movements	Movement Level of Service (LOS)	Approach Level of Service (LOS)	Intersection Capacity Utilization (ICU)	Intersection Capacity Utilization (ICU) Level of Service (LOS)
	Right Turn	A			

WB	**Through**	**C**	**B**	**61.3%**	**C**
EB	**Right Turn**	**C**	**C**		
	Through	**C**			
NB	**Right Turn**	**-**	**-**		
SB	**Right Turn**	**-**	**-**		

4.5.2: Street 60 Approach:

After adding one new lane in each direction and separating through movements from direct turning and merging from access points by medians, the level of service has increased for the segment. (HCS+T7F) program report is presented in Appendix (A). Table (4.11) Summarize the program output of Street 60 analysis.

Table (4.11): (HCS+T7F) Analysis Output for Street 60 After Applying Improvements.

Street Name	Dir	Length (km)	No. of Lanes	Flow Rate Vp (pc/ln/hr)	Average Passenger Car Travel Speed (Km/hr)	Density D (pc/km/ln)	LOS
Street 60	SB	0.8	2	848	70	12.1	C
	NB	0.8	2	1005	70	14.4	C

4.5.3: Al-Jamaa'ia Street Approach:

After increasing the number of lanes from 2 to 3 lanes in each direction and reducing median width, the level of service has increased for the segment. (HCS+T7F) program report is presented in Appendix (A). Table (4.12) Summarize the program output of Al-Jamaa'ia Street analysis.

Table (4.12): (HCS+T7F) Analysis Output for Al-Jamaa'ia Street After Applying Improvements.

Street Name	Dir	Length (km)	No. of Lanes	Flow Rate Vp (pc/ln/hr)	Average Passenger Car Travel Speed (Km/hr)	Density D (pc/km/ln)	LOS
Jamaa'ia Street	SB	0.79	3	1081	70	15.4	C
	NB	0.79	3	1028	70	14.7	C

4.5.4: Al-Tuhmazia Street Approach:

After adding one new lane in each direction and separating through movements from direct turning and merging from access points by medians, the level of service has increased for the segment. (HCS+T7F) program report is presented in Appendix (A). Table (4.13) Summarize the program output of Al-Tuhmazia Street analysis.

Table (4.13): (HCS+T7F) Analysis Output for Al-Tuhmazia Street After Applying Improvements.

Street Name	Dir	Length (km)	No. of Lanes	Flow Rate Vp (pc/ln/hr)	Average Passenger Car Travel Speed (Km/hr)	Density D (pc/km/ln)	LOS
Tuhmazia Street	SB	1.85	4	923	70	12.3	C
	NB	1.85	4	741	70	10.1	B

4.5.5: Al-Taqah Street / Street 60 Junction:

After separating through movements from right turning movements entirely by speed change lanes (acceleration/deceleration lanes) on both sides of the T-junction, the intersection overall level of service has increased as shown Table (4.14) Summarize the program output of Al-Taqah Street / Street 60 Junction analysis.

Table (4.14): (SYNCHRO) Analysis Output for Al-Taqah Street / Street 60 T-Junction After Applying Improvements.

Approach	Movements	Movement Level of Service (LOS)	Approach Level of Service (LOS)	Intersection Capacity Utilization (ICU)	Intersection Capacity Utilization (ICU) Level of Service (LOS)
Taqah St. / St. 60 T-junction	Right Turn	-	-	57.2%	C
Street 60	Through	B	C		
	Right Turn	D			

Summary:

The central idea of chapter was; data analysis and improvements presentation. Traffic volume data was analyzed using (HCS+T7F) and (SYNCHRO) computer programs. In the light of analysis results, some suitable improvements were suggested for each study segment. Then, the segments were analyzed after applying improvements, to test the significance of the change that comes with every improvement. Final conclusions and recommendations are the topics of the following chapter.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1: Introduction:

Congestion is a significant complication that modern-day cities should focus on. Each year many countries devote large funds to resolve this issue, but are still challenged with even bigger problems the next year. Therefore, the solution to such complex issue should be a properly calculated, flexible, long-term strategy.

