**Republic of Iraq**
**Ministry of Higher Education & Scientific Research**
**University of Babylon/ College of Engineering**
**Civil Engineering Department**
**Transportation Engineering**

# A Simulation of Surrogate Measures to Assess Effectiveness of Countermeasures in Traffic Intersections

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

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**A.H 1445** **A.D 2023**

بسم الله الرحمن الرحيم

﴿ إن أكرمكم عند الله أتقاكم إن الله عليم خبير ﴾

صدق الله العظيم

(الحجرات 13).

# Supervisor Certification

I certify that this thesis which is entitled **(A Simulation of Surrogate Measures to Assess Effectiveness of Countermeasures in Traffic Intersections)** has been prepared by **(Saif Saad Abd Al-Zahraa**) under my supervision at the College of Engineering, Babylon University, in partial fulfilment of the requirements for the degree of Master of Science in Transportation Engineering.

Signature:

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Date: / / 2023

# Acknowledgments

**" In the name of Allah, Most Gracious, Most Merciful"**

Praise be to Allah who gave me the ability and desire to complete this work despite all obstacles in the way of achievement. I would like to express my deep appreciation to my supervisor **Professor Dr. Hussein Ali Ewadh** for his assistance and support in all stages of preparation of my studies.

all the love and gratitude go to **my Family** and to those who were the source of strength, motivation, and assistance especially **my father and mother**, who were with me all the way and helped me walk on the path of knowledge. May God reward them with all goodness.

I am grateful to **Eng. Hussein Mahdi Abed** You have done so much for me so Thank you for your valuable help, support, and guidance.

Last but not least, I would like to thank **my friends** who helped in a certain way or another in the production of this thesis.

**Saif saad abd-alzahraa**

2023

Detected To

To the symbol of devotion and sincerity, which showered us with her.

love and tenderness

Dear mother

To the source of goodness, sacrifice, and altruism

To the example of giving, pride and sacrifice

…...My dear father……

To all who love me sincerely and sincerely

I dedicate my research to

**Abstract**

The traditional method for evaluating safety condition at signalized intersections depends on historical crash data. Difficulty and long waits for data collection as well as lack of reliability represent some limitations. As a result of safety evaluation in traditional method, countermeasures may be proposed to improve degree of safety. This study aims to assess effectiveness of countermeasures at signalized intersections using micro-simulation model (VISSIM10) software and Surrogate Safety Assessment Model (SSAM) to deal with traffic conflicts as surrogate measures rather than crash data.

The study is relied on VISSIM10 to create a trajectory file as inputs of SSAM for the purpose of conducting a traffic safety assessment using traffic conflicts and time to collision (TTC) as indicators of safety.

Four signalized 4-legged intersections in Al-Diwaniyah city are chosen to assess safety and then propose appropriate countermeasures. The countermeasures ( increasing lane widths, increasing numbers of lanes, adding left turn phasing and cancelling U-turn) are tested through simulation to estimate their effectiveness using two measures: the increasing in time to collision and percentage reduction in traffic conflicts.

The evaluation before countermeasures reveals that Al-Jamhori and Al-Oruba intersections are of high risks with TTC of 0.992 sec and 0.984 sec respectively, while the Al-Fadael and Al-Nesser intersections are moderate in danger with TTC (1.023,1.116) sec respectively. Simulation of performing the countermeasures shows that increasing lane widths reduced the traffic conflicts (39.66,43.3,36.945.93) % at Al-Jamhori, Al-Oruba, Al- Fadael and AL-Nesser intersections respectively, increase numbers of lanes reduced the traffic conflicts (38.1,44.28 45.77 53.11) % at Al-Jamhori, Al-Oruba, Al- Fadael and AL-Nesser intersections, respectively.

Add left turn phasing reduced the traffic conflicts ‘(44.28,41.8,28.34,45) % at Al-Jamhori, Al-Oruba, Al- Fadael and AL-Nesser intersections, respectively, while Cancelling U-turn reduced the traffic conflicts (30.9,21.5) % at Al-Jamhori and AL-Nesser intersections, respectively.

Simulation of traffic signal timing optimization as a countermeasure reveal that the total traffic conflicts can be reduced (23, 29.9, 28.84, 32.8)% at Al-Jamhori, Al-Oruba, Al- Fadael and AL-Nesser intersections respectively, while field observation for traffic signal timing optimization shows that the total traffic conflicts can be reduced (36,7, 25.3, 23.94, 13) % at Al-jamhori, Al-Oruba, Al- Fadael and AL-Nesser intersections respectively.

Hence, it can be concluded that in general simulation process overestimate total traffic conflicts.

The results showed that model calibration reduced the mean absolute error of prevention (MAPE) and improved the fit between both the observed and simulated conflicts. MAPE values were reduced from 43% to 24% for the rear-end conflicts, from 25% to 9% for the crossing conflicts, from 71.9% to 45.6% for the crossing conflicts and from 41.9% to 10.6% for the total conflicts. Validation of simulation has been performed compared with observed conflict. According to the linear regression that number of simulated conflicts is significantly correlated with the number of observed conflicts. In addition, the $R^2$ value for the model can be explained by the variation in the simulated conflicts. Results go with effectiveness based on crashes data and promising for unknown ones.

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# List Symbols

| Symbol | Details |
| --- | --- |
| Avs | Autonomous Vehicles |
| CC | Crossing Conflict |
| CMFS | Crash Modification Factors |
| CRR | Crash Reduction Ratio |
| CSO | Central Statistical Organization |
| DeltaS | Maximum Relative Speed Difference |
| DR | Deceleration Rate |
| EACF | Estimated Annual Crash Frequency |
| EB | Eastbound |
| EVT | Extreme Value Theory |
| FHWA | Federal Highway Administration |
| GEH | Geoffrey E. Heaver Statistic |
| HR | High Risk |
| $HTC_{APP}$ | Hourly Traffic Conflicts at Approach |
| ICTCT | International Cooperation in Traffic Conflict Techniques |
| ITS | Intelligent Transportation System |
| LCC | Lane-Change Conflict |
| LIT | Lund Institute of Technology |
| LOS | Level Of Service |
| LR | Low Risk |
| LT | Left Turn |
| MAPE | Mean Absolute Percentage Error |
| MAXD | Maximum Deceleration |
| MAXS | Maximum Speed |

| | |
|---|---|
| MR | Moderate Risk |
| NB | Northbound |
| NCHRP | National Center Highway Research Program |
| PCC | Pearson Correlation Coefficient |
| PET | Post-Encroachment Time |
| PHF | Peak-Hour Factor |
| REC | Rear-End Conflict |
| RT | Right Turn |
| ROC | Risk Of Conflict |
| SB | Southbound |
| SMOS | Surrogate Measures of Safety |
| SSMS | Surrogate Safety Measures |
| SSAM | Surrogate Safety Assessment Model |
| TA | Time To Accident |
| TCT | Traffic Conflict Technique |
| THTC | Total Hourly Traffic Conflict |
| TIT | Time – Integrated Time |
| Trj. | Trajectory |
| TRRL | Transport and Road Research Laboratory |
| Thr | Through Turn |
| TTC | Time-To-Collision |
| VISSIM | **V**erkehr **I**n **S**tädten – **Sim**ulationsmodell (German Language) |
| WB | Westbound |

# List of Plate

# Chapter One
# Introduction

# CHAPTER ONE

# INTRODUCTION

## 1.1 General.

Safe movement of vehicles through the various roads is an issue of national concern. Every year the numbers of vehicles are increasing, therefore, the movement of vehicles on the roads and previously constructed road network may possibly not be capable of to deal with it due to the increasing requirement of traffic across the country. Evaluation of traffic safety is usually based on the application of historical crashes data records, which are reactive in nature it is like waiting for the crashes to happen and then utilizing their countermeasures **(Ghanim et al., 2020).**

Traditionally, traffic safety analysis has depended on the use of historical crash data. This technique is a reactive method that presents a less complete understanding of the crash mechanism and how safety measures work. Several other shortcomings are also associated with this approach, including poor crashes data, quality and availability, and an ethical dilemma since collisions, which need to be prevented, must occur and be recorded over an adequately long period in order to draw necessary information and to conduct a sound safety diagnosis. Because of these limitations, there has been growing interest in traffic safety analysis techniques that rely on other surrogate safety measures. One key surrogate safety analysis is the observation of road user interactions such as the traffic conflict technique, which involves recording and evaluating the frequency and severity of near misses at a location that enables the safety professionals to immediately observe unsafe driving maneuvers at road locations without waiting for collisions to occur **(Arun et al., 2021).**

In case of lack of crash data, finding a surrogate measure to assess safety traffic would provide traffic engineers with a clearer idea of safety in the present and future.

Researchers are studying alternative methods, and one of these methods is the simulation method to determine road safety and find treatment for the lack of safety by simulating countermeasures. The simulation method was resorted because of the weakness of traditional methods due to poor data and at other times because of the mood of the observers **(Guo et al., 2021).**

Traffic simulation models are becoming an increasingly important tool for traffic control. Simulators are needed to generate scenarios, optimize control, and predict network behavior at the optional level. They can give the traffic engineer an overall picture of the traffic and the ability to assess current problems and project possible solutions immediately **(Boxill, & Yu, 2000).**

Intersections are among the most dangerous places on the road network. This is due to the multiple conflicting maneuvers occurring at intersections. Furthermore, severe crashes such as side crashes and angle crashes take place at intersections. Traffic accidents at intersections in urban area are the most common and take a majority of the accident toll. Analyzing and generating countermeasures has been the major task for traffic safety officials and engineers. Without knowing the safety implications of the countermeasures, the task normally concentrates on tackling accidents reflected in historic accident data. As more demand for traffic safety improvement emerges as local and national transport policy, more practical and site-specific traffic accident risk assessment methodology is needed **(Kim, & Sul, 2009).**

## 1.2Traffic Safety in Iraq

Traffic accident injuries are of great danger and are comparable to the current terrorist operations, as they are a scourge that constitutes an obsession and concern for all members of society and has become one of the problems that drain material resources and the social problems and losses in human energies that affect the elements of life in which the human element is the basis of society. Iraq is witnessing many traffic crashes and the fall of large numbers of deaths and injuries, which have reached high numbers over the past ten years. This is confirmed by the annual reports issued by the Iraqi Ministry of Planning / Central Statistical Organization (CSO) and in coordination with the Ministry of Interior / Criminal Statistics Directorate. The following are the main indicators of traffic safety for the year 2020. According to (CSO) Iraq, in all governorates except the Kurdistan region **(CSO Iraq,2021).**

### 1.2.1 Statistical Indicators of Crashes in Iraq

- There were 8186 traffic crashes recorded, of which 2152 were fatal crashes and non-fatal crashes were (6028).
- Crash accidents recorded the highest percentage during the year 2020, reaching (4524) accidents with (55.3%) of the total accidents (8186)followed by hit accidents (2793) accidents (34.1%)followed by turnover accidents (773)making (9.4%) and other accidents (96)by (1.2%)
- Numerical statistics of crashes, injuries, and deaths for the period from 2014 - 2020 are shown in Table (1-1).

**Table (1-1) Main Indicators of Traffic Accidents Recorded for The Years (2016 – 2020) (CSO Iraq,2021).**

| year | No. of accident | Deaths | injuries |
|---|---|---|---|
| 2016 | 8,763 | 2,531 | 9,016 |
| 2017 | 8,824 | 2,621 | 9,388 |
| 2018 | 9,852 | 2,767 | 10,439 |
| 2019 | 10,753 | 2,636 | 11,651 |
| 2020 | 8,186 | 2,152 | 8,383 |

### 1.2.2 Statistical Indicators Crashes of Diwaniya City

- The number of traffic crashes in diwaniya city reached 1127 crashes which were distributed to Four districts as shown in Table (1-2)

**Table (1-2) Number of Crashes in Each District [6].**

| Governorate | District | Injuries | Deaths | No. of accident |
|---|---|---|---|---|
| Al-Qadisiya | Ad diwaniya | 360 | 42 | 320 |
| | Afak | 149 | 24 | 107 |
| | AL-Shamia | 109 | 17 | 96 |
| | Al-Hamza | 63 | 24 | 64 |
| | total | 681 | 107 | 587 |

## 1.3 Problem Study

Many reasons that cause crash accidents, including engineering and administrative problems and non-compliance with traffic laws. The common way to assess traffic safety is to analyze historical crash data at those intersections and then suggest countermeasures to improve them based on the observations. However, the attempt to assess the safety of these sites is usually hampered by accident records problems in terms of reliability and the time required to wait for an appropriate sample size. For making appropriate countermeasures to improve traffic safety, an alternative traffic simulation measure was proposed to assess traffic safety at intersections in preparation for taking appropriate countermeasures to improve safety.

## 1.4 The Aim of Study

The main objectives of this study are as follows:

- Simulation field traffic conditions and creating a trajectory file by (VISSIM10) as inputs of SSAM for the purpose of conducting a traffic safety assessment.
- Determining number of traffic conflicts and the conflicts type in each approach and entire intersection.
- Using traffic conflicts and time to collision (TTC) as indicators of safety to assess safety at signalized intersections by simulating conflicts between vehicles.
- Suggestion suitable countermeasures to reduce traffic conflicts in order to enhance safety at study sites.
- Evaluation the countermeasures to see if they are reduced traffic conflicts and increased time to collision (TTC)

### 1.5 Thesis Structure

Five chapters were included in this thesis as described below:

Chapter one: gives a brief idea, definition of the Problem, and the study's objectives.

Chapter two: shows the related literature of the previous work, description of the surrogate safety measures, traffic conflict definition, microsimulation technique, VISSIM, SSAM software, VISSIM and SSAM in combination etc.

Chapter three: deals with the study area, Tables, Figures, and details of all data which are collected for this study.

Chapter four: offers the analysis's results, discussion, and the suggested improvements.

Chapter five: shows the conclusions, recommendations, and suggestions for future research.

# Chapter Two
# Literature Review

# CHAPTER TWO
# LITERATURE REVIEW

## 2.1 General

The safety of transportation has been a critical concern to roads engineers since traffic crashes often occurred at intersections due to various conflicts made by users travelling through. When studying intersection crashes, crash assessment on why they occur and how to reduce them is ways a main priority. Intersections should be continuously screened and systematically evaluated during their cycle life. Generally, safety practitioners focused their efforts and resources for studying and analyses safety at intersections in several countries to enhance safety situation for the road network **(Mohammad et al., 2022).** Most of the ongoing research in traffic safety deals with the statistical analysis of crash data. As the success of these modeling efforts and the need for better understanding. Over crash data are important, there are also limitations associated with the crash data and corresponding modeling methods, such as underreporting, small sample size, and unobserved heterogeneity **(Mannering, & Bhat, 2014).**Over the years, the limitations of crash data and crash-based methods have given rise to the study of alternate measures of safety that are not predicated on the occurrence of a crash, such as the presence and nature of traffic conflicts. These alternate safety measures (often referred to as crash surrogates in the literature) will likely play a prominent role in road safety analysis in the forthcoming era of connected and autonomous vehicles because of the vast amounts of real-time vehicle data that are likely to be available **(Papadoulis et al., 2019).** Traffic accidents are mainly caused by human misjudgments **(Nadimi et al., 2016).** With the considerable growth of communication technology, computer capabilities, and data collection technology, active vehicle safety systems have been developed to reduce collision risk. Surrogate measures of safety play an important role in definition traffic conflicts and assessing traffic safety **(Gao et al., 2020) (Shi et al., 2021).**

## 2.2 Surrogate Safety Measures (SSMs) in Safety Assessment

SSM as the method of safety measure based on observed non-crashes events, therefore the expression "surrogate" represents measures do not depend on historical crash data but depend on unsafe events (non-crash events) in the traffic process to be a complement or an alternative to crash record-based analyses **(Johnsson et al., 2018**). SSMs are any events that can be correlated with crashes. Because these methods use events that occur at a much greater frequency than crash rates, it is possible to evaluate the safety of a given location without waiting for a large number of crashes to occur so road safety analyst can strongly profit from dependable analysis measures that utilize observable non-crash traffic events (**Laureshyn, & Várhelyi, 2018).** SSM as an alternative safety measure offers the opportunity to evaluate the traffic safety when crash counts are not obtainable; the additional important attraction of SSMs is that saving time since there is no need to wait for adequate crashes to appear before a problem is known and the treatment implemented **(HSM,2010).**

The use of surrogate safety measures such as the traffic conflict technique (TCT) has been advocated as a proactive and complementary approach to study road safety from a broader perspective than relying on collision-based analysis. Surrogate Safety Measures (SSM) are important for safety performance evaluation, since crashes are rare events and historical crash data does not capture near crashes that are also critical for improving safety **(Wang et al., 2021).** The surrogate safety measures provide a better understanding of collision contributing factors and the failure mechanism that leads to road collisions. In addition, surrogate safety measures are more frequent than road collisions and are of marginal social cost. More importantly, the use of surrogate safety measures in traffic safety analysis avoids the ethical dilemma of waiting for crashes to happen to prevent them. This interest is supported by recent advanced technologies such as the use of computer vision, radar, or LiDAR techniques to analyze trajectory data and automatically identify conflicts as well as the use of microsimulation models for estimating surrogate indicators from simulated road user trajectories. Several issues were raised on the use of surrogate safety measures in safety analysis, such as the threshold issue of the surrogate measures, and the validation of the surrogate measures **(Guo et al., 2020).** Surrogate safety measures indicators have been used to investigate vehicle trajectories in order to identify risky conditions. **(Perkins et al., 1968)** were the first to present the idea of a traffic conflict in the 60s. Baker defined a traffic conflict as a condition in which a driver tries to avoid a potential crash or a dangerous event by applying an evasive maneuver, such as using the brakes, performing a lane change, or accelerating **(Baker, 1972).**

## 2.3 Traffic Conflict Definition

Traffic conflict technique was first applied in practice in the late 1960s by a team of researchers at General Motors corporation **(Perkins & Harris, 1967),** but the idea was known at least a decade earlier **(Forbes, 1957).** Following the success of early attempts, the method rapidly gained in popularity **(Laureshyn & Várhelyi, 2018).** The association for International Cooperation in Traffic Conflict Techniques (ICTCT) was founded in 1977 and became an important forum for researchers working in this area of traffic safety. At the first ICTCT workshop in Oslo, Amundsen, and Hyden (1977) proposed the following definition of a traffic conflict: A traffic conflict is an observable situation in which two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged (ICTCT ,2016) Perkins and Harris 1967 firstly defined the conflict point as follows "A traffic conflict is an evasive activity, like braking or weaving, done by a driver to avoid an accident" **(Perkins & Harris, 1968).** Federal Highway Administration (FHWA) adopted adjusted definition as follows: "A traffic conflict is a case including two or more road users, in which the activity of one user make happen the other user to do an evasive maneuver to avoid a collision. "(**Parker & Zeeger, 1988).** Lund Institute of Technology (LIT) introduced the original definition based on the Time to Accident (TA) concept." Time to Accident (TA) is defined as the time which remains to an accident in the moment when evasive action has just been started and presupposes that the road - users continue with unchanged speed and directions The events occur in different probabilities and different seriousness. Based on this idea, the following hypothesis is used "There are elementary events, defined as serious conflicts that can be characterized as breakdown in the interaction. The accident potential is then well defined, i.e., a relationship exists between the number of serious conflicts and accidents **"(Hydén, 1987).** Transport and Road Research Laboratory (TRRL) made the major addition to (FHWA) definition is the use of a severity scale of conflict. Traffic conflict was defined as simple conflict situations involving one or more vehicles taking evasive action. Serious conflicts - situations involving a vehicle in at least a sudden rapid classified according to the severity of the events**(Spicer, 1973)**.National Center Highway Research Program (NCHRP) defined the traffic conflict as 44 a traffic event involving two or more road users, in which one user performs some typical or unusual action, such as a change in direction or speed that places other users in jeopardy of collision unless an evasive maneuver is undertaken **(NCHRP,1980).**

## 2.4 Traffic Conflicts Technique (TCT)

Traffic Conflicts Technique (TCT) is a method for traffic safety estimation based on observation of traffic conflicts. The basic hypothesis of traffic-conflict techniques is that crashes and conflicts originate from the same type of processes in traffic and a relation between them can be found **(Zheng et al., 2014).**

TCT is according to **(Laureshyn, 2010)** it is the most direct of all indirect methods of road safety measures. It is based on observing and recording of the conflict events (near-crashes) in normal operation and in real time. With almost fifty years of work to develop TCTs, it could be said that TCTs are now progressed a transitional period from experiment to application stages **(Laureshyn et al., 2010).**

At first, data collection of traffic conflicts was carried out by field observation. The observers were given training before conducting a survey to get a common perception about the measurement procedures, in this case the determination of the distance and speed of the vehicle. Two observers are usually used. Field observation is considered quite difficult because it requires high concentration. In addition, observers also only have one chance to see and assess a traffic conflict event. When an event has passed, it cannot be repeated to ensure measurement. To overcome this, a video camera is used in field observations in traffic conflict data collection, through video, an event can be repeated to ensure measurement. In addition, the use of video cameras also has other advantages, such as allowing observation to take place in a longer period, can be used in locations that do not allow direct observation, have minimal influence on traffic, and allows studying complex situations in detail **(Laureshyn & Várhelyi, 2018).** The latest issue of TCT is the use of microsimulation in traffic conflict analysis. One of them that has been widely used is the Surrogate Safety Assessment Model (SSAM) developed by FHWA **(Gettman**

**et al., 2008).** SSAM works by processing trajectory data that is inputted from a file with the. trj extension. This trajectory file is generated by traffic simulation software, namely AIMSUM, PARAMICS, VISSIM, and TEXAS. With this data, SSAM will calculate several indicators, namely minimum time to collision (TTC), minimum post-encroachment time (PET), initial deceleration rate (DR), maximum speed (MaxS), maximum relative speed difference (DeltaS), location of the conflict event (CLSP, CLEP), and maximum DeltaV (MaxDeltaV. SSAM workflow can be seen in Figure (2-1) **(Bared, 2016).**

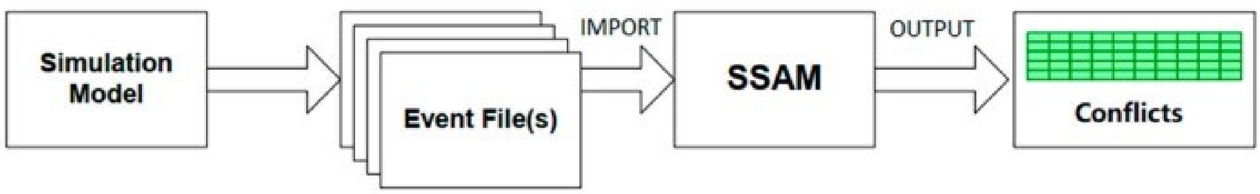



**Figure (2-1). SSAM Operational Concepts (Gettman et al., 2008).**

The basic concept of surrogate safety indicators assumes that all traffic events involving nearness of some kind between two or more road users are related to safety. These events differ in their degree of severity (unsafety), and a relationship exists between the severity and the frequency of events **(Hydén, 1987).** If this relation is known, it is theoretically possible to calculate the frequency of the very severe but infrequent events (accidents) based on the known frequency of the less severe but more frequently occurring events **(Svensson, & Hydén, 2006).** Figure (2-2) shows this relationship where fatal accidents are regarded as the most severe events. The Pyramid Bottom illustrates uninterrupted traffic events and vehicle interactions. Pyramid Intermediate conflicts may outnumber the likelihood for occurrence and in some cases, outnumber even minor conflicts in severity. Pyramid Top represents dangerous events, the severity of which varies from damages to injuries and in certain times fatality **(Alonso et al., 2020).**