These solutions better not to call for enormous budgets, or building of interchanges or underpasses that just transfer congestion from one location to another on road network. This chapter displays the conclusions and recommendations specified by the researcher, as they were built on the data investigation, data analysis and analysis results.

5.2: Conclusions:

This research established a number of outcomes that displayed that the studied segments experience frequent congestions that comes from different causes, the following points summarize the study main conclusions:

5.2.1: Through the traffic study and observations, as well as data analysis the HCS+T7F and SYNCHRO programs it's been shown that the level of service in the study area was as follows:

a) Street 60 is operating with a relatively low level of service, with LOS D at both directions during peak hour.

b) Street 60 U-Turn, it was found that the U-turn had a low capacity of 289.4 pc/hr and an average total delay of 25.97 sec/veh.

c) The study displayed that Al-Tuhmazia Street is working with a rather low level of service, with LOS D at Southbound direction and LOS C at Northbound direction during peak hour.

d) Al-Jamaa'ia Street is working with a very low level of service, with LOS E at both directions during peak hour.

e) Street 60/ Al-Taqah T-Intersection was operating with a LOS C, and the main congestion causes were the bottleneck that comes from Street 60 width reduction after Al-Tuhmazia bridge end, and conflict between Street 60 through movement and Al-Taqah Street right turning movement.

f) Al-Tuhmazia Intersection, it was found that the intersection was operating with a low level of service, with LOS E in average.

5.2.2: According to the analysis of traffic congestion cost including opportunity cost, fuel cost, vehicle operation cost, wear and tear cost of the multilane street segments the daily cost for congestion on these streets, ranged between (12Million to 18Million ID per day), while applying the suggested improvements on these segments would decrease the current congestion cost including traffic accident cost by 50% or more.

5.2.3: The study concluded that the suggested Improvements has enhanced traffic operations at study segments in the way shown in following points:

1. Constructing a new overpass above Al-Tuhmazia current overpass dedicated for Al-Jamaa'ia through movement, and widening Al-Jamaa'ia approach, would cut delay and reduce congestion, abolish conflicts, promote safety and smooth flow, as well as increase the overall level of service of the intersection from LOS (E) to LOS (C).
2. Constructing a frontage road to street 60, and separating through movement from access points merging and turning maneuvers by medians, can reduce delay, maneuver conflicts and increase accessibility without affecting the main through stream, as well as provide a gradual merge of traffic coming from the (Garage Al-

Muahad) that want to turn left, the new design has also increased the level of service from LOS (D) to LOS (C) at both directions.

3. Constructing two-lane one-way frontage roads with median openings, and designing of two-way dual left turn speed change lanes (deceleration /acceleration lane) at the Street 60 median U-turn, with a acceleration/deceleration length of (85m), taper length of (60 m) , storage length of (118.6 m) , dual turning lanes, and making flared lanes on each side to protect left turns and limiting the turning speed to (35 mph or 56 km/h), will lead to the desired result by increasing the efficiency of turning, increasing safety factors and reducing traffic accidents by a noticeable percentage.
4. Reducing Al-Jamaa'ia Street median width from (4.5m) to (1.25m), and reducing sidewalks width would create space to add two new lanes, one in each direction, preventing on-street parking and providing multi-story parking building, can actively maximize street capacity, promote safety, and help with the parking/ double-parking issue on this street, as well as increase the level of service from LOS (E) to LOS (C) at both directions.
5. Constructing a frontage road to Al-Tuhmazia Street , and separating through movement from access points merging and turning maneuvers by medians as, can reduce congestion, conflicts and increase accessibility without affecting the main through flow, which increased the level of service from LOS (D,C) to LOS (C,B) at both directions respectively.
6. Adding deceleration / acceleration lanes to Street 60/Al-Taqah Junction to separate right turning from through movement, would create sufficient space to change speed before turning, reduce conflict points, minimize traffic accidents in the future and increase the overall level of service from LOS (D) to LOS (C).