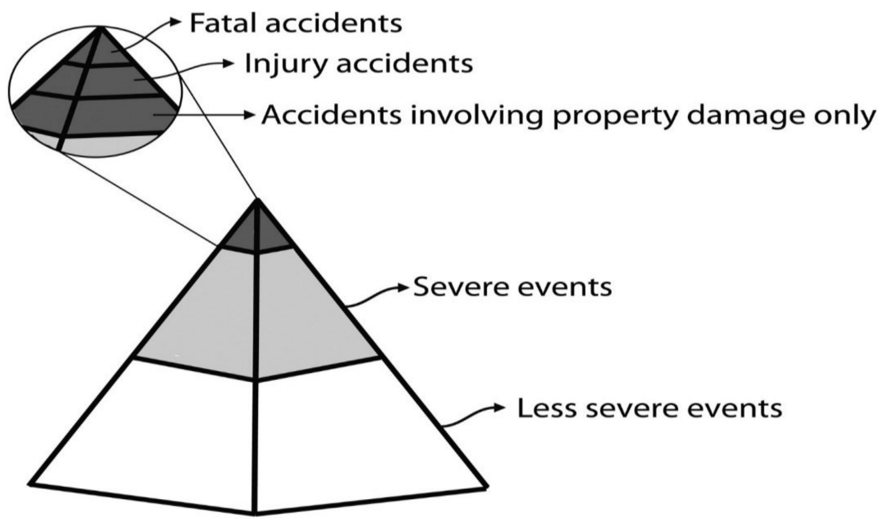



**Figure (2-2) Severity Levels of Traffic Events (Alonso et al., 2020).**

## 2.5 Micro-Simulation Technique

Simulation modelling is an increasingly popular and effective tool for analyzing a wide variety of dynamical problems associated with complex processes which cannot readily be described in analytical terms. Usually, these processes are characterized by the interaction of many system components or entities whose interactions are complex in nature. Specifically, simulation models are mathematical/logical representations of real-world systems, which take the form of software executed on a digital computer in an experimental fashion. The most important advantage is that these models are by no means exhaustive (**Mathew, 2009).** The objective of simulation model is to present a real traffic situation into dynamic model **(Azlan, & Rohani, 2018).** A microscopic model of traffic flow attempts to analyze the flow of traffic by modelling driver-driver and driver-road interactions within a traffic stream which respectively analyses the interaction between a driver and another driver on road and of a single driver on the different features of a road. Many studies and researches were carried out on driver's behavior in different situations like a case when he meets a static obstacle or when he meets a dynamic obstacle. Among these, the pioneer development of car following theories paved the way for the researchers to model the behavior of a vehicle following another vehicle in the 1950s and 1960s. **(Mathew, 2009).** Microsimulation traffic models can significantly improve the quality of road network planning and design in urban areas. They can be used as an element of the decision-making process when different solutions are analyzed and compared. To simulate the traffic status, simulation models primarily focus on the number of input and output parameters. The trip description is an input used to specify the destination and departure time. The second input is the network geometry layout, which describes the network's length, the number of lanes, etc. The third input is traffic flow, which indicates the number of vehicles on the network **(Otković et al., 2020).**

Traffic simulators are also considered a key enabler in the effective implementation of smart mobility services. Extensive simulation to evaluate and test the impact of such services will be essential prior to real-world testing. Hence, traffic analysis and modeling of 'what if' scenarios assist policymakers and traffic planners with making informed decisions regarding infrastructure planning and investments. The ability of these traffic simulators to model various levels of traffic complexity and city-wide scales ranging from a single detailed intersection to a specific region will provide valuable insights into traffic modeling and analysis **(Djukic et al., 2015).**

To simulate the traffic status, simulation models primarily focus on the number of input and output parameters. The trip description is an input used to specify the destination and departure time. The second input is the network geometry layout, which describes the network's length, the number of lanes, etc. The third input is traffic flow, which indicates the number of vehicles on the network **(Mahmud et al., 2019).** Previously, microscopic simulations, e.g., Vissim, have been extensively used by traffic engineers to estimate the operational performance of road facilities, e.g., capacity, delay and travel time. Recently, there has been a growing interest to apply microscopic simulation to safety assessment of traffic systems **(Mahmud et al., 2019).**

Gettman and Head (2003) first developed an advanced method called Surrogate Safety Assessment Model (SSAM) and investigated the possible of obtaining SSMs from obtainable microscopic simulation models, The SSAM is a software application developed by FHWA to estimate surrogate safety measures based on traffic simulation modeling **(Zhou,2020).** A traffic conflict occurs when two vehicles approach each other so that if no evasive action is taken during their original trajectories, a collision occurs. SSAM reads trajectory files generated by microscopic simulation programs to recognize the number and type of the traffic conflicts between vehicles during the simulation period. The vehicle trajectories files can be obtained from microscopic traffic simulation software's such as AIMSUN, VISSIM, PARAMICS, and TEXAS. Furthermore, the SSAM and simulation model (VISSIM or AIMSUN) have also been used to:

1- estimate safety improvements by converting a standard roundabout into an egg turbo roundabout **(Gallelli, & Vaiana, 2019).**

2-investigate safety impacts of autonomous vehicles (AVs) **(Mahmud et al., 2019).**

1- 3-evaluate the countermeasures for the conflicts among motorists entering an intersection with a red-light signal **(Lee, & Ma, 2018).**

4-estimate crash modification factors (CMFs) for intelligent transportation system (ITS) countermeasures **(Das et al., 2019).**

5-assess the safety of two alternative designs for high-occupancy vehicle lane at junctions with bus terminals or parking lots **(Karimi, & Alecsandru, 2019).**

6-examine safety impacts for the cooperative vehicle intersection control algorithm allowing vehicles to pass urban intersections without any stops caused by traffic signals **(Park et al., 2013).**

7-assess safety impact for connected vehicles based on the traffic applications, using considerations of potential positioning errors as well as communication delays that are likely to actually occur in the field **(So, & Kweon, 2015).**

8-optimize the traffic signal timings based on surrogate measures of safety **(Stevanovic, & Persaud, 2015).**

Some studies have indicated that some excessive numbers of conflicts were observed in the process. However, many studies have compared the results of the microsimulation environment (SSAM and VISSIM or SSAM and AIMSUN) with the results observed in the field for intersections in many countries such as: fifty-three signalized intersections in Canada **(Shahdah, et al.,2015).**Twenty-four signalized intersections as well as Eighty-six segments in Virginia, United States **(So, & Kweon, 2015).**roundabouts in Rende, Italy **(Gallelli,& Vaiana, 2019)**,signalized intersections in China **(Chen, et al.,2019)**.Twenty-six Slovenian roundabouts (single-lane, double-lane, and turbo roundabout) **(Giuffrè, et al.,2018).** highway segments in United States **(Kim, et al.,2018).** Seventy- eight 3-leg and fifty-five four-leg intersections for two-way stop-controlled intersections within the city of Toronto, Canada **(Lorion, & Persaud, 2015).**4-legged signalized intersections in Toronto Ontario, Canada **(Saleem, et al.,2014).** Seven intersections in Orlando, Florida, United States **(Wu, et al.,2018).** and signalized intersections in Doha, Qatar **(Ghanim, & Shaaban, 2019),**They found that potential conflicts could be reasonably predicted from the microsimulation environment (SSAM and VISSIM or SSAM and AIMSUN). Also, these can be used to predict the type and location of potential conflicts and assess the impact of geometric improvement in reducing potential conflicts. Moreover, they found that their results support the view that countermeasure impacts may be estimated reliably through conflicts derived from the microsimulation **(Ghanim, & Shaaban, 2019).**

## 2.6 PTV VISSIM

PTV VISSIM software is according to PTV Group (2020) the standard microscopic traffic and transport planning tool which is based on modelling and simulation. This software can be used in the following areas (PTV Group ,2020):

- Traffic Flow Simulation – software helps in the decision-making process for creating sustainable transport system **(Muchlisin,& Widodo, 2019).**
- Advanced Traffic Management Systems – software helps to reduce the negative impacts of transport system **(Xing, et al.,2018).**
- Multimodal Systems – software helps to study of all transport modes including pedestrians **(Saleem, et al.,2014).**
- Autonomous Vehicles and New Mobility – software helps to model and to simulate the impacts of autonomous driving **(Songchitruksa, et al.,2014).**
- Virtual Reality Traffic Simulation – software helps to create microscopic traffic simulation **(Kučera, & Chocholáč, 2021).**

VISSIM simulation platform was used in this study to simulate the traffic interaction at signalized intersection locations. The main advantages of VISSIM other contemporary software are:

- Flexibility in dealing with interactions between two vehicles in the same lane, lateral movement of vehicles, and gap acceptance controls **(Habtemichael, & Picado, 2021).**
- Allows calibration of different parameters that include the driver's behavior to reach real traffic situations.
- VISSIM has many routing decisions for vehicles, allowing many scenarios.

Thus, companies and cities save money and time, enhance road safety, and reduce the impact on the environment with VISSIM. So VISSIM is a valuable and effective tool for transportation engineering **(Atamo,2012).**

There are four regimes that a vehicle can belong to in the Wiedemann model. These are:

- Free driving: There is no influence from a preceding vehicle. A driver seeks to reach and maintain the desired speed.
- Approach: This regime is entered when a driver passes the threshold to start perceiving the actions of a leading vehicle and starts to adapt its speed to the speed of the preceding vehicle. During an approach, a driver applies a deceleration so that the speed difference between the two vehicles is zero when a desired safety distance is reached.
- Following: A driver of a following vehicle unconsciously accelerates and decelerates to keep a desired safety distance to a lead vehicle.
- Braking: The regime is entered when a driver is forced to apply medium to high deceleration, this occurs when the distance to a lead vehicle becomes less than the desired safety distance. This situation may arise if a lead vehicle

changes speed abruptly or reacts to the actions of a vehicle further in front **(Elefteriadou,2014).**

An illustration of the regimes described by PTV (2011) and Elefteriadou (2014) can be seen in Figure (2-3), where a driver closes in on a leading vehicle.

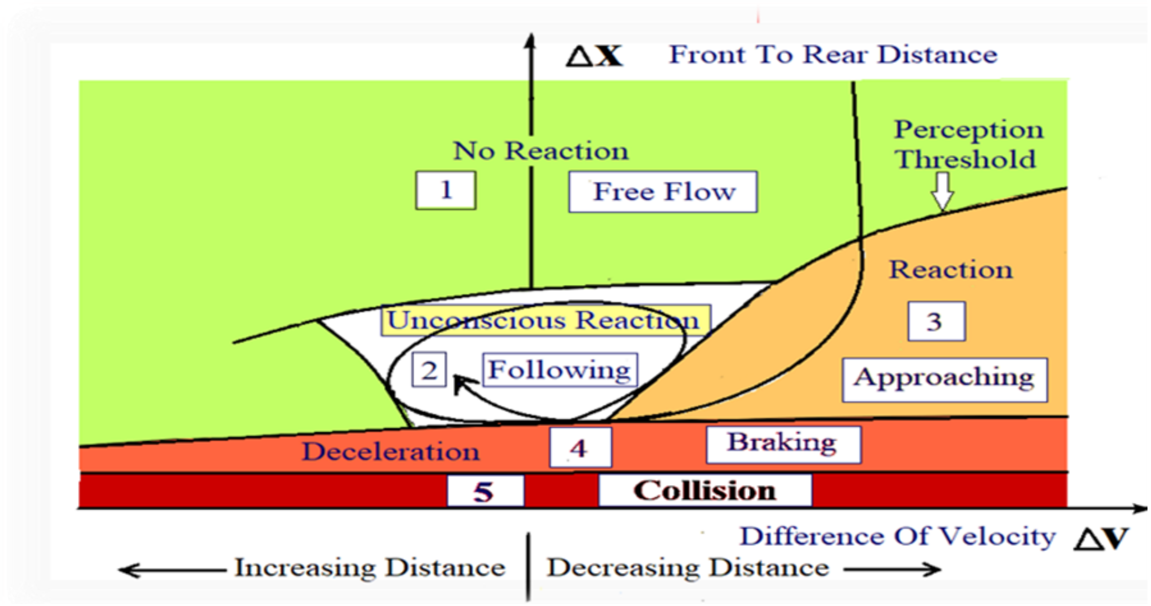



**Figure (2-3) Driving Logic According to Wiedemann (PTV,2013).**

Until the driver passes the perception threshold (SDV) the driver is unhindered by the preceding vehicle and exist in the free driving regime, where the driver maintains a desired speed. When the SDV threshold is passed the approach regime begins and the driver decelerates to reach a desired safety distance (Δx) when the relative speed difference (Δv) is zero. The driver then enters the following regime and unconsciously changes his/her velocity by acceleration and deceleration in an iterative process. The deceleration continues until the driver reaches the point where he/she notices that he/she is slower than the leading vehicle (OPDV) or the maximal desired following distance (SDX) is attained. The driver then starts to accelerate again to reach the desired following distance and speed. The minimum desired following distance is composed of two factors, the desired distance at stand still to the lead vehicle (AX) and a safety distance depending on the travelling speed (BX). If the distance to the preceding vehicle is less than AX+BX for a certain speed, the driver enters the previously explained braking regime **(PTV,2013).**

### 2.6.1 Calibration VISSIM Software

Calibration is the process in which the various parameters of the simulation model are adjusted till the model accurately represents field conditions. The parameters of VISSIM, which affect the behavior of the network created in it, are adjusted during calibration so that the model replicates field conditions. The numerous calibration parameters that can be modified are categorized based on their characteristics. Manually calibrating VISSIM by changing all the sensitive parameters and simulating the model to get the errors between the actual and simulated measure is time consuming. In the past, analysis of the simulation models was done relying on values of default parameters which lead to incorrect results and to huge discrepancy of the simulated results and observed field data. In order to overcome such a situation, researches were pushed to do the calibration of the used models. Similar to other microscopic models of traffic simulation, VISSIM encounters the necessity to calibrate its parameters in order to gain reliability and accuracy of its use by bridging a conditional match of the simulated parameter values with observed traffic field data. There are numerous efforts done by researchers in the direction of doing successful calibration and validation processes of VISSIM parameters **(Rrecaj, & Bombol, 2015).** The calibration process means finding suitable model's parameters based on try and error process to get good agreement between real data set and the simulation results. The validation process means using the same parameters that obtained from the calibration process in testing the agreement between real and simulation data for other set(s) of data. If the obtained parameters from calibration process do not satisfy the validation process, the selected parameters should be changes until the simulation results satisfy the data for both data sets used in calibration and validation process. For calibration purposes of VISSIM traffic simulation software, literature identifies several key measures being used, consisting with single or multi-parameter calibrations **(Al-Obaedi, J. 2019).**

There are two predominant methods of calibrating microsimulation models. Both methods involve selecting one or more measures of effectiveness that guide the ways data are collected from the existing traffic conditions. These data serve as the baseline to which the modeler attempts to match microsimulation results. Matching the measures of effectiveness is achieved through adjustments to the model parameters, and this is where the two main calibration methods differ. In the first method, the parameters are adjusted manually in a trial-and-error process, while in the second method the parameters are changed automatically through the use of metaheuristic algorithms. In both methods, once calibrated, the model is applied to a new time and compared to the existing traffic during that time to assess the model's predictive abilities, which is referred to as validation **(Dong, et al.,2015)**

## 2.7 Surrogate Safety Assessment Model (SSAM)

The Surrogate Safety Assessment Model (SSAM) is a software application designed to perform statistical analysis of vehicle trajectory data output from microscopic traffic simulation models. The software computes a number of surrogate measures of safety for each conflict that is identified in the trajectory data and then computes summaries (mean, max, etc.) of each surrogate measure **(Gettman, et al.,2015).** SSAM identifies four types of conflicts: crossing (angle), lane-changing, rear-end and unclassified. The type is determined based on the conflict angle, link, and lane information. A conflict angle for a pair of vehicles is calculated based on the angle at which these vehicles converge to a hypothetical collision point. For each conflict, SSAM computes several corresponding surrogate measures of safety (TTC, PET, etc.) along with their summaries (mean, max, and variance). SSAM approach exhibits promise to provide significant support to evaluations of traffic engineering alternatives without expensive field crash studies **(Gettman, et al.,2015).**

Federal Highway Administration (FHWA) of the United States of America (USA) has developed software (SSAM) that detects simulated vehicle conflicts from space-time trajectory of individual vehicles provided from micro simulation platforms. SSAM analyzes the vehicle-to-vehicle interactions and categorizes the detected conflicts either as crossing, rear-end or lane- changing conflicts depending on the conflict angle. Besides, the frequency of simulated vehicle conflicts, SSAM provides important surrogates measures for each conflict which can be used for conflict severity analysis. SSAM, in combination with VISSIM, has been intensively used for safety analysis by researchers **(Habtemichael, & Picado, 2021).**

The severity and nature of traffic conflicts enables qualitative analysis and diagnose inappropriate traffic control, geometric design at intersections and road user behavior. It can lead to identify site specific and accident type specific remedial measures. Where traffic accident records are not readily available, traffic conflict analysis provide very valuable information and quantifiable (although sometimes subjective) safety measures for safety evaluation purposes **(Kim, & Energy, 2008).**

### 2.7.1 Definitions of Surrogate Measures Computed by SSAM (Pu, & Sul, 2009).

- **TTC:** is the minimum time-to-collision value observed during the conflict. This estimate is based on the current location, speed, and future trajectory of two vehicles at a given instant. A TTC value is defined for each time step during the conflicts event. A conflict event is concluded after the TTC value rises back above the critical threshold value. This value is recorded in seconds.

- **PET:** is the minimum post-encroachment time observed during the conflict. Post encroachment time is the time between when the first vehicle last occupied a position and the time when the second vehicle subsequently arrived to the same position. A value of zero indicates a collision. A post-encroachment time is associated with each time step during a conflict. A conflict event is concluded when the final PET value is recorded at the last location where a time-to-collision value was still below the critical threshold value. This value is recorded in seconds.

- **MaxS**: is the maximum speed of either vehicle throughout the conflict (i.e., while the TTC is less than the specified threshold). This value is expressed in feet per second or meters per second, depending on the units specified in the corresponding trajectory file.

- **DeltaS**: is the difference in vehicle speeds as observed at tMinTTC. More precisely, this value is mathematically defined as the magnitude of the difference in vehicle velocities (or trajectories), such that if $v_1$ and $v_2$ are the velocity vectors of the first and second vehicles respectively, then DeltaS = $\| v_1 - v_2 \|$.

- **DR:** is the initial deceleration rate of the second vehicle, recorded as the instantaneous acceleration rate. If the vehicle brakes (i.e., reacts), this is the first negative acceleration value observed during the conflict. If the vehicle does not brake, this is the lowest acceleration value observed during the conflict. This value is expressed in feet per second or meters per second, depending on the units specified in the corresponding trajectory file.

. • **MaxD:** is the maximum deceleration of the second vehicle, recorded as the minimum instantaneous acceleration rate observed during the conflict. A negative value indicates deceleration (braking or release of gas pedal). A positive value indicates that the vehicle did not decelerate during the conflict. This value is expressed in feet per second or meters per second, depending on the units specified in the corresponding trajectory file.

. • **Conflict Type**: describes whether the conflict is the result of a rear end, lane change, or crossing movement. The type is classified as a rear-end conflict if ||Conflict Angle|| < 30 °, a crossing conflict if ||Conflict Angle|| > 85 °, or otherwise a lane-changing conflict.

**2.8 Using VISSIM and SSAM in Combination**

**(Cruz et al.2021)** presented their paper that includes a study of traffic safety in two roundabouts using a simulation approach their paper showed the results of a comparative safety assessment between the proposed basic turbo-roundabout and existent two-lane roundabout, they're designed for the same intersection, to define the best of the two from a safety perspective, depending on surrogate safety measures and traffic conflict through the micro-simulation model (VISSIM) and SSAM software to identify six surrogate measures. The number of conflicts was found (72%) fewer at the turbo-roundabout and found that traffic conflict at the turbo round about in a form cluster group, while conflict at the roundabout is scattered.

**(Molan et al.2021)** studied safety assessment by using the VISSIM simulation model and the surrogate safety assessment model SSAM at new offset diamond interchange (ODI) instead of the traditional interchange due to its failure.Based on the results, the (ODI) showed the possibility to be a successful alternative and favorable design in terms of safety.

**(Mahdi & Ewadh 2020)** used VISSM micro-simulation model and SSAM to assess safety at signalized intersections in Hilla city. SSAM computes selected traffic conflict indicators. The severity of approach conflicts ranged from 0.74 (high-risk) to 1.8 (low risk) using a micro-simulation model (VISSM) coupled with (SSAM). Three signalized intersections are modeled using the microsimulation VISSM (version 10) model by calculating the traffic flows and speeds extracted from field data. Also, geometric characteristics and timing of the signal are simulated to reach the real-world. Then the vehicle trajectory files are exported to SSAM (version 3). The results showed that the optimal values for the two safety indicators at intersections differ from one location to another, where TTC values ranged between (1.5-1.8) s and PET (4.7-5.3) s. Rear-end conflicts prevailed in all sites until their reached 55% of all conflicts. The severity of the conflicts at approaches varied from 0.74 as a high-risk collision to 1.8 as a low-risk collision, while the (TTCI) values for 40 St and Bab Al Hussein intersections were 0.86 and 0.82. respectively. Therefore, they are both classified as high-risk intersections. As for the Bab AlMashed intersection (TTCI=1.23), it is classified as moderate risk.

**(firaol 2019)** used combination of VISSIM and (SSAM) to assess the traffic safety of a roundabout as per the result of the assessment of this study the result of time to collision 0.7sec which is less than 1sec. Therefore, the roundabout has high risk of proximity to accident (conflict severity).

**(Xuan and Rui 2019)**. showed that the safety performance of the intersection was improved by timing optimization. The results of this study also showed that the use of VISSIM, along with the SSAM is a fast way to examine the safety impact of proposed solutions A typical signalized intersection in Hanoi city where motorcycles are used prevalently was selected and a micro-simulation model using VISSIM according to the field traffic data was developed to obtain vehicles' trajectories. And then the output file of vehicles' trajectories was analyzed by the SSAM to identify simulated conflicts, including (TTC) and the numbers of conflicts which consist of rear-end, crossing and lane-change conflicts. The analysis results indicated that compared to initial signal timings the estimated number of conflicts was reduced by 14.6% and improved the average value of TTC (15.4%). This means that the timing optimization plan not only improves traffic conditions but also improves traffic safety in comparison to the existing timing plan. Moreover, the use of VISSIM, along with the SSAM at intersections is a fast way to examine the safety impact of proposed solutions, as well as contribute to the improvement of safety in mixed traffic flow.

**(Ribeiro et al.2019)** presented a case study to identify road safety conflicts in an interchange of the road network of the city of Guimarães, Portugal. using the SSAM software in order to identify and characterized the network points of conflict according to their category and severity. To obtain vehicle routes a microsimulation traffic modelling was performed through the usage of PTV VISSIM software. Thus, a traffic and geometric data collection was done for the peak hour in the morning, to identify and analyze three types of conflicts (rear end, lane change and crossings) with SSAM were evaluated two parameters the TTC and the PET. The location of the conflicts was analyzed in a GIS, which allowed the creation of maps of conflicts. The results shown that the most frequent conflicts are the rear end conflicts (1174), which occurs a little throughout the entire interchange and are more frequently in the entrances and exits of the freeway, which was also verified for lane change conflicts (107), but in a lower frequency. Based on these results it was also possible to conclude that the high number of conflicts should be a matter of concern for transport authorities, who may have to adopt measures to improve safety and reduce the potential for accidents, which may imply a reduction of speed in this interchange or a police reinforcement.

**(Kolk et al. 2018)** combined between usage of microscopic traffic simulation and Extreme value theory (EVT) for safety evaluation. SSAM was used to extract simulated conflict data from vehicle trajectory files from VISSIM and video-based data collection was introduced to assist trained observers to collect field conflict data. EVT-based methods were then employed to model both simulated/field conflict data and derive the Estimated Annual Crash Frequency (EACF), used as Surrogate Safety Measures (SSM) it was possible to show that on the one hand, a combination of microscopic traffic flow simulation and accident simulation is not only technically feasible but can also provide a large number of unique traffic scenarios as well as valuable additional information, e.g., on environmental traffic that is indirectly involved in conflicts.

**(Muley et al.2018)** used the micro-simulation environment to predict the conflict between a vehicle and another vehicle, as well as between vehicles and pedestrians' conflicts at Doha signalized intersections in Qatar's country.The studied intersections are modeled by the VISSIM simulation tool, where vehicles and pedestrian trajectories were created. Then (SSAM) was used to analyze the simulated to identify conflicts within the study zones. The results displayed that conflict could be reasonably surmised. Further, the micro-simulation approach can be used to foresee potential conflicts during scenario testing, and the outcomes can be identified to assess the effect of the geometric improvement in decreasing the potential conflicts. **(Jaehyun et al, 2015)**. developed and evaluated two types of models that could replace the integrated simulation approach with much faster computation time, feasible for real-time implementation. The models were developed and trained on the basis of three simulation data sets obtained from the VISSIM-CarSim-SSAM integrated simulation approach, and their performances were compared in terms of the prediction accuracy. The models were evaluated using six simulation data sets. The results indicated that the neural network approach showing 97.7% prediction accuracy was superior to the logit model with 85.9% prediction accuracy. In addition, the correlation analysis results between the traffic conflicts obtained from the neural network approach and the actual traffic crash data collected in the field indicated a statistically significant relationship. The study results indicated that the neural network approach is not only a time-efficient way to implementing the VISSIM-CarSimSSAM integrated simulation but also superior alternative in assessing surrogate safety.

**(Prathmesh 2014)** showed the safety effects of access management using VISSIM and SSAM. The researcher used VISSIM 5.4 microsimulation software to model the existing conditions and surrogate safety assessment model (SSAM) to identify the simulated conflicts generated by VISSIM. For the research, three models with different levels of access management such as low, medium, and high were implemented and for these, the simulated conflicts and travel times of each model were compared with each other. The result of the study showed that there was an increase in the travel times for the low level and the high level of access management compared to existing conditions. The medium level of access management experienced a slight decrease in the travel time compared to the existing conditions. In case of total simulated conflicts, there was a significant decrease and a slight decrease in the low level and the medium level respectively when compared with the existing conditions. In conclusion, the findings of the study indicated that the access management strategies have a positive effect on the safety of the corridor.

**(Xuan and Huang 2013)** developed a traffic safety evaluation method with the use of VISSIM microsimulation and SSAM. The site selection criteria were little or no pedestrians, no on-street parking, and good sight distances, which led to the selection of a two-phase signalized intersection in Nanjing the vehicle trajectories from VISSIM were inputted in the SSAM, which then identified the conflicts. The researchers also performed an evaluation of a speed limit reduction as another treatment. The researchers concluded that a safety evaluation of a signalized intersection can be done using the VISSIM and SSAM and speed limit reduction does improve the safety of the intersection.

## 2.9 Safety Indicators

### 2.9.1 Time-To-Collision (TTC)

The time-to-collision notion has been applied beneficially as a safety indicator in safety analyses. The time-to-collision (TTC) concept was introduced in 1971 by the US researcher Hayward. A TTC value at an instant (t) is defined as the time that remains until a collision between two vehicles would have occurred if the collision course and speed difference are maintained **(Hydén,1996).** The time-to-collision distribution has been applied in several studies to identify traffic safety **(Sacchi, & Sayed, 2016).** The time-to collision of a vehicle-driver combination i at instant t with respect to a leading vehicle i−1 can be calculated with:

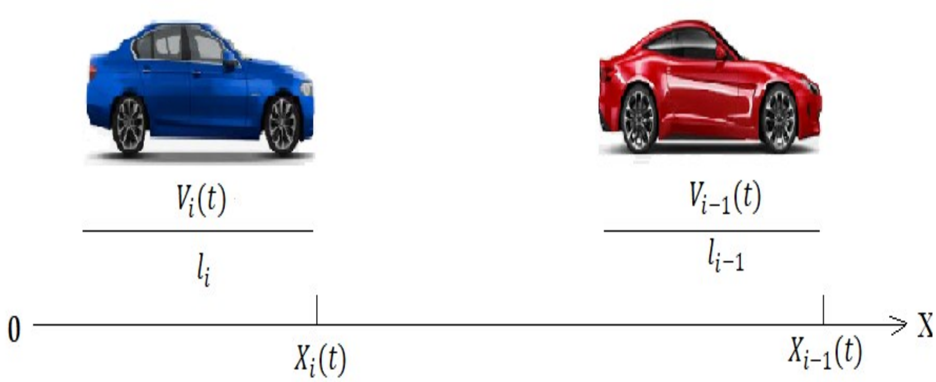



**Figure (2-4) Time-To-Collision Notion Illustrated with Vehicle Trajectories (Ramezani et al.2020)**

$$TTC_i(t) = \frac{X_{i-1}(t) - X_i(t) - l_{i-1}}{V_i(t) - V_{i-1}(t)} \qquad (2\text{-}1)$$

Where:

$TTC_i(t)$=Time To Collision between two consecutive vehicles at any time t.

(($X_i(t)$ **and** $V_i(t)$)= Position and velocity of the following vehicle i respectively at any time t.

(($X_{i-1}(t)$ *and* $V_{i-1}(t)$)= Position and velocity of the leading vehicle i respectively at any time t.

($l_i$ **and** $l_{i-1}$)= Length of the following and leading vehicle i respectively.

The value of the threshold for TTC may be used as the default value 1.5 s by researchers as the most common value at intersections as a threshold for distinguishing between serious and non-serious conflict **(Ramezani et al.2020)**

**2.9.2 Post-Encroachment Time (PET).**

Represents the time difference between a vehicle leaving the area of encroachment and a conflicting vehicle entering the same area as shown in Figure (2-5) **(Ramezani et al.2020)**

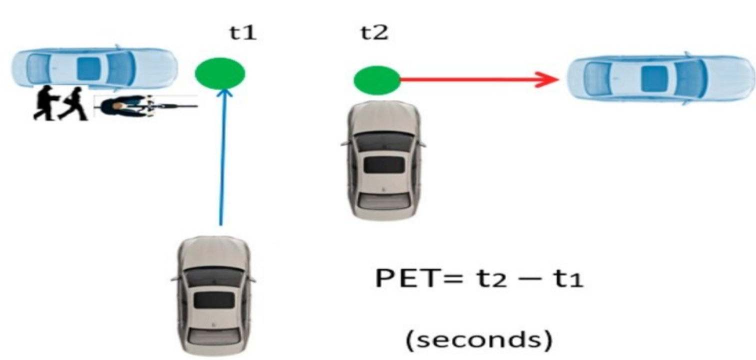



**Figure (2-5) Post-Encroachment Time (PET) (Poó et al.2018).**

Instead of using a reactive crash-based approach, recent developments in surrogate safety measures and video analytic tools offer an alternative approach that can lower the monetary and time costs of traffic safety analysis. These measures utilize data on road user interactions or conflicts that do not turn into crashes but can be observed frequently. They can be divided into measures of time or distance proximity, such as post-encroachment time (PET) or time-to-collision (TTC), **(Scholl et al.2018).** It can also provide a rapid analysis in the stages of diagnosis and in before-and-after studies, allowing for the development and implementation of pro-active road safety programs and strategies, enabling authorities to act before collisions occur.

With regard to the simulation-based approach, both TTC and PET values are very important and are determined by the SSAM model and do not rely on the values of previous studies because they are the backbone of conflict analysis. After creating the trajectory file with a micro-simulation VISSIM and exporting the file to SSAM, SSAM analyzes the file, The first step in SSAM's analysis is to find the optimal values of both TTC and PET for each intersection separately **(Argade,2014).**

## 2.10 Safety Countermeasures

Safety countermeasures are activities done to enhance transportation safety and then reduction the number of injuries and fatalities. Safety countermeasures may consist of geometric design, systemic safety **(overton,2019).** Programmatic countermeasures are used to attack systemic safety problems that prevail throughout the highway system. These measures generally involve education and/or control of drivers, vehicles, or highway design features **(Prassas, & Roess,2020).**

The selected intersections suffer from large turn volume, absence of left-turn phase, inadequate signal timing, large total intersection volume and other problems that increase the risk of collision and reduce safety.

In this study, many countermeasures are used to improve safety at intersections according to the literature review which summarized at Table (2-1), Table (2-2) and Table (2-3) a review summary of crash type and countermeasures and crash reduction percentage of traffic conflicts to improve traffic safety. These countermeasures are summarized as follows:

- Increasing width of lane
- Increasing numbers of lanes
- Improving traffic signal
- Adding left turn phasing.
- Canceling U-turn

**Table (2-1) Types of Crashes at Intersections and Countermeasures Used to Enhance Them (Prassas, & Roess,2020).**

| Crash Model | Possible Reason | Countermeasures |
|---|---|---|
| Lane Change | • Large Turn Volume<br>• Absence of Left-Turn Phase | • Retime Signal.<br>• Provide Left-Turn Signal Phase.<br>• Add Lanes.<br>• Add Turning Lanes |
| Rear-End At Signalized Intersection | • Large Turn Volume<br>• Inadequate Signal Timing | • Provide Left-Turn Signal Phase.<br>• Prohibit Turn.<br>• Provide Right-Turn Lane.<br>• Add Lanes.<br>• Add Exclusive Left-Turn Phase (Protected)<br>• Prohibit Left-Turns |
| Crossing At Signalized Intersection | • Inadequate Signal Timing<br>• Large Total Intersection Volume | • Retime Signal.<br>• A Add Left And Right Turning Lanes With Signal Dd Lane.<br>• Provide Right-Turn Lane.<br>• Add Lane.<br>• Add Exclusive Left-Turn Phase (Protected) |

### 2.10.1 Selection of Potential Countermeasures.

There are three main steps to selecting a countermeasure(s) for a site:

1. Identify factors contributing to the cause of crashes at the subject site.
2. Identify countermeasures which may address the contributing factors; and
3. Conduct cost-benefit analysis, if possible, to select preferred treatment

The goal of any general or site-specific safety analysis is the development of programmatic or site-specific improvements to mitigate the circumstances leading to those accidents. Each case, however, has its own unique characteristics that must be studied and analyzed in detail. Program development must consider national, regional, and local statistics; site mediation requires detailed collision and condition information. Programmatic countermeasures are used to attack systemic safety problems that prevail throughout the highway system. These measures generally involve education and/or control of divers, vehicles, or highway design features.

**(Binghong et al., 2021)** investigated a model for determining the recommended length of added DLT lanes by using the VISSIM traffic simulation model and SSAM evaluation model. the results showed that the development intersections with added DLT lanes significantly reduced the number of conflicts compared with the existing intersection, especially in the “rear end” and “lane change.” (e research proves that the added DLT lane length evaluation and analysis model proposed in this paper can eliminate the controversy of subjective human factors and achieve multi objective optimization projects. It also proves that the evaluation and analysis model is advanced, reasonable, and maneuverable, and the considering multifactor design process for determining the recommended length of added DLT lanes with applying the analysis model also has good practicability. It can provide meaningful guidance for the designers in the design of the reconstructed DLT intersections.

**(Yang and Li Meiqi2020)** used VISSIM modal to study the simulation, verification and optimization of two adjacent intersections. It provides effective verification for the solution of the traffic problem. The purpose is to try to get the most effective solution to the problem of road congestion at the least cost. The adjacent intersections can only be qualitatively optimized from the aspects of channelization of intersections and timing of signal lights.

**(Ragab and El-Naga, 2019)** used VISSIM (Software) at Mansoura city, Egypt for two 3-legged intersections. The study investigates three different strategies: the original technique, signal cycle time optimization, and lane width expansion. According to the simulation results, the second and third techniques resulted in a reduction in delay and an increase of LOS from D to C.

**(Mazaheri and Rahimi, 2017)** showed the effect of U-turn at signalized intersection in Tehran city, three intersections data were collected for 6 hours in one day, from 8 am. to 11 am and 4.30 pm to 7.30 pm. According to the software's outputs for the case study of Tehran, the network travel time and delay will be minimized if a median is opened to create a U-turn 190 meters before a signalized intersection.

**(Zhang et al., 2017)** used VISSIM software an optimization model for signalized intersection in Shanghai China, found the addition of a right turn lane in one way to reduce delays by 27.3 percent and improve traffic efficiency for the entire intersection.

**(Sahar 2009)** aimed to develop traffic safety at four 4-leg signalized intersections in Baghdad city. Results were provided permitted left turn treatment reduce average stopped delay 48.43% while it reduces hourly traffic conflict 46.05%., Provided protected left turn phase treatment reduce average stopped delay 82.81 % while it reduces hourly traffic conflict 74.63%. Provided adequate auxiliary left turn lane treatment reduce average stopped delay 61.35% while it reduces hourly traffic conflict 58.07%, increase lane width treatment reduce average stopped delay 59.66% while it reduces hourly traffic conflict 54.37%, increase number of lanes treatment reduce average stopped delay 54.80% while it reduces hourly traffic conflict 51.81%. The result shows the hourly traffic conflict reduce after geometric countermeasures treatment about 58.07% while it reduces about 74.63% after signalization countermeasures treatment.

**Table (2-2) A Review Summary of Authors Adopt Countermeasures to Reduce Percent of Traffic Accident to Improve Traffic Safety**.

| Reduction in Traffic Accident % | Type of countermeasures | Author |
|---|---|---|
| 54.37<br>51.81 | Increase lane width.<br>Increase number of lanes | Sahar S. 2009. |
| 62.64<br>35.85 | Increase lane width.<br>Increase number of lanes | HA Ewadh 2008 |
| 23-48 | Add left turn phasing | NCHRP 2003 |
| 46-69 | Add left turn phasing | Thomas, Gary B. & Daniel J.2001 |
| 75 | Increase lane width | Hauer, E. 2000 |
| 30-80 | Modified traffic signal | Ogden, K.W. 1997 |
| 5-56 | Additional lane | Agent, Kenneth 1996 |

**Table (2-3) A Review Summary of Crash Type and Countermeasures and Crash Reduction Percentage of Traffic Conflicts to Improve Traffic Safety (Gan et al., 2005).**

| Countermeasure | Crash Type | Crash Reduction% |
|---|---|---|
| Provide Protected Left Turn Phase | • All<br>• Left Turn.<br>• Rear-End<br>• Crossing | • 36<br>• 46<br>• 35<br>• 63 |
| Prohibit Turns | • All Turns | • 45 |
| Increase Number of Lanes | • Left Turn.<br>• Rear-End<br>• Crossing | • 71<br>• 52<br>• 45 |
| Widen Lanes | • All | • 50 |
| Retiming Signal | • All<br>• Left Turn.<br>• Crossing | • 18<br>• 75<br>• 46 |

# Chapter Three

# Methodology and Data Collection

# CHAPTER THREE

# DATA COLLECTION AND METHODOLOGY

## 3.1 Introduction

This chapter provides detailed information about the study areas and the required data used to assess intersections for the purpose of conducting assessments and then countermeasures for the purpose of improving traffic safety and reducing conflicts points at intersections, traffic collisions occur because of poor driving behavior. The lack of traffic signs and unsafe maneuvering give an urgent need for the purpose of traffic improvements. The shortage of traffic accident records requires the search for alternative safety indicators that can be used and approved for the purpose of evaluation and taking countermeasures to solve these problems and raising the level of safety at intersections. Collecting field data is essential work, as the data must be sufficient for all details of the study area and with high accuracy to ensure the accuracy of the VISSIM simulation software to provide reliable outputs for the SSAM software.

## 3.2 Study Area Description.

To collect the required data that need to reach the objectives of the study, the study areas are identified to implement the research topic, Therefore, the study area was signalized traffic intersections and consisted of four signalized intersections, all 4-legged intersections within the city of Al-Diwaniyah, the center of Al-Qadisiya Governorate, the study area shown in Figure (3-1). Table (3-1) showing the general description of intersections in the study sites.

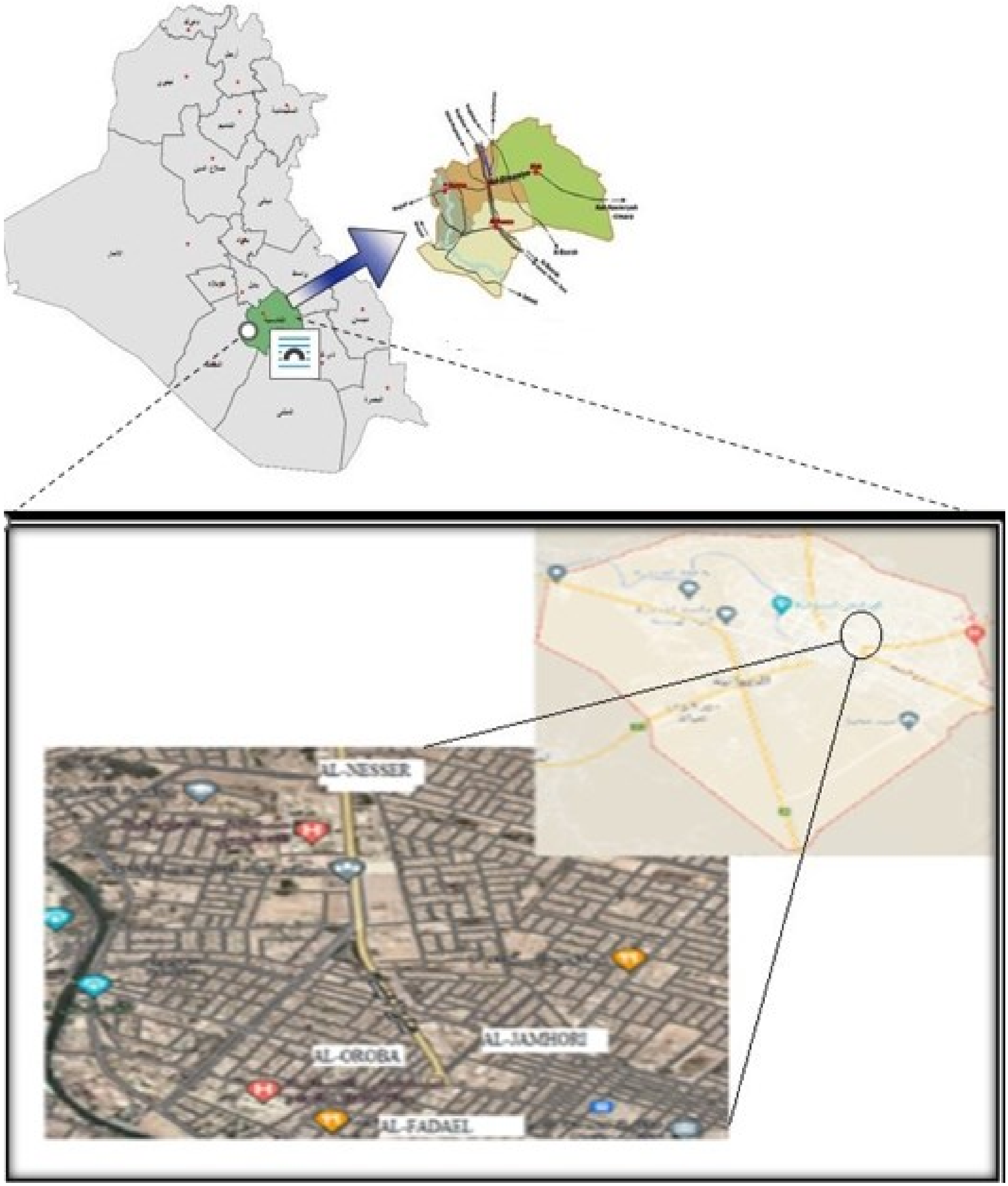



**Figure (3-1) The Selected Network in The City of Al-Diwaniyah**

## Table (3-1) General Description of Intersections in the Study Sites

| Intersection Name | Approach Direction | From | To |
|---|---|---|---|
| **Al-jamhori** | NB | Al-jamhori sharqi | mutaqadeen |
| | EB | Al-dubbad - | Al-jamhori |
| | SB | mutaqadeen | Al-jamhori sharqi |
| | WB | Al-jamhori | Al-dubbad |
| **Al-Oroba** | NB | Al Orouba | Center city roadway |
| | EB | Al Orouba Market | Alfadhliyah |
| | SB | Center city roadway | Al Orouba |
| | WB | Alfadhliyah | Al Orouba Market |
| **Al-Fadael** | NB | Al djazaer | Al huryaa |
| | EB | Al tarbyah roadway | Al markazyah |
| | SB | Al huryaa | Al djazaer |
| | WB | Al markazyah | Al tarbyah roadway |
| **Al-nesser** | NB | public hospital | altasfirat |
| | EB | El Alma Street | college of Medicine |
| | SB | altasfirat | public hospital |
| | WB | college of Medicine | El Alma Street |

## 3.3 Characteristics of Intersections

There are several characteristics of the intersections that affect at the safety should be defined for the purpose of conducting simulation in the VISSIM software. Simulation model used for the purpose of evaluating accuracy the safety of the intersections using the SSAM software for the purpose suggesting countermeasures to improve the intersections.

Some of the characteristics related to the studied intersections are as follows.

- All selected four-legged intersections are located within an urban area of the city.
- All approaches to intersections are of the same level.
- Pedestrian crossing areas are not specified, in spite of the occurrence of a high proportion of pedestrians at intersections.
- All intersections operate a fixed traffic signal for all phases during the day of data collection.

### 3.4 Data Collection and Methodology

The required data should be sufficient and highly detailed to present a more realistic picture and find more accurate results because it is considered important as an input to the VISSIM program to create a trajectory file for the purpose of simulation Figure (3-2) shows data collection and methodology of study and Table (3-2) shows location description of intersections in the study sites.

The required data consists of four stages as follows.