5.3: Recommendations:

In order to reduce the effects of traffic congestion in study area, many efforts must be employed to re-design the street main congestion and conflict points, promote mindfulness amongst pedestrians and motorists, enforcing strong regulations to hold back violators, and establishing parking areas that are free to use to encourage drivers to use them instead of parking on street sides, in addition to parting movements to give them independence in flow direction.

As segments capacity is influenced by number of lanes, unsuitable berm capacity, unorganized parking and neglected attention for pedestrian sidewalks and street footpaths. it was found that several additional constraints were increasing travel time and decreasing the level of service on studied segments. Therefore, study area requires core developments and upgrades. The study suggested a number of recommendations and alternatives to enhance traffic performance at study segments, these recommendations can be summarized in the following points:

5.3.1: Imposing current highway traffic regulations and monitoring road system more effectively by the presence of more police officers on the city roads, as prohibited parking and waiting, decreases capacity at highways and intersections, and heightens hazard to pedestrian. Not following speed limits or driving over prohibited zones all participate in more mortalities, injuries and property damages.

5.3.2: Establishing an organized public transport system with a sufficient number of buses that reach most areas with high population concentration, dividing the city into several sectors and establishing a modern garages for each sector, hiring skilled drivers with a good degree of training and professionalism, which contributes to creating new local jobs, and lastly, actively promoting the system Public transportation to encourage citizens to use public transportation instead of private vehicles to save both time and money.

5.3.3: Thinking seriously of investing in underground metro systems, as the metro transport system greatly reduces the problem of congestion and air pollution and provides underground transportation between parts of the city center, where the Al-Hillah City is devoid of these systems that would solve a significant part of the worsening traffic congestion. As the establishment of such systems may spare the city government the problems of the city road system failure to accommodate to the number of vehicles increasing significantly and more costly solutions in the future.

5.3.4: Establishing organized parking stations for vehicles to reduce the problem of vehicles parking on streets and double-parking problem that decreases road capacity and maximize the possibility of traffic accidents.

5.3.5: Working to redesign main roads and create new roads to increase capacity to accommodate to the increasing traffic demand and the continuously expanding city.

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APPENDIX (A): CONGESTION COST CALCULATIONS

1- Street 60 Congestion Cost:

Table (4.4) shows average occupancy factors, average daily traffic (ADT) and average delay of vehicles traveling under posted speed for street 60 segment taken from speed and travel time collected data.

Table (A.1): Average Occupancy Factors, Classified ADT volumes and Average Delay for Street 60 Segment.

Vehicle Type	Average Occupancy Factor	Average Daily Traffic (ADT) (veh/day)	Average Delay Under Posted Speed (hr/veh)
Passenger Car	1.5	21633	0.134
Bus	3.5	2380	0.216
Truck	1.2	853	0.383

A- For Passenger Cars:

$OC = (1{,}527.66 \times 0.134 \times 21633 \times 1.5)$ = 6,639,751 ID/day

$FC = 10 \times 500 \times 0.86 = 4300$ ID/day

$VOC = 0.5 \times 4300 \times 0.134 \times 21633 = 6{,}232{,}467$ ID/day

$Wear\ \&\ Tear\ Cost = 10\%\ of\ VOC$

$Wear\ \&\ Tear\ Cost = 0.1 \times 6{,}232{,}467 = 623{,}246$ ID/day

$Total\ Cost = 6{,}639{,}751 + 6{,}232{,}467 + 623{,}246 = 13{,}495{,}464\ ID/day$

B- For Buses:

$OC = (1{,}527.66 \times 0.216 \times 2380 \times 3.5) = 2{,}747{,}500$ ID/day

$FC = \ 10 \times 500 \times 0.86 = 4300 \text{ ID/day}$

$VOC = 0.5 \times 4300 \times 0.216 \times 2380 = 1{,}052{,}272 \text{ ID/day}$

$Wear \,\&\, Tear\ Cost = 10\%\ of\ VOC$

$Wear \,\&\, Tear\ Cost = 0.1 \times 1{,}052{,}272 = 105{,}227 \text{ ID/day}$

$Total\ Cost = 2{,}747{,}500 + 1{,}052{,}272 + 105{,}227 = 3{,}904{,}999\ ID/day$

C- For Trucks:

$OC = (1{,}527.66 \times 0.383 \times 853 \times 1.2) = 598{,}643 \text{ ID/day}$

$FC = \ 10 \times 500 \times 0.86 = 4300 \text{ ID/day}$

$VOC = 0.5 \times 4300 \times 0.383 \times 853 = 702{,}402 \text{ ID/day}$

$Wear\ Cost = 10\%\ of\ VOC = 0.1 \times 702{,}402 = 70{,}240 \text{ ID/day}$

$Total\ Cost = 598{,}643 + 702{,}402 + 70{,}240 = 1{,}371{,}285 \text{ ID/day}$

$\boldsymbol{Total\ Cost}\ (\boldsymbol{PC} + \boldsymbol{Bus} + \boldsymbol{Truck}) = 13{,}495{,}464 + 3{,}904{,}999 + 1{,}371{,}285 = 18{,}771{,}748 \text{ ID/day.}$

2- Al-Tuhmazia Street Congestion Cost:

Table (4.5) shows average occupancy factors, average daily traffic (ADT) and average delay of vehicles traveling under posted speed for Al-Tuhmazia Street taken from speed and travel time collected data.

Table (A.2): Average Occupancy Factors, Classified ADT volumes and Average Delay for Al-Tuhmazia Street.

Vehicle Type	Average Occupancy Factor	Average Daily Traffic (ADT) (veh/day)	Average Delay Under Posted Speed (hr/veh)
Passenger Car	1.5	16553	0.128

Bus	3.5	1313	0.207
Truck	1.2	513	0.358

A- For Passenger Cars:

$OC = (1{,}527.66 \times 0.128 \times 16553 \times 1.5)$ = 4,853,074 ID/day

$FC = 10 \times 500 \times 0.86 = 4300$ ID/hr

$VOC = 0.5 \times 4300 \times 0.128 \times 16553 = 4{,}555{,}385$ ID/day

$Wear \ \& \ Tear \ Cost = 10\% \ of \ VOC$

$Wear \ \& \ Tear \ Cost = 0.1 \times 4{,}555{,}385 = 455{,}538$ ID/day

$Total \ Cost = 4{,}853{,}074 + 4{,}555{,}385 + 455{,}538 = 9{,}863{,}997 \ ID/day$

B- For Buses:

$OC = (1{,}527.66 \times 0.207 \times 1313 \times 3.5) = 1{,}452{,}587$ ID/day

$FC = 10 \times 500 \times 0.86 = 4300$ ID/hr

$VOC = 0.5 \times 4300 \times 0.207 \times 1313 = 584{,}350$ ID/day

$Wear \ \& \ Tear \ Cost = 10\% \ of \ VOC$

$Wear \ \& \ Tear \ Cost = 0.1 \times 584{,}350 = 58{,}435$ ID/day

$Total \ Cost = 1{,}452{,}587 + 584{,}350 + 58{,}435 = 2{,}095{,}372 \ ID/day$

C- For Trucks:

$OC = (1{,}527.66 \times 0.358 \times 513 \times 1.2) = 336{,}527$ ID/day

$FC = 10 \times 500 \times 0.86 = 4300$ ID/hr

$VOC = 0.5 \times 4300 \times 0.358 \times 513 = 394{,}856$ ID/day

$Wear \ Cost = 10\% \ of \ VOC = 0.1 \times 394{,}856 = 39{,}485$ ID/day

$Total \ Cost = 336{,}527 + 394{,}856 + 39{,}485 = 770{,}868$ ID/day

$\boldsymbol{Total\ Cost\ (PC + Bus + Truck)} = 9{,}863{,}997 + 2{,}095{,}372 + 770{,}868 = 12{,}730{,}237\ \text{ID/day}.$