**Stage one**: - Traffic data

**Stage two**: - Geometric characteristics data.

**Stage three**: - Traffic conflict data.

**Stage four**: - Calibration Data

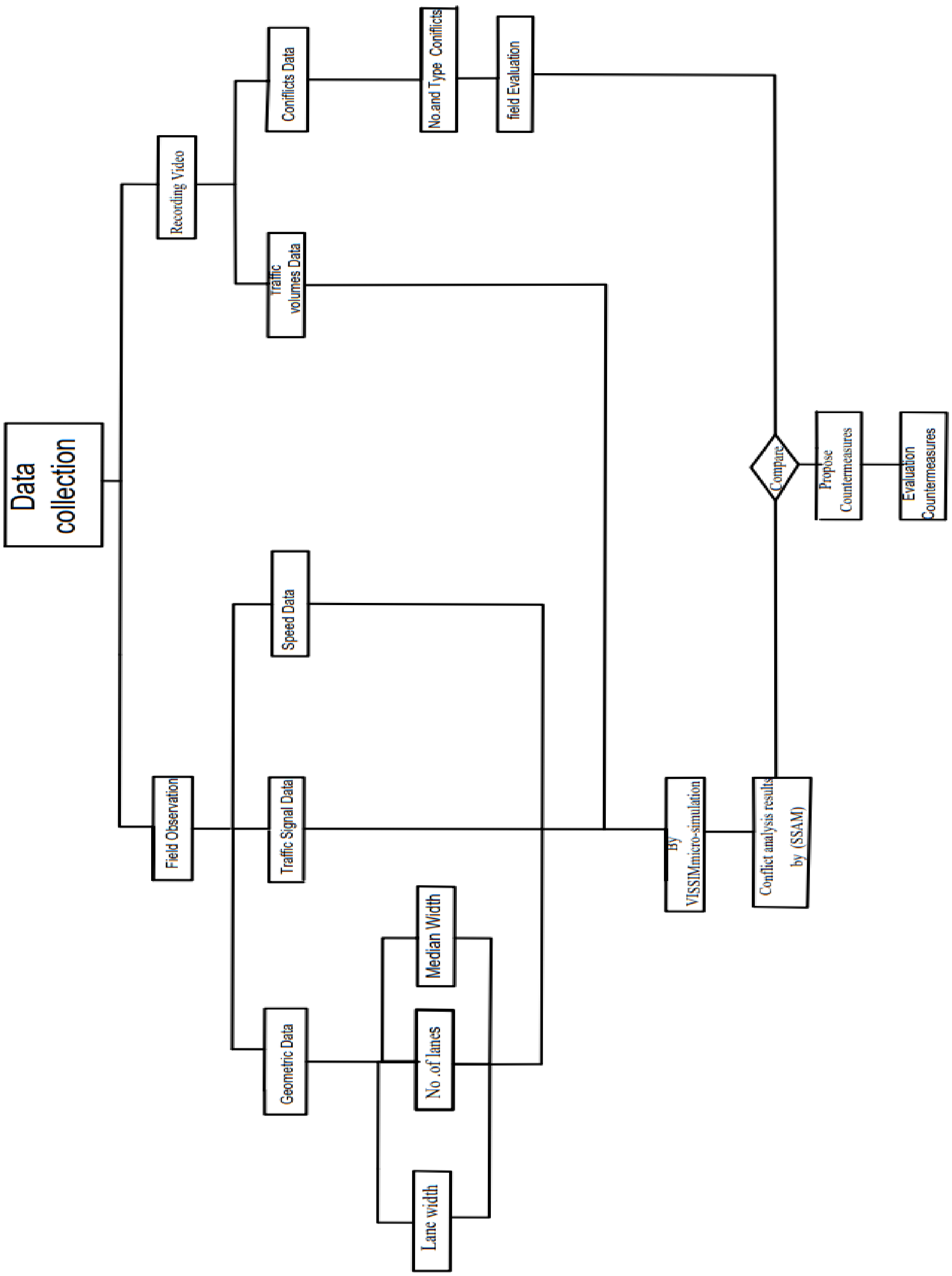



**Figure (3-2) Data Collection and Methodology of Study**

**Table (3-2) Location Description of Intersections in the Study Sites**

| Intersections name | Type | Location | |
|---|---|---|---|
| | | Latitude | Longitude |
| **Al-Jamhori** | 4-leg | 31° 59′ 42.3″ N | 44° 55′ 23.0″ E |
| **Al-Oroba** | 4-leg | 31° 59′ 40.3″ N | 44° 55′ 00.2″ E |
| **Al-Fadael** | 4-leg | 32°29'22.8"N | 44°25'56.2"E |
| **Al-Nesser** | 4-leg | 32°59'27.8"N | 44°54'57.5"E |

## 3.5 Characteristics Geometric

Geometric characteristics are important factors that contribute significantly in terms of safety of roads, they play an important role in preventing or reducing crashes where some studies showed the impact of engineering properties such as the number of lanes, lane widths, and turning radius, where accidents or increased depends on those characteristics. Figures (3-3) to (3-6) and Plates (3-1) to (3-4) show geometry layout within study area. Data geometric properties must be collected at accuracy for the purpose of making the simulation of the VISSIM program as much as possible, details of the geometric characteristics of all intersections in the Table (3-3)

**Table (3-3) Details of The Geometric Characteristics of All Intersections**

| Intersecti -on Name | Approach Direction | No. of Lanes | Lanes Width (m) | Median Width (m) | Exclusive RT |
|---|---|---|---|---|---|
| **Al-jamhori** | NB | 3 | 3 | 4.5 | No |
| | EB | 3 | 3.2 | 3.8 | No |
| | SB | 3 | 3 | 4.2 | No |
| | WB | 3 | 3.2 | 3.8 | No |
| **Al-Oroba** | NB | 3 | 2.8 | 1.5 | No |
| | EB | 3 | 3.3 | 2 | No |
| | SB | 3 | 2.8 | 1.5 | No |
| | WB | 3 | 3.3 | 2 | No |
| **Al-Fadael** | NB | 3 | 3 | 2.5 | No |
| | EB | 4 | 3.1 | 2.7 | No |
| | SB | 3 | 3 | 2.5 | No |
| | WB | 4 | 3.1 | 2.7 | No |
| **Al-nesser** | NB | 4 | 3.3 | 4.5 | Yes |
| | EB | 4 | 3.1 | 1.5 | Yes |
| | SB | 4 | 3.3 | 4.3 | Yes |
| | WB | 4 | 3.1 | 1.1 | Yes |

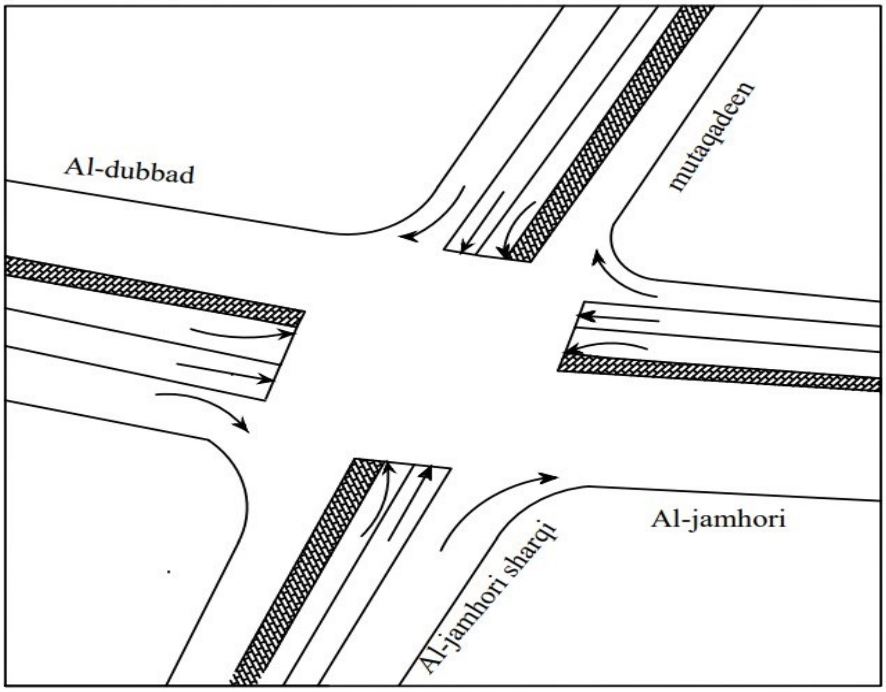



**Figure (3-3) Geometric Layout of Al-Jamhori Intersection**

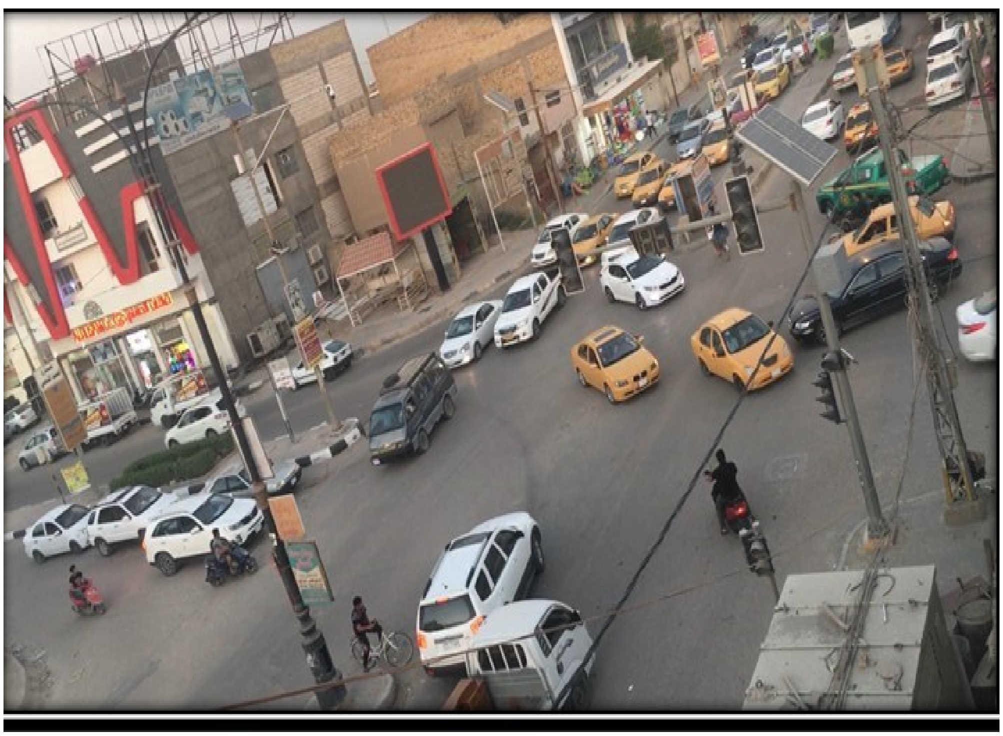


**Plate (3-1): Al-Jamhori Signalized Intersection**

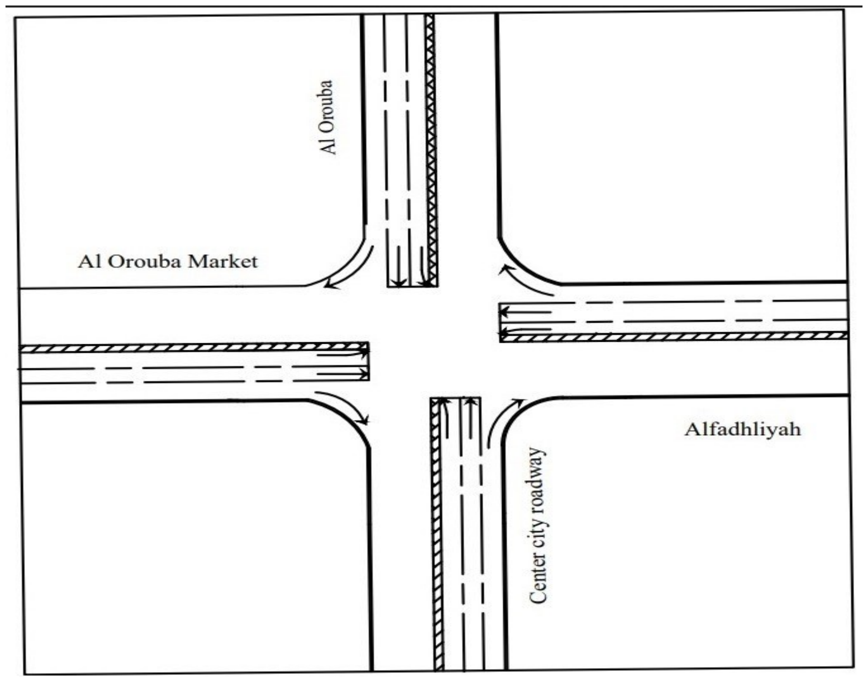



**Figure (3-4) Geometric Layout of Al-Oruba Intersection**

**Plate (3-2): Al-Oruba Signalized Intersection**

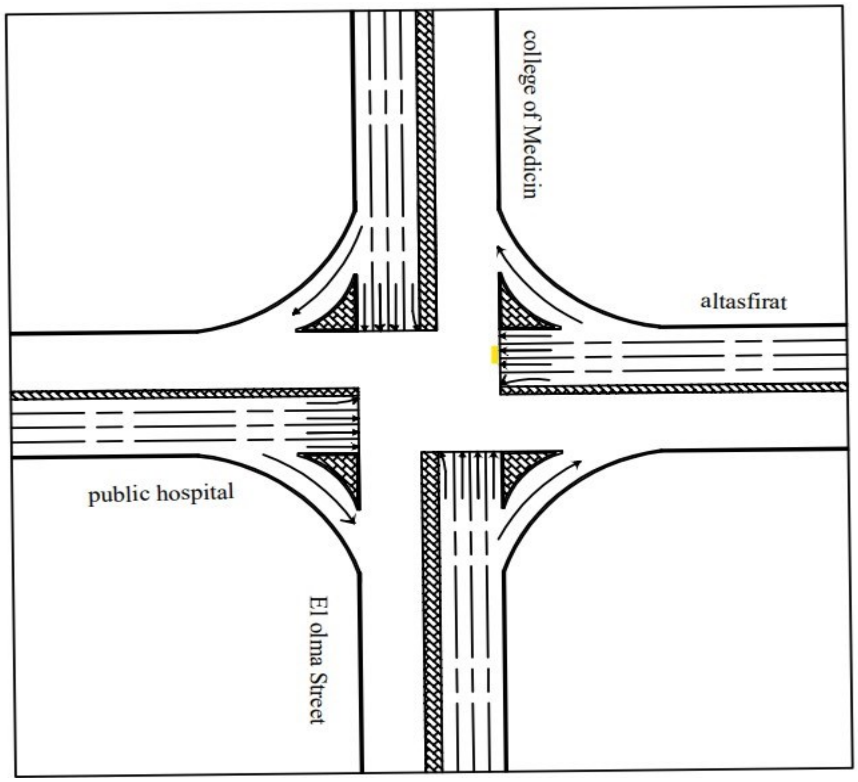



**Figure (3-5) Geometric Layout of Al-Nesser Intersection**

**Plate (3-3): Al-Nesser Signalized Intersection**

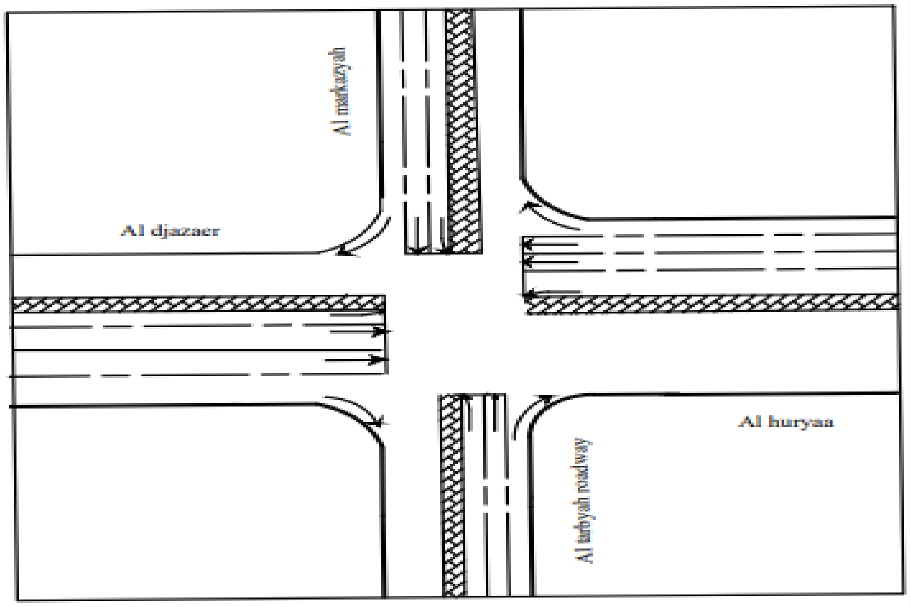



**Figure (3-6) Geometric Layout of Al-Fadael Intersection**

**Plate (3-4): Al-Fadael Signalized Intersection**

## 3.6 Traffic Data

Traffic volumes data is one of the most important data that must be available in this study for the purpose of conducting simulations in the VISSIM software, as well as conducting a safety assessment through the SSAM software. The data for traffic volumes is collected through monitoring the site through video recordings. The required data includes the number of vehicles that move to the right, left, through and U- turn. Table (3-4) shows the traffic volumes, the data collected were during peak period from 7:30 to 9:30 am and the evening start from 12:30 to 2:30 pm during two days of data collection starting from Monday and Tuesday for the year 2022. Traffic volumes were collected every five minutes and then extracted the highest peak hour.

**Table (3-4) Traffic Peak Hour Volume of Intersections in the Study Sites**

| **name** | time | **Approach** | **left** | **through** | **right** | **U-turn** | **Total traffic volume** |
|---|---|---|---|---|---|---|---|
| **Aljamhori** | 12:50-1:50 | NB | 447 | 487 | 402 | 119 | 1455 |
| | | EB | 405 | 495 | 497 | 128 | 1525 |
| | | SB | 415 | 446 | 412 | 57 | 1330 |
| | | WB | 465 | 567 | 426 | 132 | 1590 |
| **AlOruba** | 7:45-8:45 | NB | 587 | 532 | 325 | / | 1444 |
| | | EB | 437 | 584 | 508 | / | 1529 |
| | | SB | 550 | 591 | 362 | / | 1503 |
| | | WB | 540 | 557 | 457 | / | 1554 |
| **AlFadael** | 8:05-9:05 | NB | 567 | 454 | 411 | / | 1491 |
| | | EB | 551 | 398 | 438 | / | 1387 |
| | | SB | 405 | 527 | 475 | / | 1405 |
| | | WB | 502 | 519 | 376 | / | 1397 |
| **Alnesser** | 8:35-9:35 | NB | 312 | 377 | 113 | 134 | 936 |
| | | EB | 461 | 985 | 320 | 72 | 1838 |
| | | SB | 258 | 497 | 161 | 59 | 975 |
| | | WB | 646 | 952 | 159 | 44 | 1801 |

## 3.7 Speed Data

Speed is essential in all means of transportation because it correlates largely to travel time, safety, comfort, etc. Implements spot speed for each approach to find the necessary values for the VISSIM software. Spot speed studies are used to find the distribution of velocities for the movement of vehicles at a specific location. It is calculated by recording the speed of a sample of vehicles at a specific location and used in the analysis of accidents to find out the causes of their occurrence, as well as in the engineering design of road elements and to determine safe speeds at intersections. There are two ways to measure the speed, which is the radar or the stopwatch. In this study, the manual method used the stopwatch, where a distance between two points is determined and the speed of the vehicle is measured .The recommended lengths are summarized in the Table (3-5).The following figure illustrates the speed measurement method where two drawn marks are used to set the path length at the beginning and end of the measured distance, the specified distance is chosen behind the queuing approach, the speed data is measured under the same conditions as the traffic volumes data were collected, the following equation is used to find the minimum sample size required to calculate spot speed data

**Table (3-5) Recommended Course Length (Sayed, & Zein1999).**

| No. | Average speed of traffic stream(mph) | Course length (ft) |
|---|---|---|
| 1 | Less than 25 | 88 |
| 2 | 25 to 40 | 176 |
| 3 | Greater than 40 | 264 |

.

Figure (3-7) presents a sample of course length to accomplish spot speed study. Two painted signs are applied to select the length of the course at the pavement from the start to end of the measured course. The location of the course is taken beyond the queue approach. Spot speed data are measured at the similar condition in which traffic conflict and traffic volume data are collected.

The following formula can be used to calculate the minimum sample size for the of spot speed data **(Box, & Oppenlander,1976).**

$$N = \left(\frac{Z\sigma}{E}\right)^2 \qquad (3\text{-}1)$$

Where

$N$= Minimal sample size.

Z= calculated sample standard deviation (km/h).

.

$\sigma$= Standard deviation (km/h)

E = Normal limit error of estimation the average speed (km/h).

The allowable error may range from ± 8kph to ± 1.5kph or even less depending on the purpose of the study. However, in this study a value of ±2 kph has been used to compensate for a possible error in measurement **(Box, & Oppenlander,1976).**

Appendix (B) presents a sample of spot speed data for Al jamhori intersection.

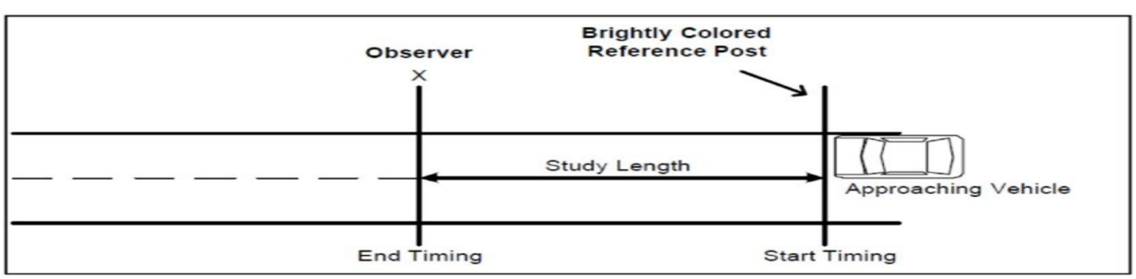



**Figure (3-7) Spot Speed Measuring Principle Based on Distance and Time**

### 3.8 Traffic Conflict Data

Traffic conflicts are collected in the field through surveillance cameras. Traffic conflicts data was collected during the days Monday and Tuesday during peak hour times. The monitoring site must be located within 30 to 90 m for each approach at the intersection and according to the available space. The camera must be installed at high places and there are no obstructions to reduce the visibility of conflicts at intersections. According to the definitions provided by (Parker and Zegeer, 1989) of traffic conflicts, they are classified into six types as shown in the Figure (3-8).

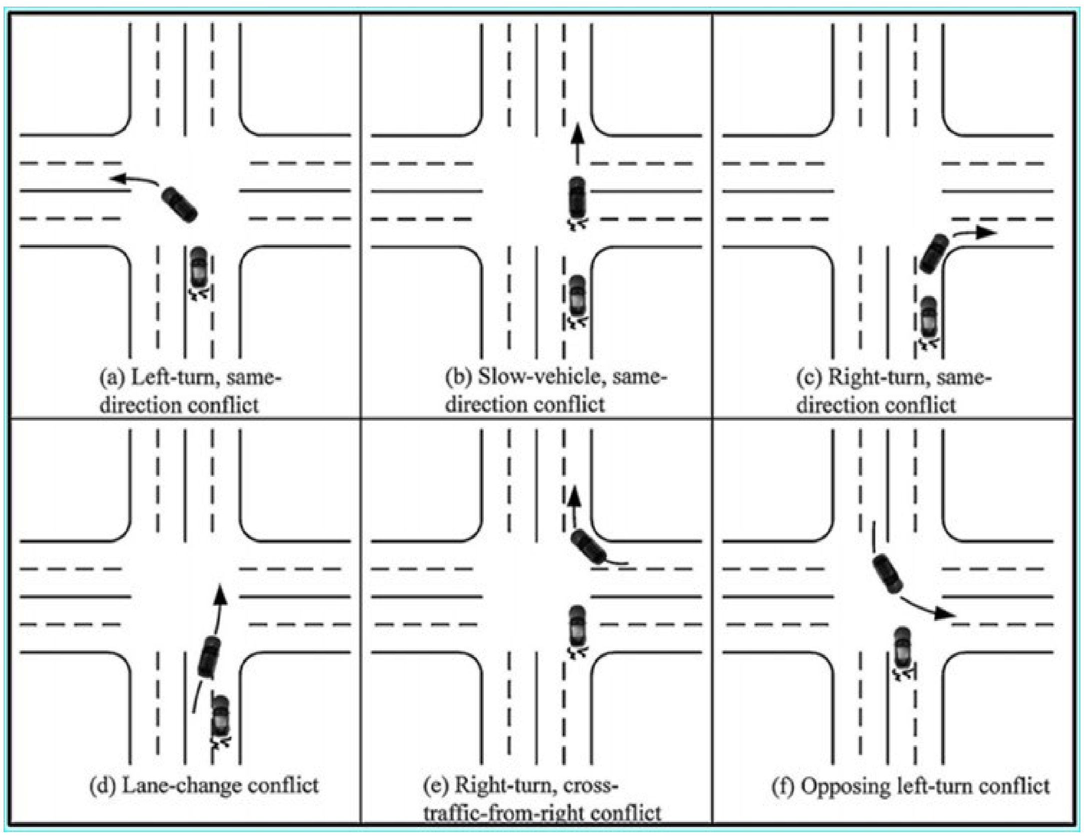



**Figure (3-8) Conflict Types Observed in the Field (Parker & Zeeger, 1988).**

## 3.9 Methodology Using the SSAM And VISSIM Program.

Methodology for assessing intersections and proposing countermeasures using the SSAM and VISSIM software includes several steps where after collecting the required data, such as geometric design data and traffic data such as cycle length then enter this data into VISSIM software to create a trajectory file. It includes the following steps.

### Step 1: Locate Intersections on The Network.

Open the program the interface shows earth map make zooming to reach the target location of the study through the google map where the first step is important to locate the intersection on which the study is being conducted as shown in Figures (3-9) and (3-10)

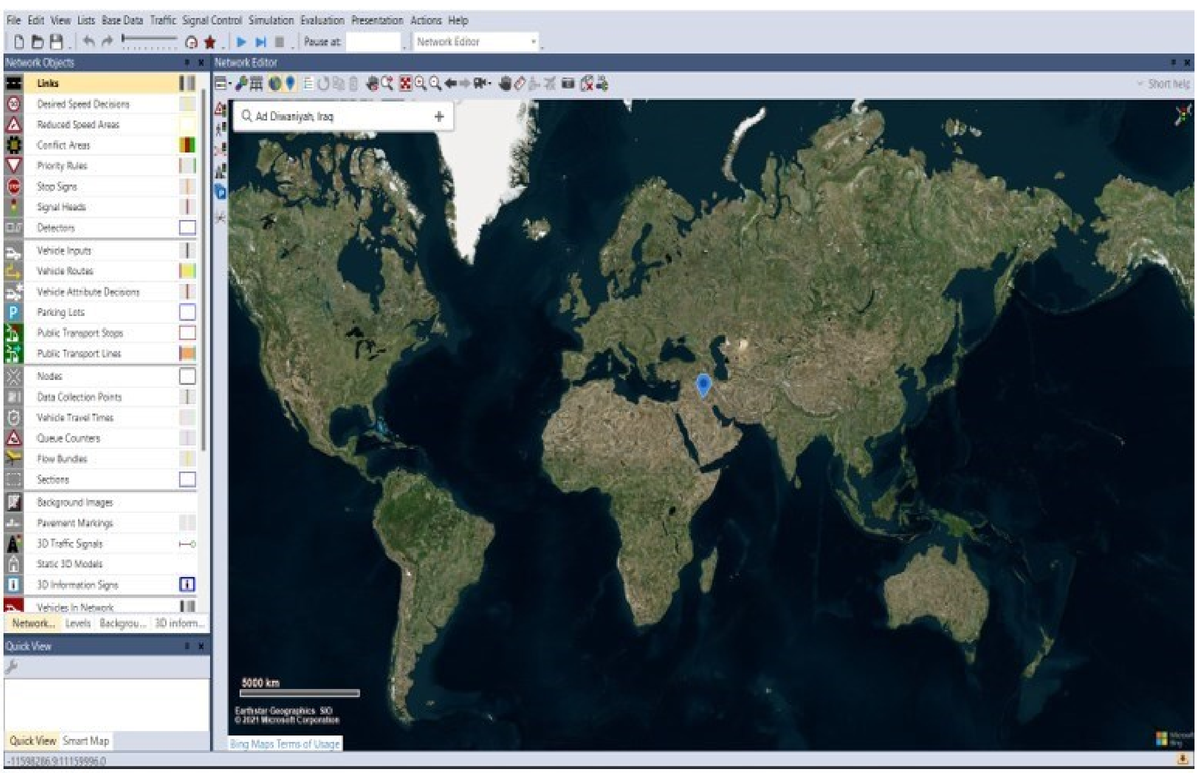



**Figure (3-9) A Screenshot of the Earth Map Network of VISSIM**

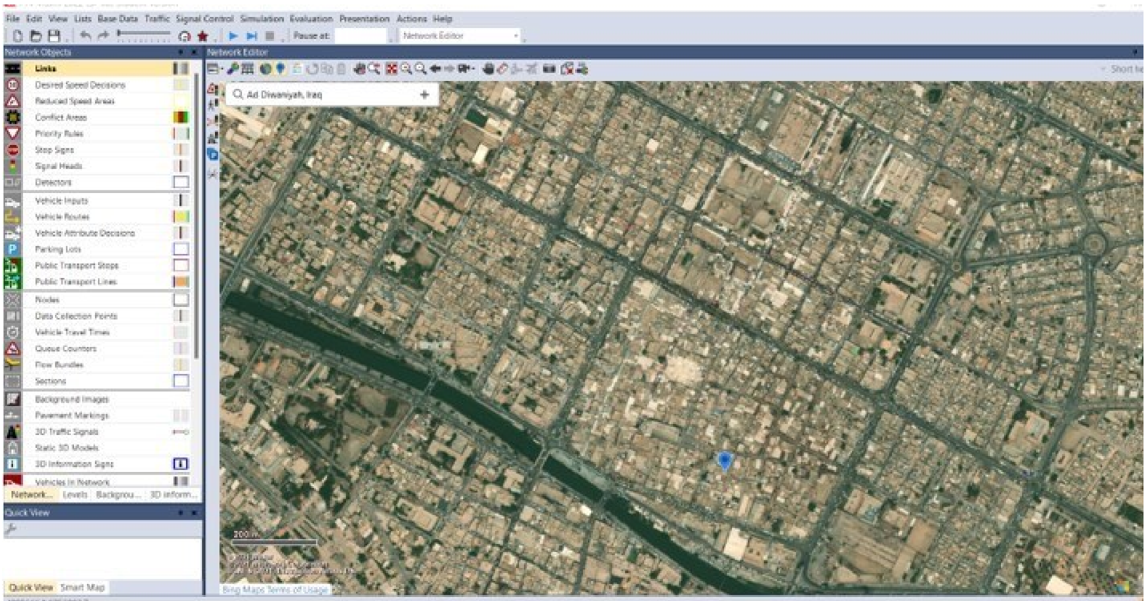



**Figure (3-10) A Screenshot of the Street Map Network of VISSIM**

**Step**

**2: Drawing the Intersection at VISSIM Software.**

The second step is drawing the intersection at VISSIM software, add links refers to the main routes, while connectors refer to the connection between those roads through a link command. The list appears through which the number of lanes can be entered, and each lane is displayed, as well as the connectors that connect the teams. Figure (3-11) shows the links, the number of lanes, and the width of each lane. It also shows the connectors that connect these links.

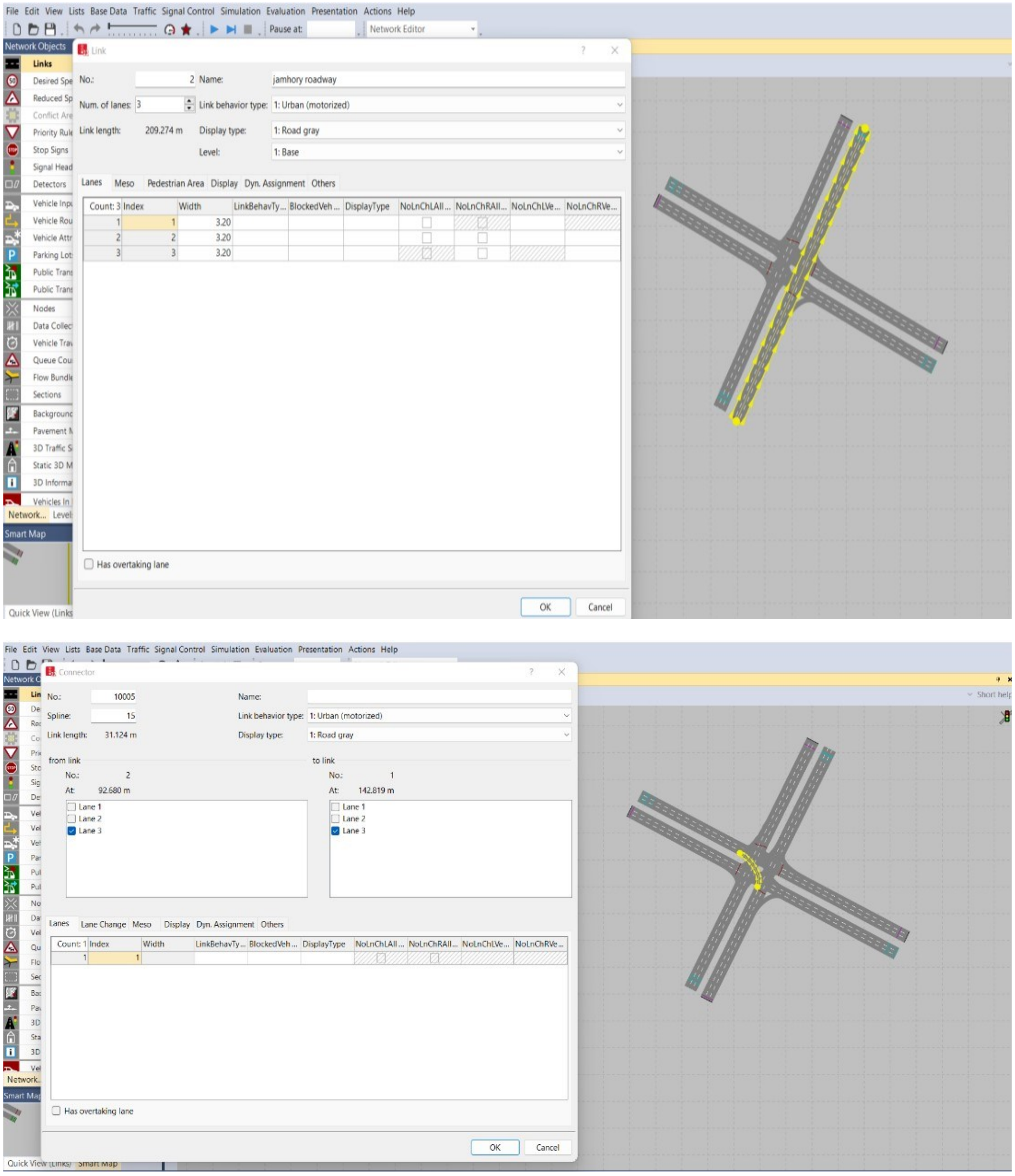



**Figure (3-11) Establishing Links and Connectors and Their Characteristics at Al-Jamhori Intersection**

## Step 3: Enter the Traffic Volumes

The third step including enter the traffic volumes, where after collecting the traffic volumes from the site, they are entered into the VISSIM software through the command of **vehicle input**, from this command, can enter the real traffic volumes that are collected from the site. The (vph) unit's field traffic volumes are dealt with by VISSIM as shown in Figure (3-12)

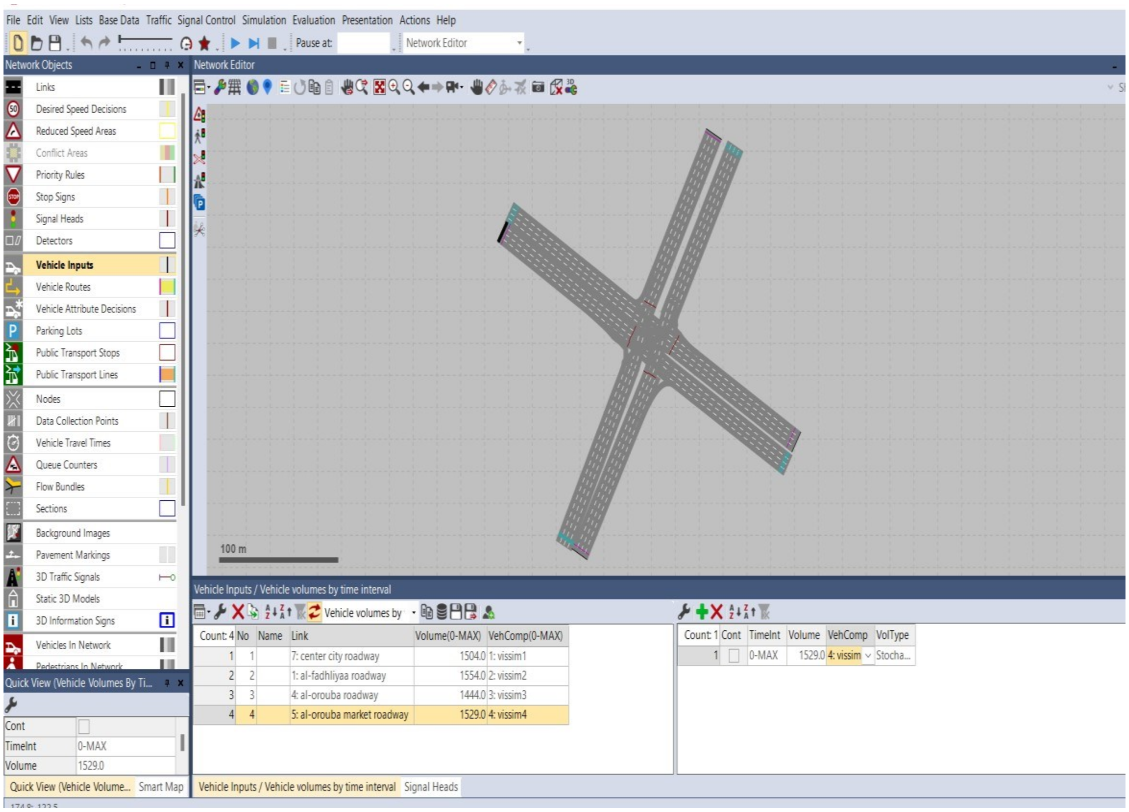


**Figure (3-12) Assigning Inputs and Compositions of Vehicles at Intersection**

**Step 4: Distribution of Vehicles According to Their Type**

The fourth step includes the distribution of vehicles according to their type, including types such as (car, bus, tram, HGV, etc.) then a list appears detailing the types of vehicles and the desired speed for each type of car. The different types of vehicles are distributed according to the real percentages of each type so that the total of the vehicles is equal to 100% of the traffic flow. Figure (3-13) illustrates vehicle compositions as well as shows vehicle inputs.

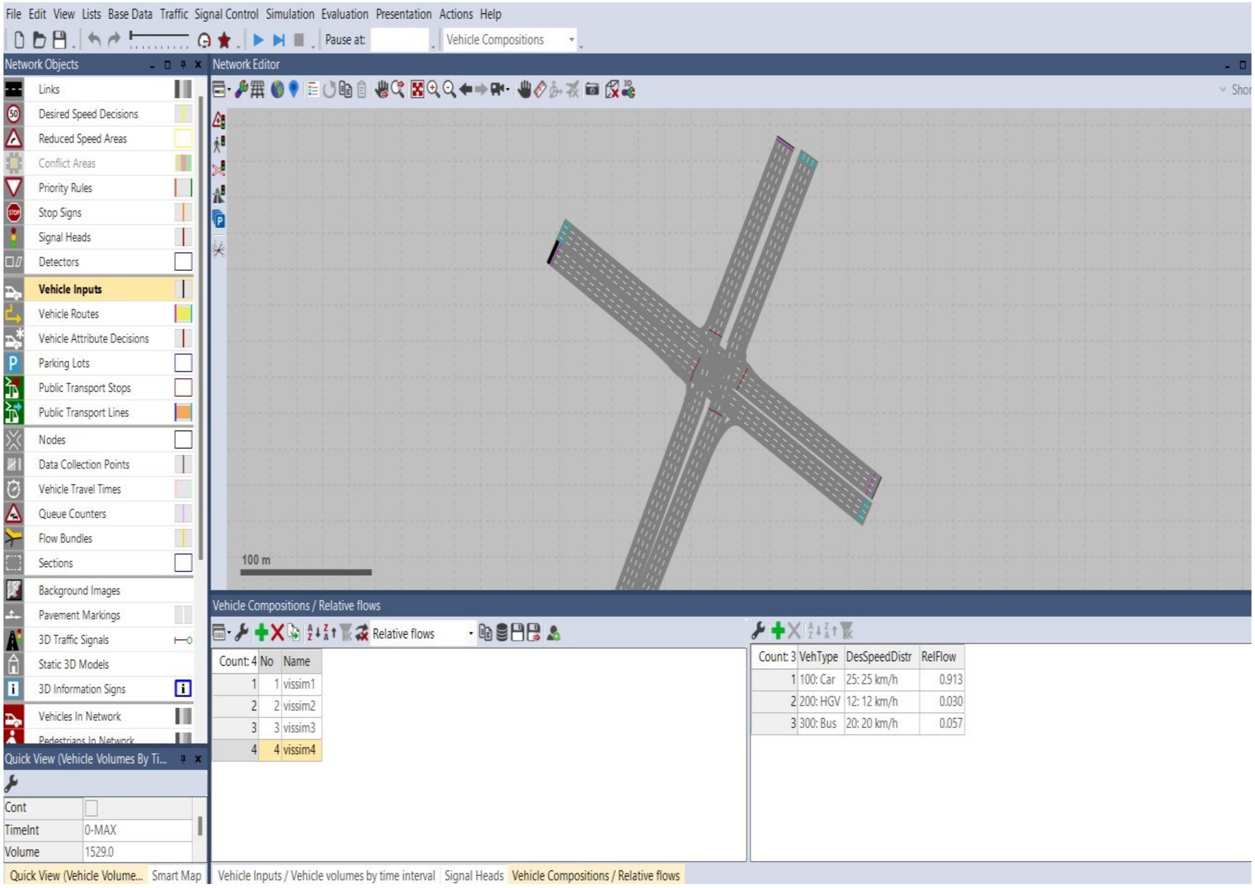



**Figure (3-13) Assigning Inputs and Compositions of Vehicles At AL-Oruba Intersection**

### Step 5: Route of Vehicles

In this step, the traffic volumes are distributed according to the direction of their movement for each approach, where the movement of vehicles is distributed in the intersections of the following directions: (right, left, U-turn, and through). The direction of the movement of vehicles can be set as a percentage for each direction of the total traffic volumes, so that the sum of the percentages of traffic loads from all types of vehicles equals 100%. Figure (3-14) shows the branching of the vehicle routs departing from the northern approach of AL-Oruba. Intersection

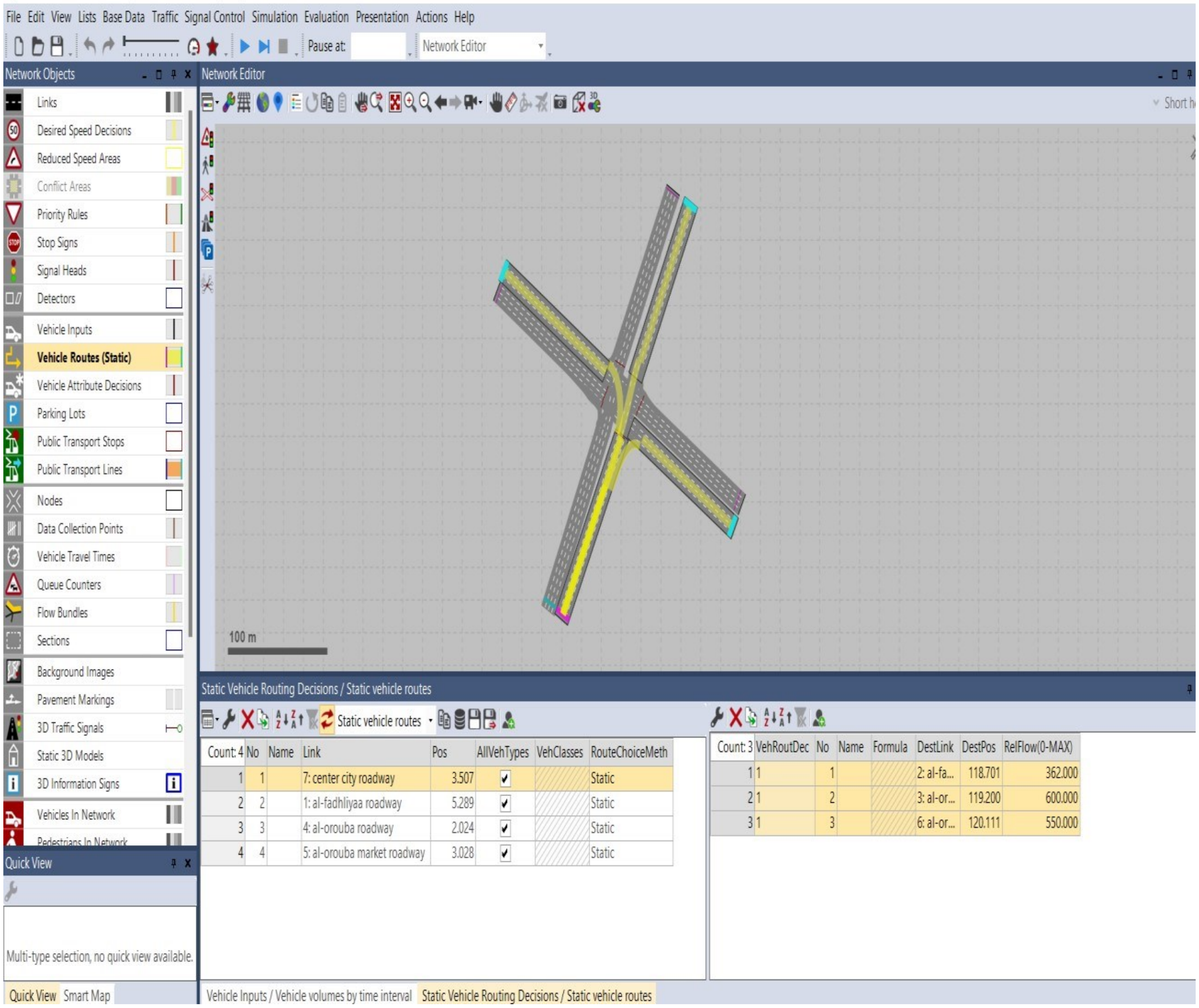


**Figure (3-14) Process of Determining Route of the Vehicles at AL-Oruba Intersection**

## Step 6: Model the Traffic Light Signal

The sixth step is to model the traffic light signal in the VISSIM software that simulates the light signal at the study site. The light signal must be same time at the study site. The actual cycle time of the site must be entered, taking into account that the signal groups are the number of approaches and determine the type of signal with the time entry where it was the type of the signal is constant and sequentially green, red, yellow as shown in Figure (3-15).