3- Al-Jamaa'ia Street Congestion Cost:

Table (4.6) shows average occupancy factors, average daily traffic (ADT) and average delay of vehicles traveling under posted speed for Al-Jamaa'ia Street segment taken from speed and travel time collected data.

Table (A.3): Average Occupancy Factors, Classified ADT volumes and Average Delay for Al-Jamaa'ia Street.

Vehicle Type	Average Occupancy Factor	Average Daily Traffic (ADT) (veh/day)	Average Delay Under Posted Speed (hr/veh)
Passenger Car	1.5	16520	0.150
Bus	3.5	900	0.247
Truck	1.2	340	0.402

A- For Passenger Cars:

$OC = (1{,}527.66 \times 0.150 \times 16520 \times 1.5) = 5{,}675{,}859\ \text{ID/day}$

$FC = 10 \times 500 \times 0.86 = 4300\ \text{ID/hr}$

$VOC = 0.5 \times 4300 \times 0.150 \times 16520 = 5{,}327{,}700\ \text{ID/day}$

$Wear\ \&\ Tear\ Cost = 10\%\ of\ VOC$

$Wear\ \&\ Tear\ Cost = 0.1 \times 5{,}327{,}700 = 532{,}770\ \text{ID/day}$

$Total\ Cost = 5{,}675{,}859 + 5{,}327{,}700 + 532{,}770 = 11{,}536{,}329\ ID/day$

B- For Buses:

$OC = (1{,}527.66 \times 0.247 \times 900 \times 3.5) = 1{,}188{,}082\ \text{ID/day}$

$FC = \ 10 \times 500 \times 0.86 = 4300$ ID/hr

$VOC = \ 0.5 \times 4300 \times 0.247 \times 900 = 477{,}945$ ID/day

$Wear \ \& \ Tear \ Cost = \ 10\% \ of \ VOC$

$Wear \ \& \ Tear \ Cost = \ 0.1 \times \ 477{,}945 \ = \ 47{,}794$ ID/day

$Total \ Cost = 1{,}188{,}082 + \ 477{,}945 \ + 47{,}794 = \ 1{,}713{,}821 \ ID/day$

C- For Trucks:

$OC = (1{,}527.66 \times 0.402 \times 340 \times 1.2) = \ 250{,}452$ ID/day

$FC = \ 10 \times 500 \times 0.86 = 4300$ ID/hr

$VOC = \ 0.5 \times 4300 \times 0.402 \times 340 = 293{,}862$ ID/day

$Wear \ \& \ Tear \ Cost = \ 10\% \ of \ VOC$

$Wear \ \& \ Tear \ Cost = \ 0.1 \times \ 293{,}862 \ = \ 29{,}386$ ID/day

$Total \ Cost = \ 250{,}452 + \ 293{,}862 \ + 29{,}386 = \ 573{,}700 \ ID/day$

$\boldsymbol{Total \ Cost} \ (\boldsymbol{PC} + \boldsymbol{Bus} + \boldsymbol{Truck}) = 11{,}536{,}329 + \ 1{,}713{,}821 + 573{,}700 = \ 13{,}823{,}850$ ID/day.

الخــــلاصـــــــــــة

اجريت هذه الدراسة لغرض تقييم مدى الزحام المروري في مقاطع مختارة في مركز مدينة الحلة الحضري بسبب تزايد هذه المشكلة بشكل كبير نظراً للنمو السكاني الكبير داخل المدينة وازدياد اعداد السيارات الخاصة بشكل لا يتناسب مع استيعابية الطرق في الجزء الحضري من المدينة. حيث تم قياس الزحام عن طريق حساب مستوى الخدمة لكل مقطع داخل منطقة الدراسة ومن ثم اقتراح حلول مناسبة لتخفيف الزحام وزيادة مستويات الامان في هذه المقاطع.