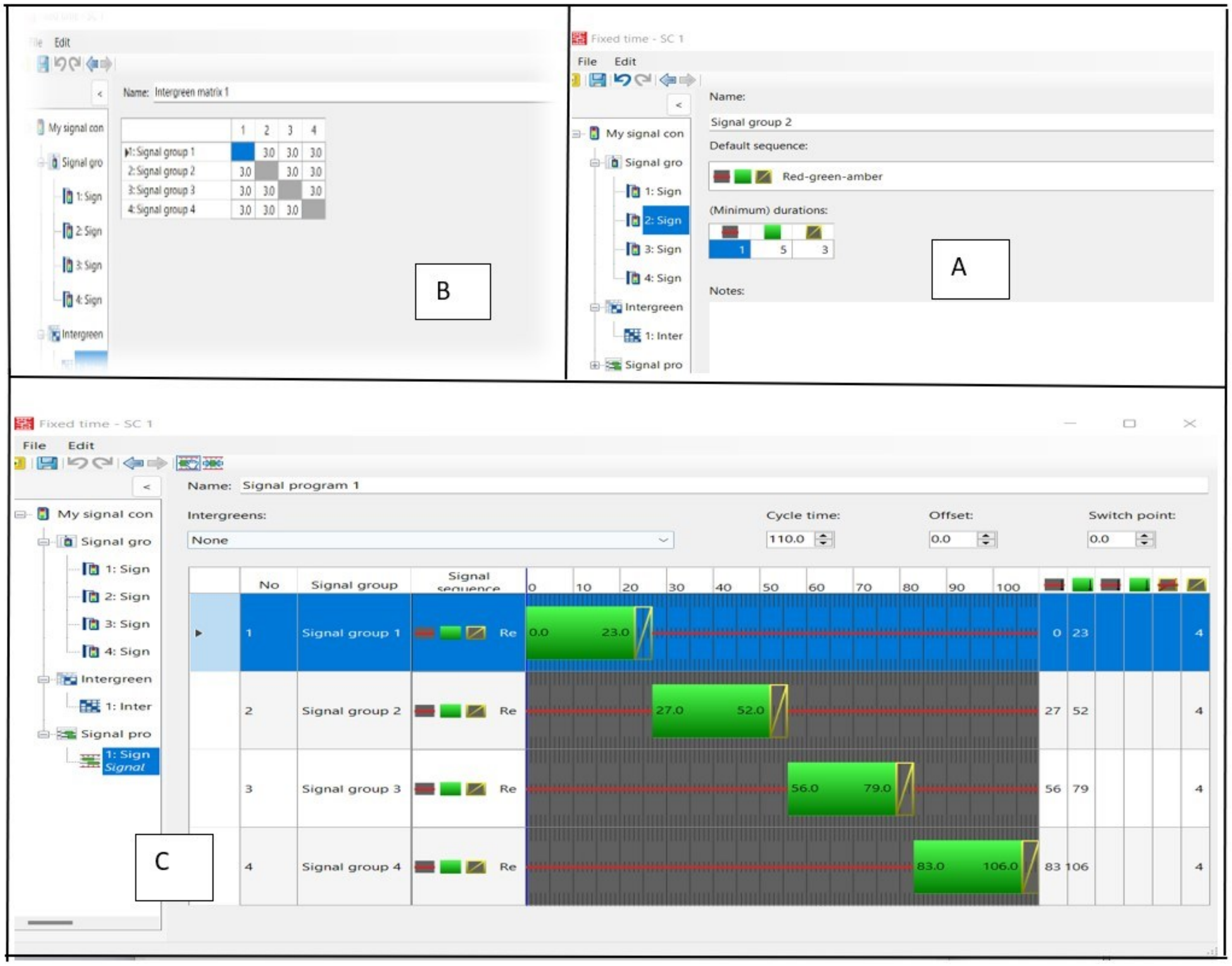



**Figure (3-15) Multiple Screenshots Illustrating Stages Modeling Traffic Signal Light**

**Step 7: Configure the Trj File's Output and Export It to SSAM.**

After completing the modeling of the intersections, will be saved the file as a trajectory file, as the outputs of the VISSIM program will be as inputs for the SSAM program and according to the following steps.

1- after completing the drawing of the intersections and entering the traffic signal, go to command **evaluation**

2-after clicking, another command appears, which is that **configuration**. When you click on it, a menu will appear.

3- of that list go to instruct direct entry from the list, and it will appear at the bottom of the list the SSAM program click on it and then we click on the command **OK** to get a trajectory file according to the Figure (3-16)

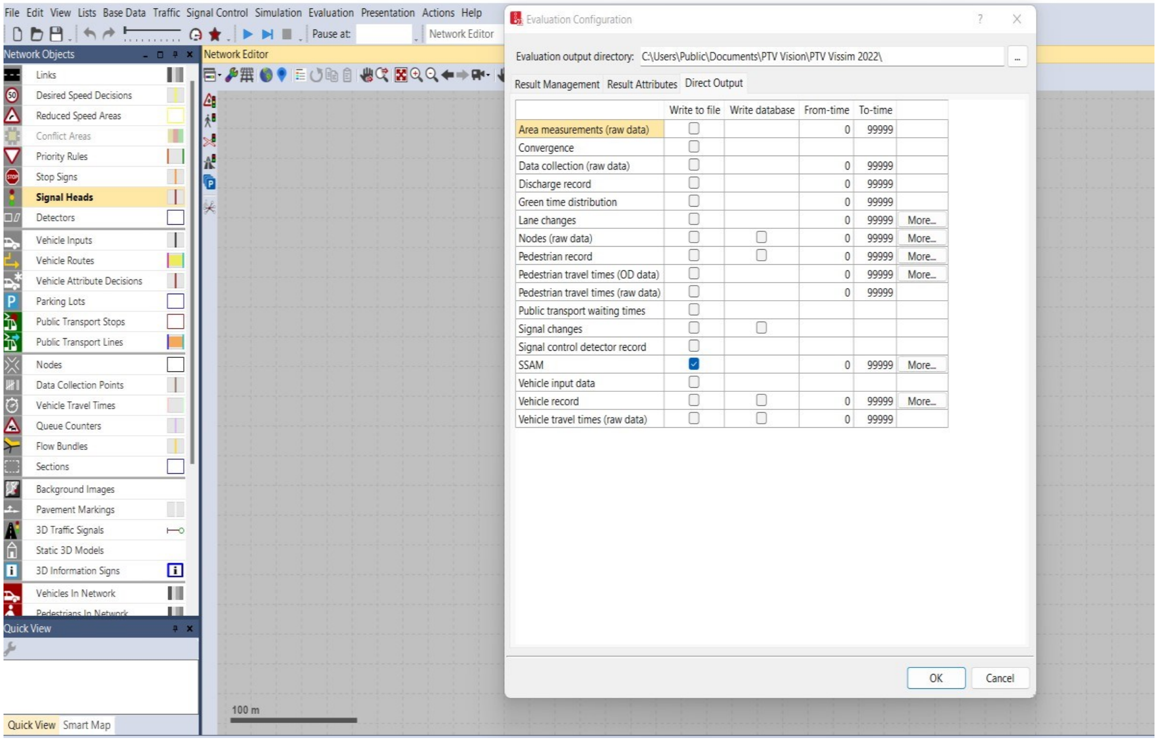



**Figure (3-16) Configuration of the Output of The Trj File and Exporting It To SSAM.**

# Chapter Four
# Results and Analysis

# CHAPTER FOUR
# RESULTS AND ANALYSIS

## 4.1 Introduction

This chapter describes analyzing the collected data (geometric, traffic conflicts and traffic data) as well as the evaluation of intersections by SSAM and VISSIM software's, then the analysis and evaluation of countermeasures at intersections to see if these countermeasures can reduce traffic conflicts, then increasing the rate of safety at the selected intersections. Simulation is carried out by the VISSIM software, where a trajectory file is created, which will be as inputs to the SSAM software to find out the numbers of traffic conflicts. Also, SSAM calculates the total collision time (TTC) for each approach.

### 4.2 Simulation Parameters

Except simulation speed, simulation resolution influences the vehicle's interactions and behavior. The main parameters for the VISSIM simulation model are as follows **(Sayed, & Zein,1999): -**

- The simulation period starts from zero. This gives SSAM an hour to complete conflict analysis.
- The number of simulations was set to 10 runs with random seeds differing in each run. i.e., 10 seeds were used.
- The simulation resolution, which defines how repeatedly vehicle locations are re-calculated at one-second simulation, was identified in 10 places. The value should not be less than 5 and the best between 10 and 20.
- Simulation speed time per second compare to real-time, the simulation speed does not affect the simulation results, but it is a very important parameter to

shorten the result time and accomplish the largest simulation runs within a reasonable time In this study, This feature facilitated conducting more than 400 hours of simulation, so the simulation speed is set to 10 (value 10 represents a simulation speed equal to (10) times the real-time while value (1) represents a simulation speed equal to real-time.

Referring to the steps for creating trajectory files for the movement and interactions of vehicles defined in chapter three article (3.9), it is now SSAM's will be analyze the trj file data, but before that, the velocities essential modeled in VISSIM.

**4.3 Spot Speed**

Despite the intersection areas are characterized by low speeds and close to each other, unlike other traffic facilities, speed remains a risk factor in these areas as speed increases the potential crashes. To calculate the spot speed, a test of normality for speed data has been conducted using SPSS statistical analysis software as shown in Table (4-1).

**Table (4-1) The Speed Descriptive Statistics and The Normal Distribution Test At Al-Jamhori Intersection.**

| Intersection | | Minimum Speed(km/h) | Maximum Speed(km/h) | Range | Mean Speed(km/h) | St. Deviation |
|---|---|---|---|---|---|---|
| Al-jamhori | NB | 18.24 | 28.64 | 10.4 | 22.62 | 2.74 |
| | EB | 16.6 | 27.7 | 10.2 | 21.6 | 2.68 |
| | SB | 17.7 | 28.9 | 11.2 | 22.625 | 3.19 |
| | WB | 17.41 | 28.87 | 11.46 | 21.45 | 2.50 |

According to the examination, the outputs of the speed data were a normal distribution at Al-jamhori intersection. The average speed value of each class will be entered correctly as 21.6 km/h at (SB) at Al-jamhori Intersection. Details in the Appendix (G). The outputs of the VISSIM software traj file simulation will be as inputs to the SSAM software. SSAM will evaluate the intersections by finding the number of traffic conflicts and (TTC) then suggest the appropriate countermeasure.

## 4.4 The Steps Needed to Evaluation Safety Condition at the Intersections.

After conducting the field survey of the intersections by the videos, calculating the number of traffic conflicts, and finding (TTC), the next step is to evaluate the intersections using the SSAM software, where the software calculates the number of traffic conflicts and TTC for the traj file created by VISSIM software. Figure (4-1) Showing TTC Threshold Values at Al-jamhori intersection.

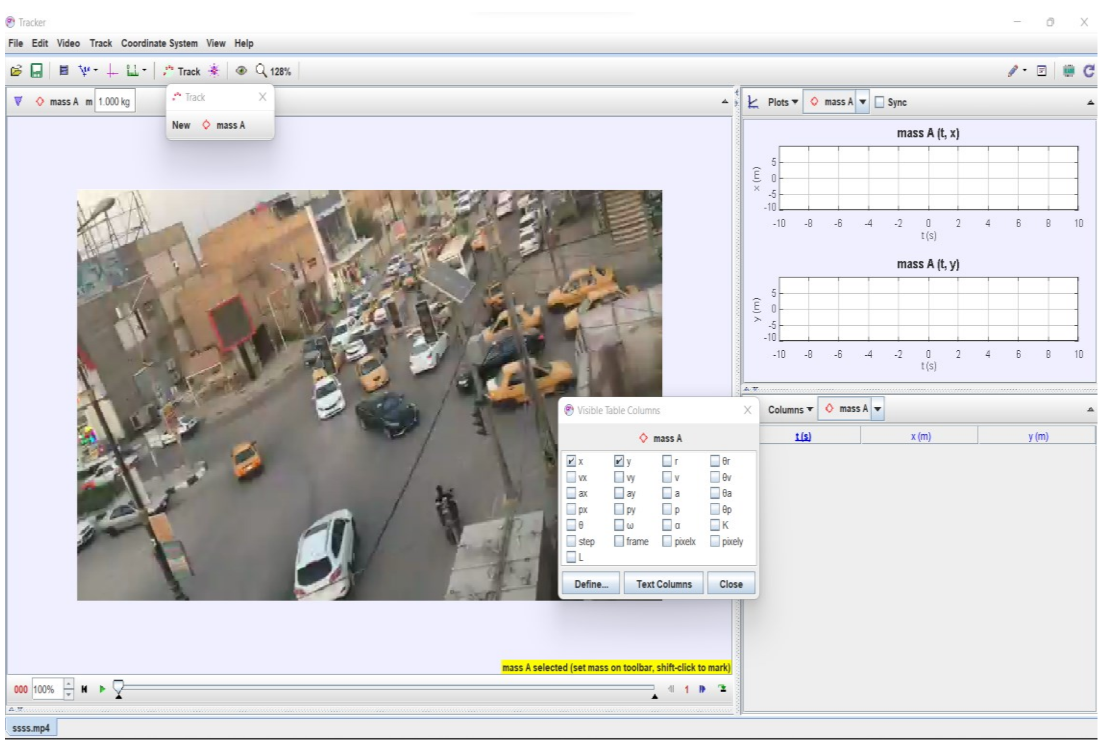



**Figure (4-1) Screenshot Showing TTC Threshold Values at Al-jamhori intersection.**

### 4.4.1 Steps for Evaluating the Intersection by SSAM Software

The steps for evaluating the intersection by SSAM software are as follows.

**Step 1: Creating A Trj File by VISSIM Software.**

after performing the simulation by VISSIM software and creating a trj file, enter this file into the SAAM software, as shown in the Figure (4-2)

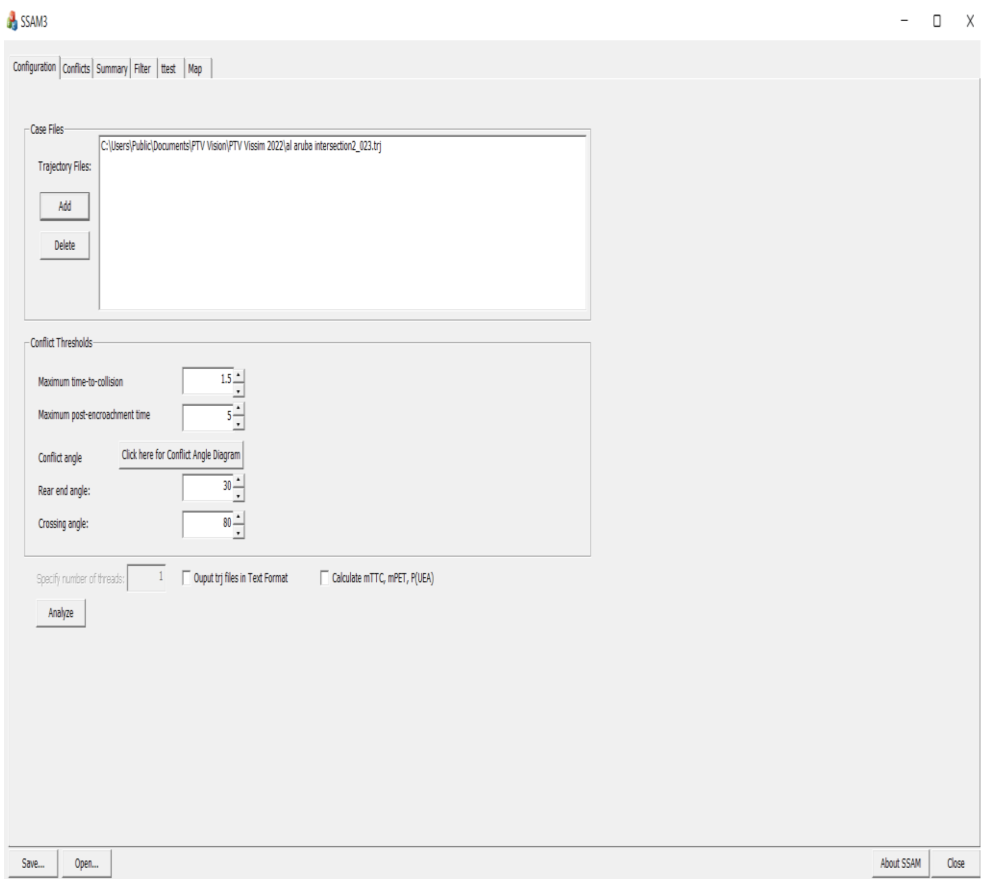
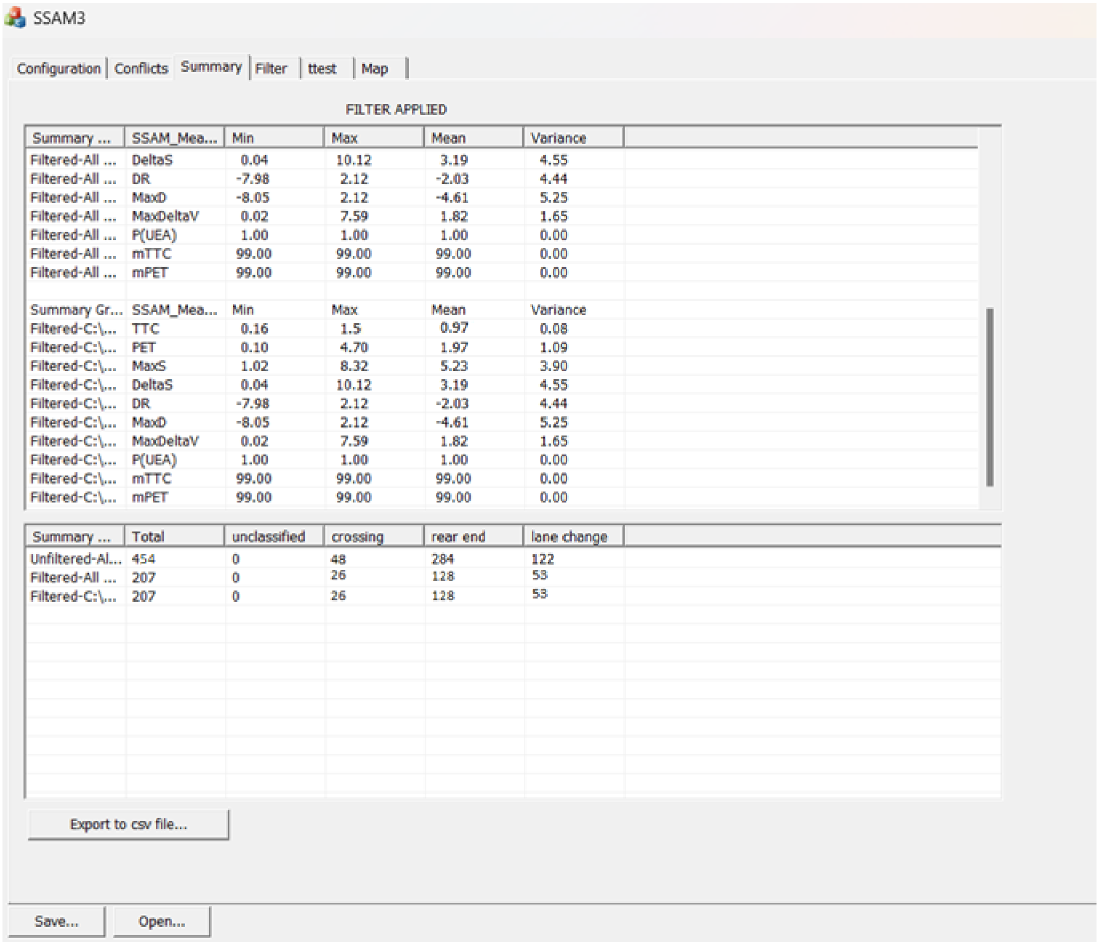



**Figure (4-2) Screenshot for the SSAM Software Framework, Showing the Conflict Threshold Values**

**Step 2: Find Values TTC and the Number of Traffic Conflicts.**

Finding the number of traffic conflict and evaluating whether the intersection is safe. Indicators of safety alternatives are found TTC, as values TTC start from zero to five sec, according to the Figure (4-3).