تضمنت منطقة الدراسة ثلاث شوارع متعددة الممرات (مقطع من شارع ٦٠ ، شارع الطهمازية وشارع الجمعية) وتقاطعين بدون اشارات ضوئية (تقاطع الطهمازية الأرضي وتقاطع شارع ٦٠ / شارع الطاقة) واستدارة واحدة (استدارة شارع ٦٠ بالقرب من الكراج الموحد).

لإنجاز هذا الهدف تم عمل مسوحات هندسية لمنطقة الدراسة اولا حيث تم جمع المعلومات اللازمة مثل عدد الممرات، عرض كل ممر، عرض الجزرات الوسطية وغيرها بالاستعانة بالمعلومات المقدمة من مكتب بلدية الحلة. بعد ذلك تم جمع الحجوم المرورية لكل مقطع في ساعة الذروة الصباحية (٧:٤٥ - ٨:٤٥ ص) وساعة الذروة المسائية (١:٤٥ - ٢:٤٥ م) حيث تم جمع الحجوم عن طريق التصوير الفيديوي لمقاطع الدراسة وحساب وتصنيف المركبات من مقاطع الفيديو باستخدام برنامج (Smart Traffic Analyzer) .

تم استخدام برنامج (HCS+T7F) لتحليل وحساب مستوى الخدمة لمقاطع الشوارع متعددة الممرات، واستخدام برنامج (SYNCHRO) لتحليل وحساب مستوى الخدمة التقاطعات بدون اشارات. حيث تم ايجاد ان جميع المقاطع في منطقة الدراسة تعمل بمستويات خدمة متدنية نسبياً حيث تراوحت ما بين (LOS C) و (LOS E) ثم تم حساب تكلفة الازدحام ووجد ان تكاليف الازدحام اليومية على هذه القطاعات تراوحت بين (12 -18 مليون عراقي).

خلصت الدراسة إلى أن التحسينات المقترحة رفعت المستوى العام للخدمة للتقاطع من ((LOS (E) إلى LOS (C)) عند تقاطع الطهمازية الارضي، من ((LOS (D) إلى ((LOS (C) في كلا الاتجاهين. شارع 60 ، من (LOS (E)) إلى ((LOS (C) في كلا الاتجاهين في شارع الجمعية ، من ((LOS (C, D) إلى LOS (B, (C)) في كلا الاتجاهين على الترتيب في شارع الطهمازية ومن ((LOS (D) إلى ((LOS (C) في تقاطع شارع 60 / شارع الطاقة ، بينما يؤدي تطبيق التحسينات المقترحة على هذه المقاطع إلى تقليل تكلفة الازدحام الحالية بما في ذلك تكلفة الحوادث المرورية بنسبة 50٪ أو أكثر. وفي النهاية اقترحت الدراسة عددا من التوصيات والبدائل لتحسين الأداء المروري في مناطق الدراسة.

جمهورية العراق

وزارة التعليم العالي والبحث العلمي

جامعة بابل / كلية الهندسة

قسم الهندسة المدنية / هندسة النقل

تقييم وتحسين مقاطع زحام مختارة في الطرق الحضرية الرئيسية

رسالة

مقدمة الى قسم الهندسة المدنية في كلية الهندسة /جامعة بابل

كجزء من متطلبات نيل درجة الماجستير في الهندسة المدنية/هندسة النقل

من قبل

دينا خالد خلفة جاسم

بكالوريوس في علوم الهندسة المدنية (2015-2016)

دبلوم عالي في هندسة النقل (2018-2019)

بإشراف

أ.م. عبد الكريم ناجي عبود

1443 هجري

2022 ميلادي