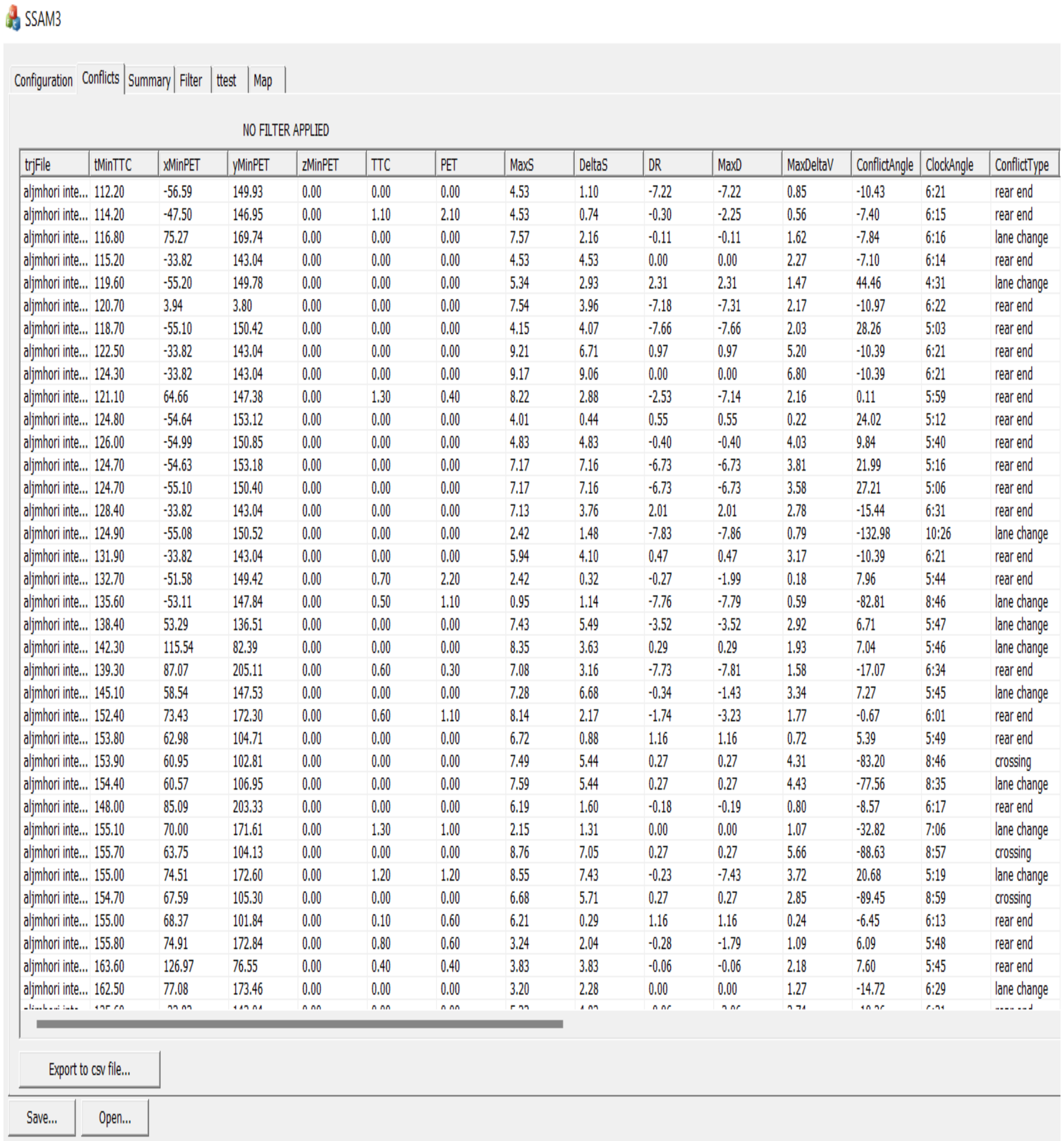

| Summary ... | SSAM_Mea... | Min | Max | Mean | Variance |
|---|---|---|---|---|---|
| Filtered-All ... | DeltaS | 0.04 | 10.12 | 3.19 | 4.55 |
| Filtered-All ... | DR | -7.98 | 2.12 | -2.03 | 4.44 |
| Filtered-All ... | MaxD | -8.05 | 2.12 | -4.61 | 5.25 |
| Filtered-All ... | MaxDeltaV | 0.02 | 7.59 | 1.82 | 1.65 |
| Filtered-All ... | P(UEA) | 1.00 | 1.00 | 1.00 | 0.00 |
| Filtered-All ... | mTTC | 99.00 | 99.00 | 99.00 | 0.00 |
| Filtered-All ... | mPET | 99.00 | 99.00 | 99.00 | 0.00 |
| | | | | | |
| Summary Gr... | SSAM_Mea... | Min | Max | Mean | Variance |
| Filtered-C:\... | TTC | 0.16 | 1.5 | 0.97 | 0.08 |
| Filtered-C:\... | PET | 0.10 | 4.70 | 1.97 | 1.09 |
| Filtered-C:\... | MaxS | 1.02 | 8.32 | 5.23 | 3.90 |
| Filtered-C:\... | DeltaS | 0.04 | 10.12 | 3.19 | 4.55 |
| Filtered-C:\... | DR | -7.98 | 2.12 | -2.03 | 4.44 |
| Filtered-C:\... | MaxD | -8.05 | 2.12 | -4.61 | 5.25 |
| Filtered-C:\... | MaxDeltaV | 0.02 | 7.59 | 1.82 | 1.65 |
| Filtered-C:\... | P(UEA) | 1.00 | 1.00 | 1.00 | 0.00 |
| Filtered-C:\... | mTTC | 99.00 | 99.00 | 99.00 | 0.00 |
| Filtered-C:\... | mPET | 99.00 | 99.00 | 99.00 | 0.00 |

| Summary ... | Total | unclassified | crossing | rear end | lane change |
|---|---|---|---|---|---|
| Unfiltered-Al... | 454 | 0 | 48 | 284 | 122 |
| Filtered-All ... | 207 | 0 | 26 | 128 | 53 |
| Filtered-C:\... | 207 | 0 | 26 | 128 | 53 |

**Figure (4-3) Screenshot for the SSAM Software Showing the Conflicts Values and TTC Values**

### Step 3: SAAM's Preliminary Analysis

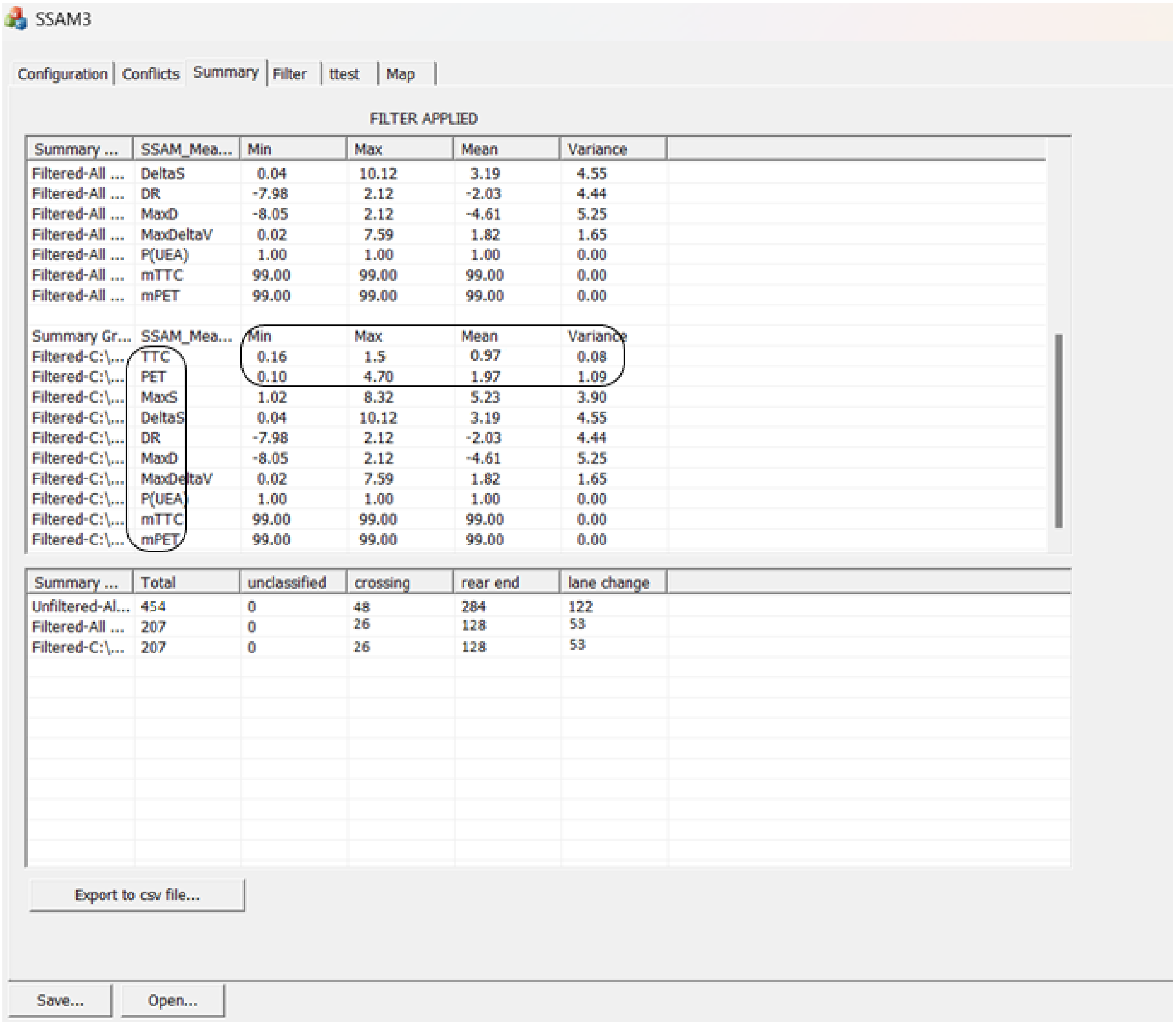
After entering TTC and PET values, analyze the trajectory file by bringing the file to the SSAM software in the form of a trajectory file. When click on the "Analyze", the process of analyzing the file begins and finding the number of traffic conflicts for each approach, as well as (TTC) for each approach. After completing the analysis process, the numbers of traffic conflict will appear as soon as are clicking on the "conflict". These points are the result of the initial analysis of the program before performing the filtering process as shown in Figure (4-4), which provides a summary of the conflicts points according to its type.




| trjFile | tMinTTC | xMinPET | yMinPET | zMinPET | TTC | PET | MaxS | DeltaS | DR | MaxD | MaxDeltaV | ConflictAngle | ClockAngle | ConflictType |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| aljmhori inte... | 112.20 | -56.59 | 149.93 | 0.00 | 0.00 | 0.00 | 4.53 | 1.10 | -7.22 | -7.22 | 0.85 | -10.43 | 6:21 | rear end |
| aljmhori inte... | 114.20 | -47.50 | 146.95 | 0.00 | 1.10 | 2.10 | 4.53 | 0.74 | -0.30 | -2.25 | 0.56 | -7.40 | 6:15 | rear end |
| aljmhori inte... | 116.80 | 75.27 | 169.74 | 0.00 | 0.00 | 0.00 | 7.57 | 2.16 | -0.11 | -0.11 | 1.62 | -7.84 | 6:16 | lane change |
| aljmhori inte... | 115.20 | -33.82 | 143.04 | 0.00 | 0.00 | 0.00 | 4.53 | 4.53 | 0.00 | 0.00 | 2.27 | -7.10 | 6:14 | rear end |
| aljmhori inte... | 119.60 | -55.20 | 149.78 | 0.00 | 0.00 | 0.00 | 5.34 | 2.93 | 2.31 | 2.31 | 1.47 | 44.46 | 4:31 | lane change |
| aljmhori inte... | 120.70 | 3.94 | 3.80 | 0.00 | 0.00 | 0.00 | 7.54 | 3.96 | -7.18 | -7.31 | 2.17 | -10.97 | 6:22 | rear end |
| aljmhori inte... | 118.70 | -55.10 | 150.42 | 0.00 | 0.00 | 0.00 | 4.15 | 4.07 | -7.66 | -7.66 | 2.03 | 28.26 | 5:03 | rear end |
| aljmhori inte... | 122.50 | -33.82 | 143.04 | 0.00 | 0.00 | 0.00 | 9.21 | 6.71 | 0.97 | 0.97 | 5.20 | -10.39 | 6:21 | rear end |
| aljmhori inte... | 124.30 | -33.82 | 143.04 | 0.00 | 0.00 | 0.00 | 9.17 | 9.06 | 0.00 | 0.00 | 6.80 | -10.39 | 6:21 | rear end |
| aljmhori inte... | 121.10 | 64.66 | 147.38 | 0.00 | 1.30 | 0.40 | 8.22 | 2.88 | -2.53 | -7.14 | 2.16 | 0.11 | 5:59 | rear end |
| aljmhori inte... | 124.80 | -54.64 | 153.12 | 0.00 | 0.00 | 0.00 | 4.01 | 0.44 | 0.55 | 0.55 | 0.22 | 24.02 | 5:12 | rear end |
| aljmhori inte... | 126.00 | -54.99 | 150.85 | 0.00 | 0.00 | 0.00 | 4.83 | 4.83 | -0.40 | -0.40 | 4.03 | 9.84 | 5:40 | rear end |
| aljmhori inte... | 124.70 | -54.63 | 153.18 | 0.00 | 0.00 | 0.00 | 7.17 | 7.16 | -6.73 | -6.73 | 3.81 | 21.99 | 5:16 | rear end |
| aljmhori inte... | 124.70 | -55.10 | 150.40 | 0.00 | 0.00 | 0.00 | 7.17 | 7.16 | -6.73 | -6.73 | 3.58 | 27.21 | 5:06 | rear end |
| aljmhori inte... | 128.40 | -33.82 | 143.04 | 0.00 | 0.00 | 0.00 | 7.13 | 3.76 | 2.01 | 2.01 | 2.78 | -15.44 | 6:31 | rear end |
| aljmhori inte... | 124.90 | -55.08 | 150.52 | 0.00 | 0.00 | 0.00 | 2.42 | 1.48 | -7.83 | -7.86 | 0.79 | -132.98 | 10:26 | lane change |
| aljmhori inte... | 131.90 | -33.82 | 143.04 | 0.00 | 0.00 | 0.00 | 5.94 | 4.10 | 0.47 | 0.47 | 3.17 | -10.39 | 6:21 | rear end |
| aljmhori inte... | 132.70 | -51.58 | 149.42 | 0.00 | 0.70 | 2.20 | 2.42 | 0.32 | -0.27 | -1.99 | 0.18 | 7.96 | 5:44 | rear end |
| aljmhori inte... | 135.60 | -53.11 | 147.84 | 0.00 | 0.50 | 1.10 | 0.95 | 1.14 | -7.76 | -7.79 | 0.59 | -82.81 | 8:46 | lane change |
| aljmhori inte... | 138.40 | 53.29 | 136.51 | 0.00 | 0.00 | 0.00 | 7.43 | 5.49 | -3.52 | -3.52 | 2.92 | 6.71 | 5:47 | lane change |
| aljmhori inte... | 142.30 | 115.54 | 82.39 | 0.00 | 0.00 | 0.00 | 8.35 | 3.63 | 0.29 | 0.29 | 1.93 | 7.04 | 5:46 | lane change |
| aljmhori inte... | 139.30 | 87.07 | 205.11 | 0.00 | 0.60 | 0.30 | 7.08 | 3.16 | -7.73 | -7.81 | 1.58 | -17.07 | 6:34 | rear end |
| aljmhori inte... | 145.10 | 58.54 | 147.53 | 0.00 | 0.00 | 0.00 | 7.28 | 6.68 | -0.34 | -1.43 | 3.34 | 7.27 | 5:45 | lane change |
| aljmhori inte... | 152.40 | 73.43 | 172.30 | 0.00 | 0.60 | 1.10 | 8.14 | 2.17 | -1.74 | -3.23 | 1.77 | -0.67 | 6:01 | rear end |
| aljmhori inte... | 153.80 | 62.98 | 104.71 | 0.00 | 0.00 | 0.00 | 6.72 | 0.88 | 1.16 | 1.16 | 0.72 | 5.39 | 5:49 | rear end |
| aljmhori inte... | 153.90 | 60.95 | 102.81 | 0.00 | 0.00 | 0.00 | 7.49 | 5.44 | 0.27 | 0.27 | 4.31 | -83.20 | 8:46 | crossing |
| aljmhori inte... | 154.40 | 60.57 | 106.95 | 0.00 | 0.00 | 0.00 | 7.59 | 5.44 | 0.27 | 0.27 | 4.43 | -77.56 | 8:35 | lane change |
| aljmhori inte... | 148.00 | 85.09 | 203.33 | 0.00 | 0.00 | 0.00 | 6.19 | 1.60 | -0.18 | -0.19 | 0.80 | -8.57 | 6:17 | rear end |
| aljmhori inte... | 155.10 | 70.00 | 171.61 | 0.00 | 1.30 | 1.00 | 2.15 | 1.31 | 0.00 | 0.00 | 1.07 | -32.82 | 7:06 | lane change |
| aljmhori inte... | 155.70 | 63.75 | 104.13 | 0.00 | 0.00 | 0.00 | 8.76 | 7.05 | 0.27 | 0.27 | 5.66 | -88.63 | 8:57 | crossing |
| aljmhori inte... | 155.00 | 74.51 | 172.60 | 0.00 | 1.20 | 1.20 | 8.55 | 7.43 | -0.23 | -7.43 | 3.72 | 20.68 | 5:19 | lane change |
| aljmhori inte... | 154.70 | 67.59 | 105.30 | 0.00 | 0.00 | 0.00 | 6.68 | 5.71 | 0.27 | 0.27 | 2.85 | -89.45 | 8:59 | crossing |
| aljmhori inte... | 155.00 | 68.37 | 101.84 | 0.00 | 0.10 | 0.60 | 6.21 | 0.29 | 1.16 | 1.16 | 0.24 | -6.45 | 6:13 | rear end |
| aljmhori inte... | 155.80 | 74.91 | 172.84 | 0.00 | 0.80 | 0.60 | 3.24 | 2.04 | -0.28 | -1.79 | 1.09 | 6.09 | 5:48 | rear end |
| aljmhori inte... | 163.60 | 126.97 | 76.55 | 0.00 | 0.40 | 0.40 | 3.83 | 3.83 | -0.06 | -0.06 | 2.18 | 7.60 | 5:45 | rear end |
| aljmhori inte... | 162.50 | 77.08 | 173.46 | 0.00 | 0.00 | 0.00 | 3.20 | 2.28 | 0.00 | 0.00 | 1.27 | -14.72 | 6:29 | lane change |

**Figure (4-4) Screenshot for SSAM Preliminary Conflicts Analysis and Details**

SSAM provides a summary Table of the conflicts, the summary Table consists of two parts. the first provides statistical information include (Minimum, Maximum, Mean, and Variance) for SSAM-measure (TTC, PET, MaxS, MaxD, Delta S, and Max DeltaV), which are described in (Chapter 2), the second part of the summary Table displays the total number of conflicts for the analyzed trj file and the conflicts number of each type of conflicts as shown in Figure (4-5).


SSAM3

Configuration | Conflicts | Summary | Filter | ttest | Map

FILTER APPLIED

| Summary ... | SSAM_Mea... | Min | Max | Mean | Variance |
|---|---|---|---|---|---|
| Filtered-All ... | DeltaS | 0.04 | 10.12 | 3.19 | 4.55 |
| Filtered-All ... | DR | -7.98 | 2.12 | -2.03 | 4.44 |
| Filtered-All ... | MaxD | -8.05 | 2.12 | -4.61 | 5.25 |
| Filtered-All ... | MaxDeltaV | 0.02 | 7.59 | 1.82 | 1.65 |
| Filtered-All ... | P(UEA) | 1.00 | 1.00 | 1.00 | 0.00 |
| Filtered-All ... | mTTC | 99.00 | 99.00 | 99.00 | 0.00 |
| Filtered-All ... | mPET | 99.00 | 99.00 | 99.00 | 0.00 |
| | | | | | |
| Summary Gr... | SSAM_Mea... | Min | Max | Mean | Variance |
| Filtered-C:\... | TTC | 0.16 | 1.5 | 0.97 | 0.08 |
| Filtered-C:\... | PET | 0.10 | 4.70 | 1.97 | 1.09 |
| Filtered-C:\... | MaxS | 1.02 | 8.32 | 5.23 | 3.90 |
| Filtered-C:\... | DeltaS | 0.04 | 10.12 | 3.19 | 4.55 |
| Filtered-C:\... | DR | -7.98 | 2.12 | -2.03 | 4.44 |
| Filtered-C:\... | MaxD | -8.05 | 2.12 | -4.61 | 5.25 |
| Filtered-C:\... | MaxDeltaV | 0.02 | 7.59 | 1.82 | 1.65 |
| Filtered-C:\... | P(UEA) | 1.00 | 1.00 | 1.00 | 0.00 |
| Filtered-C:\... | mTTC | 99.00 | 99.00 | 99.00 | 0.00 |
| Filtered-C:\... | mPET | 99.00 | 99.00 | 99.00 | 0.00 |

| Summary ... | Total | unclassified | crossing | rear end | lane change |
|---|---|---|---|---|---|
| Unfiltered-Al... | 454 | 0 | 48 | 284 | 122 |
| Filtered-All ... | 207 | 0 | 26 | 128 | 53 |
| Filtered-C:\... | 207 | 0 | 26 | 128 | 53 |



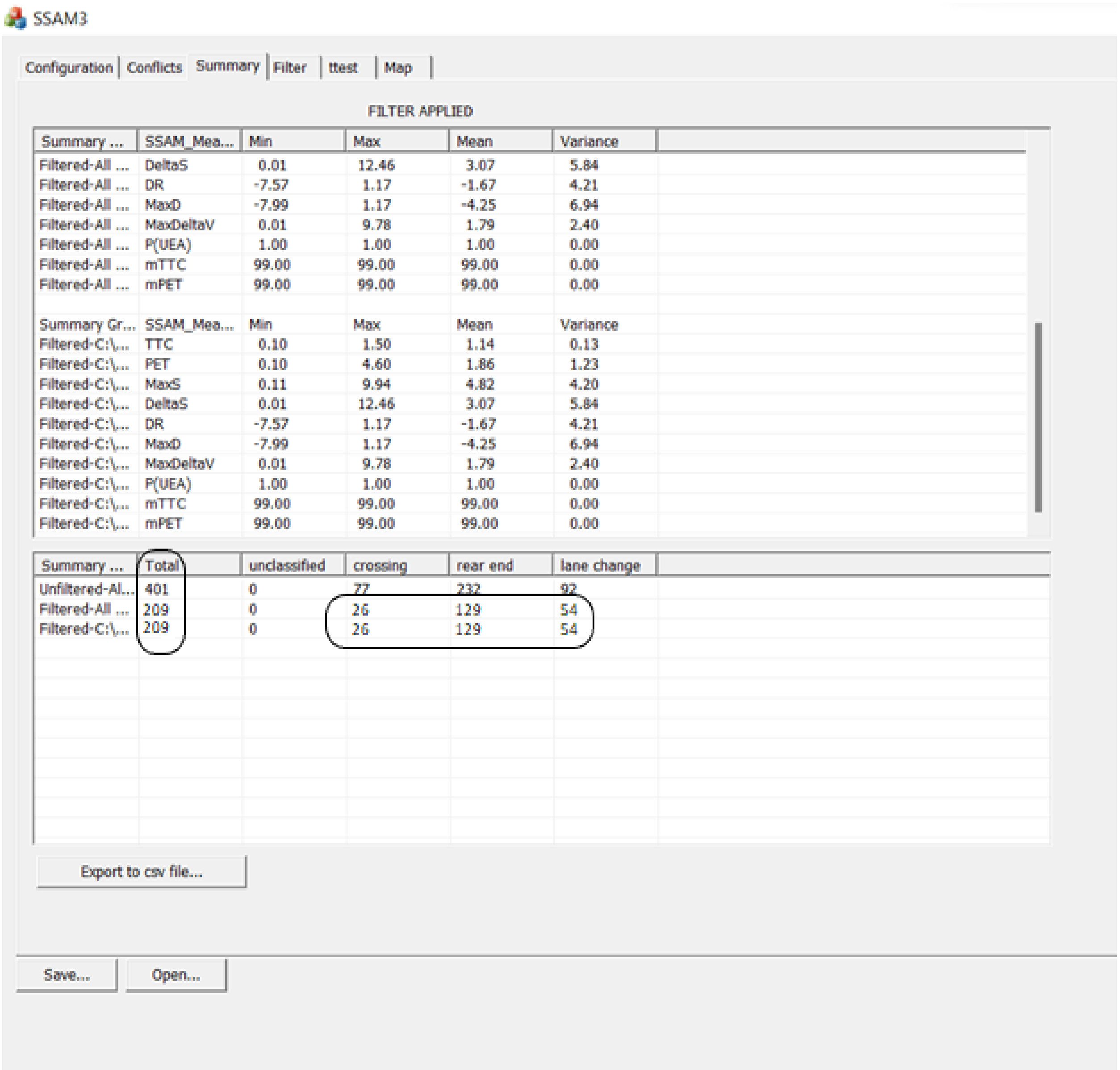
**Figure (4-5) SSAM Software Screenshot to Display Summary of Conflict, after Applied Filter**

**Step 4: Filter the Results for The Traffic Conflicts**.

In this step, filter the traffic conflict for the purpose of removing any errors. The SAAM software can filter the results of the traffic conflicts in two stages.

**A- Filter the Results of Conflict Points, TTC And PET**

After evaluating the intersections with the SAAM software, accomplish the first filtering process for the purpose of removing the zero values of both TTC and PET, which are caused by errors in the simulation process, where the lowest value of PET, the TTC is not less than( 0.1), when press the filter command, it will be excluded the values zero, and when go to summery, the results appear in the form of a Table representing the remaining numbers of traffic conflicts, as shown in Figure (4-6) and Figure (4-7)




| Summary ... | SSAM_Mea... | Min | Max | Mean | Variance |
|---|---|---|---|---|---|
| Filtered-All ... | DeltaS | 0.01 | 12.46 | 3.07 | 5.84 |
| Filtered-All ... | DR | -7.57 | 1.17 | -1.67 | 4.21 |
| Filtered-All ... | MaxD | -7.99 | 1.17 | -4.25 | 6.94 |
| Filtered-All ... | MaxDeltaV | 0.01 | 9.78 | 1.79 | 2.40 |
| Filtered-All ... | P(UEA) | 1.00 | 1.00 | 1.00 | 0.00 |
| Filtered-All ... | mTTC | 99.00 | 99.00 | 99.00 | 0.00 |
| Filtered-All ... | mPET | 99.00 | 99.00 | 99.00 | 0.00 |
| Summary Gr... | SSAM_Mea... | Min | Max | Mean | Variance |
| Filtered-C:\... | TTC | 0.10 | 1.50 | 1.14 | 0.13 |
| Filtered-C:\... | PET | 0.10 | 4.60 | 1.86 | 1.23 |
| Filtered-C:\... | MaxS | 0.11 | 9.94 | 4.82 | 4.20 |
| Filtered-C:\... | DeltaS | 0.01 | 12.46 | 3.07 | 5.84 |
| Filtered-C:\... | DR | -7.57 | 1.17 | -1.67 | 4.21 |
| Filtered-C:\... | MaxD | -7.99 | 1.17 | -4.25 | 6.94 |
| Filtered-C:\... | MaxDeltaV | 0.01 | 9.78 | 1.79 | 2.40 |
| Filtered-C:\... | P(UEA) | 1.00 | 1.00 | 1.00 | 0.00 |
| Filtered-C:\... | mTTC | 99.00 | 99.00 | 99.00 | 0.00 |
| Filtered-C:\... | mPET | 99.00 | 99.00 | 99.00 | 0.00 |

| Summary ... | Total | unclassified | crossing | rear end | lane change |
|---|---|---|---|---|---|
| Unfiltered-Al... | 401 | 0 | 77 | 232 | 92 |
| Filtered-All ... | 209 | 0 | 26 | 129 | 54 |
| Filtered-C:\... | 209 | 0 | 26 | 129 | 54 |



**Figure (4-6) SSAM Screen Display Statistical Summary of Conflicts After Applied Filter to Exclude Illogical Results**

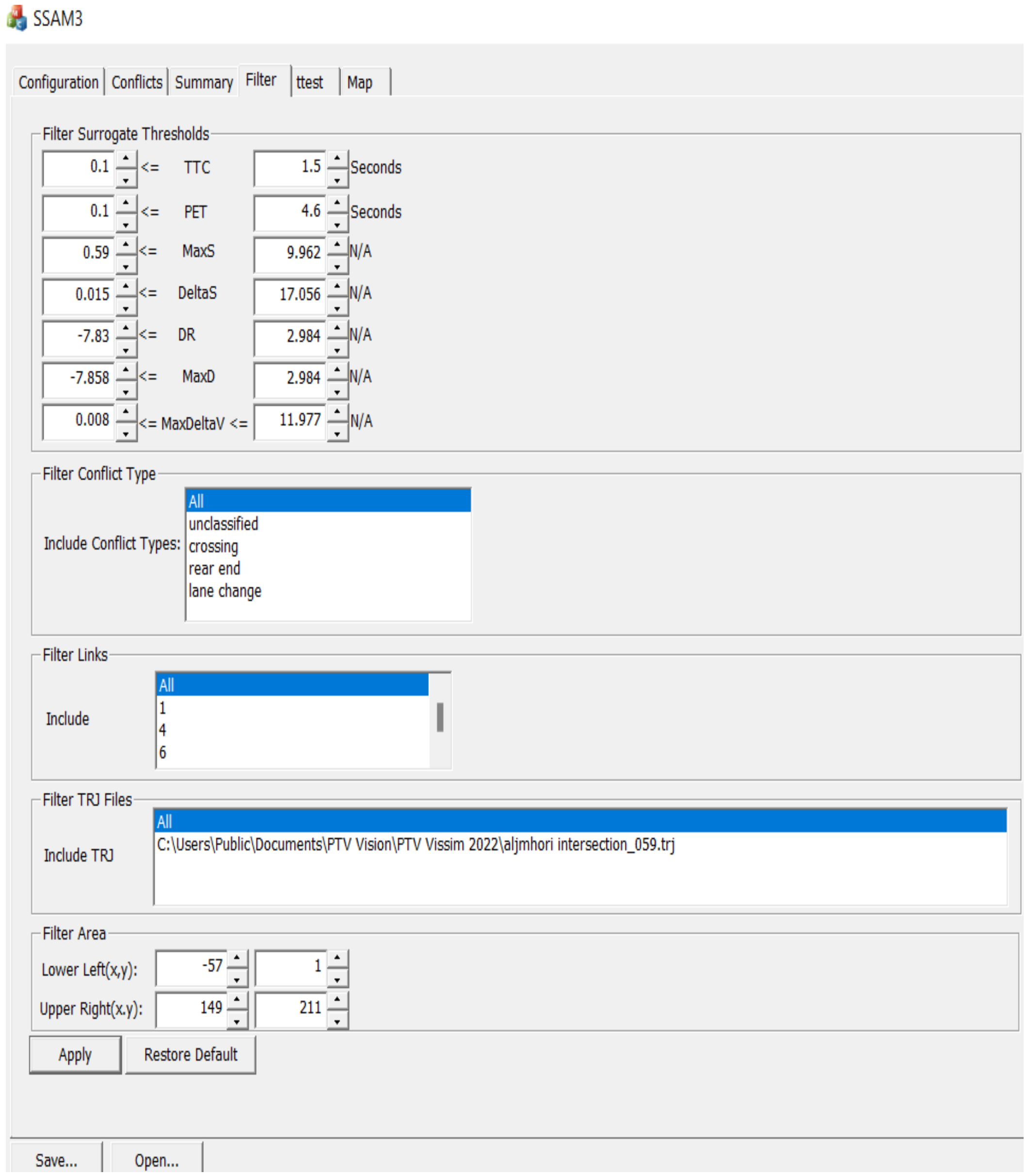
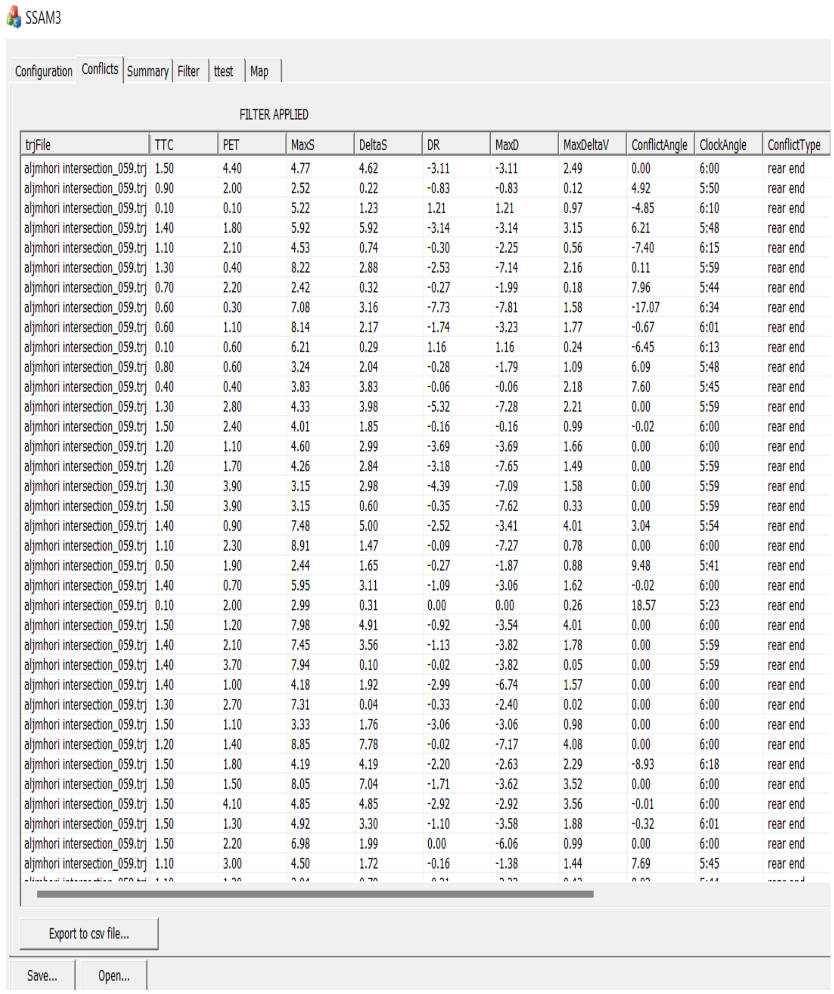



**Figure (4-7) Screenshot Showing the Filtered of Conflict Types by Excluding Illogical Results**

**B- Filter Conflicts Points by Type.**

**1-Filter the Results by Type of Traffic Conflict.**

Through this filter, one type of traffic conflict, or two types, or all types can be shown, according to the Figure (4-8)



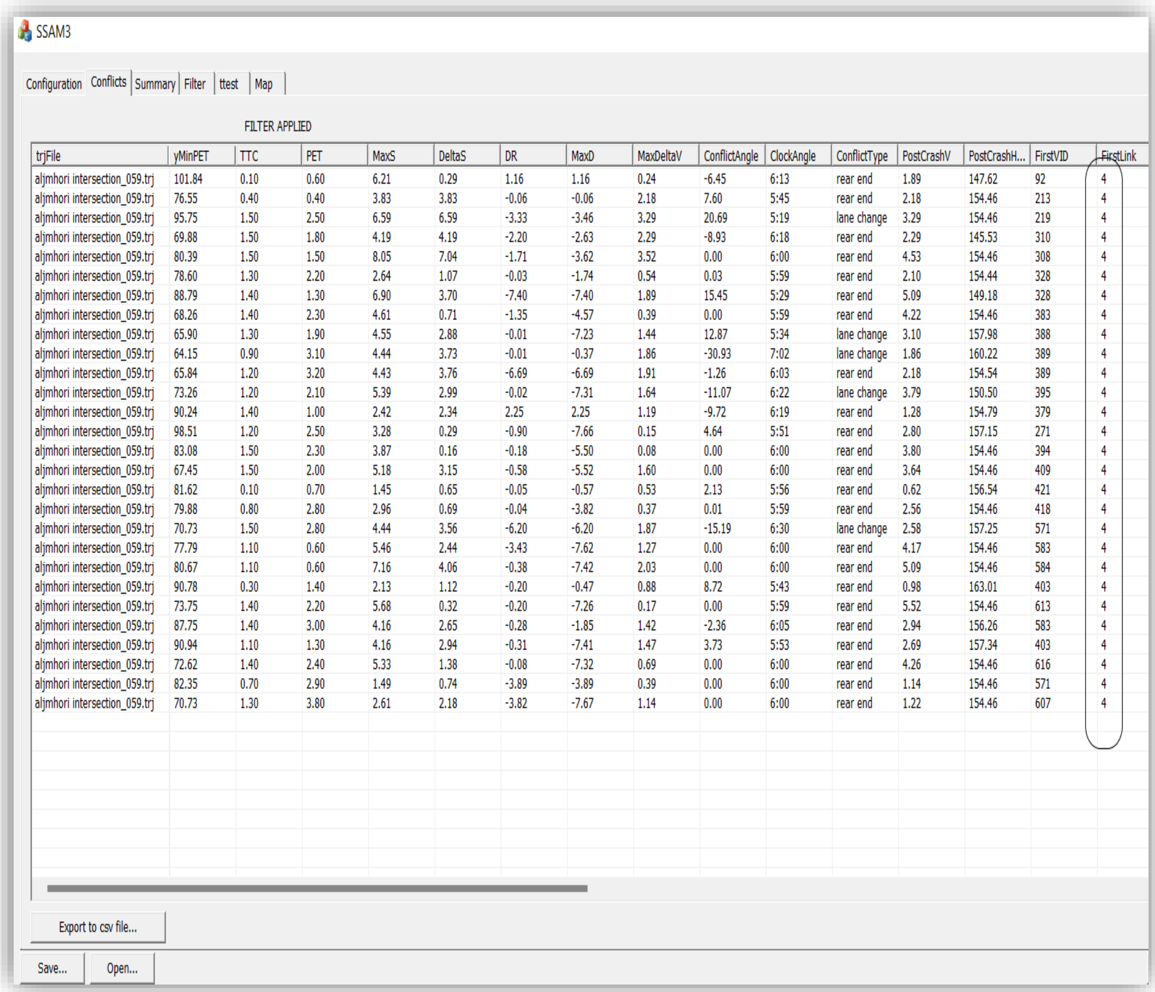

| trjFile | TTC | PET | MaxS | DeltaS | DR | MaxD | MaxDeltaV | ConflictAngle | ClockAngle | ConflictType |
|---|---|---|---|---|---|---|---|---|---|---|
| aljmhori intersection_059.trj | 1.50 | 4.40 | 4.77 | 4.62 | -3.11 | -3.11 | 2.49 | 0.00 | 6:00 | rear end |
| aljmhori intersection_059.trj | 0.90 | 2.00 | 2.52 | 0.22 | -0.83 | -0.83 | 0.12 | 4.92 | 5:50 | rear end |
| aljmhori intersection_059.trj | 0.10 | 0.10 | 5.22 | 1.23 | 1.21 | 1.21 | 0.97 | -4.85 | 6:10 | rear end |
| aljmhori intersection_059.trj | 1.40 | 1.80 | 5.92 | 5.92 | -3.14 | -3.14 | 3.15 | 6.21 | 5:48 | rear end |
| aljmhori intersection_059.trj | 1.10 | 2.10 | 4.53 | 0.74 | -0.30 | -2.25 | 0.56 | -7.40 | 6:15 | rear end |
| aljmhori intersection_059.trj | 1.30 | 0.40 | 8.22 | 2.88 | -2.53 | -7.14 | 2.16 | 0.11 | 5:59 | rear end |
| aljmhori intersection_059.trj | 0.70 | 2.20 | 2.42 | 0.32 | -0.27 | -1.99 | 0.18 | 7.96 | 5:44 | rear end |
| aljmhori intersection_059.trj | 0.60 | 0.30 | 7.08 | 3.16 | -7.73 | -7.81 | 1.58 | -17.07 | 6:34 | rear end |
| aljmhori intersection_059.trj | 0.60 | 1.10 | 8.14 | 2.17 | -1.74 | -3.23 | 1.77 | -0.67 | 6:01 | rear end |
| aljmhori intersection_059.trj | 0.10 | 0.60 | 6.21 | 0.29 | 1.16 | 1.16 | 0.24 | -6.45 | 6:13 | rear end |
| aljmhori intersection_059.trj | 0.80 | 0.60 | 3.24 | 2.04 | -0.28 | -1.79 | 1.09 | 6.09 | 5:48 | rear end |
| aljmhori intersection_059.trj | 0.40 | 0.40 | 3.83 | 3.83 | -0.06 | -0.06 | 2.18 | 7.60 | 5:45 | rear end |
| aljmhori intersection_059.trj | 1.30 | 2.80 | 4.33 | 3.98 | -5.32 | -7.28 | 2.21 | 0.00 | 5:59 | rear end |
| aljmhori intersection_059.trj | 1.50 | 2.40 | 4.01 | 1.85 | -0.16 | -0.16 | 0.99 | -0.02 | 6:00 | rear end |
| aljmhori intersection_059.trj | 1.20 | 1.10 | 4.60 | 2.99 | -3.69 | -3.69 | 1.66 | 0.00 | 6:00 | rear end |
| aljmhori intersection_059.trj | 1.20 | 1.70 | 4.26 | 2.84 | -3.18 | -7.65 | 1.49 | 0.00 | 5:59 | rear end |
| aljmhori intersection_059.trj | 1.30 | 3.90 | 3.15 | 2.98 | -4.39 | -7.09 | 1.58 | 0.00 | 5:59 | rear end |
| aljmhori intersection_059.trj | 1.50 | 3.90 | 3.15 | 0.60 | -0.35 | -7.62 | 0.33 | 0.00 | 5:59 | rear end |
| aljmhori intersection_059.trj | 1.40 | 0.90 | 7.48 | 5.00 | -2.52 | -3.41 | 4.01 | 3.04 | 5:54 | rear end |
| aljmhori intersection_059.trj | 1.10 | 2.30 | 8.91 | 1.47 | -0.09 | -7.27 | 0.78 | 0.00 | 6:00 | rear end |
| aljmhori intersection_059.trj | 0.50 | 1.90 | 2.44 | 1.65 | -0.27 | -1.87 | 0.88 | 9.48 | 5:41 | rear end |
| aljmhori intersection_059.trj | 1.40 | 0.70 | 5.95 | 3.11 | -1.09 | -3.06 | 1.62 | -0.02 | 6:00 | rear end |
| aljmhori intersection_059.trj | 0.10 | 2.00 | 2.99 | 0.31 | 0.00 | 0.00 | 0.26 | 18.57 | 5:23 | rear end |
| aljmhori intersection_059.trj | 1.50 | 1.20 | 7.98 | 4.91 | -0.92 | -3.54 | 4.01 | 0.00 | 6:00 | rear end |
| aljmhori intersection_059.trj | 1.40 | 2.10 | 7.45 | 3.56 | -1.13 | -3.82 | 1.78 | 0.00 | 5:59 | rear end |
| aljmhori intersection_059.trj | 1.40 | 3.70 | 7.94 | 0.10 | -0.02 | -3.82 | 0.05 | 0.00 | 5:59 | rear end |
| aljmhori intersection_059.trj | 1.40 | 1.00 | 4.18 | 1.92 | -2.99 | -6.74 | 1.57 | 0.00 | 6:00 | rear end |
| aljmhori intersection_059.trj | 1.30 | 2.70 | 7.31 | 0.04 | -0.33 | -2.40 | 0.02 | 0.00 | 6:00 | rear end |
| aljmhori intersection_059.trj | 1.50 | 1.10 | 3.33 | 1.76 | -3.06 | -3.06 | 0.98 | 0.00 | 6:00 | rear end |
| aljmhori intersection_059.trj | 1.20 | 1.40 | 8.85 | 7.78 | -0.02 | -7.17 | 4.08 | 0.00 | 6:00 | rear end |
| aljmhori intersection_059.trj | 1.50 | 1.80 | 4.19 | 4.19 | -2.20 | -2.63 | 2.29 | -8.93 | 6:18 | rear end |
| aljmhori intersection_059.trj | 1.50 | 1.50 | 8.05 | 7.04 | -1.71 | -3.62 | 3.52 | 0.00 | 6:00 | rear end |
| aljmhori intersection_059.trj | 1.50 | 4.10 | 4.85 | 4.85 | -2.92 | -2.92 | 3.56 | -0.01 | 6:00 | rear end |
| aljmhori intersection_059.trj | 1.50 | 1.30 | 4.92 | 3.30 | -1.10 | -3.58 | 1.88 | -0.32 | 6:01 | rear end |
| aljmhori intersection_059.trj | 1.50 | 2.20 | 6.98 | 1.99 | 0.00 | -6.06 | 0.99 | 0.00 | 6:00 | rear end |
| aljmhori intersection_059.trj | 1.10 | 3.00 | 4.50 | 1.72 | -0.16 | -1.38 | 1.44 | 7.69 | 5:45 | rear end |

**Figure (4-8) Screenshot Showing One Type of Conflicts That were Filtered.**

Only the quantity of rear-end conflicts is shown in Figures (4-8). Al-jamhori, Al-Oruba, Al- Fadael and AL-nesser intersections, respectively, had (128, 93, 112 and 128) rear-end conflicts, but the other kinds of conflicts were not disclosed (given zero values to the rest of the types of conflicts).

### 2- Filter of The Approach

Each link represents an approach, so the SAAM software can filter the link, as the link filter is important because of the important details of the traffic conflict that can be observed for each link, through which the number of traffic conflicts is known, and thus the evaluation that each link represents in the process of filtering the link. Details can be shown link one or more, Figure (4-9) shows the number traffic conflicts at Link no (4) in Al-jamhori intersection.




| trjFile | yMinPET | TTC | PET | MaxS | DeltaS | DR | MaxD | MaxDeltaV | ConflictAngle | ClockAngle | ConflictType | PostCrashV | PostCrashH... | FirstVID | FirstLink |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| aljmhori intersection_059.trj | 101.84 | 0.10 | 0.60 | 6.21 | 0.29 | 1.16 | 1.16 | 0.24 | -6.45 | 6:13 | rear end | 1.89 | 147.62 | 92 | 4 |
| aljmhori intersection_059.trj | 76.55 | 0.40 | 0.40 | 3.83 | 3.83 | -0.06 | -0.06 | 2.18 | 7.60 | 5:45 | rear end | 2.18 | 154.46 | 213 | 4 |
| aljmhori intersection_059.trj | 95.75 | 1.50 | 2.50 | 6.59 | 6.59 | -3.33 | -3.46 | 3.29 | 20.69 | 5:19 | lane change | 3.29 | 154.46 | 219 | 4 |
| aljmhori intersection_059.trj | 69.88 | 1.50 | 1.80 | 4.19 | 4.19 | -2.20 | -2.63 | 2.29 | -8.93 | 6:18 | rear end | 2.29 | 145.53 | 310 | 4 |
| aljmhori intersection_059.trj | 80.39 | 1.50 | 1.50 | 8.05 | 7.04 | -1.71 | -3.62 | 3.52 | 0.00 | 6:00 | rear end | 4.53 | 154.46 | 308 | 4 |
| aljmhori intersection_059.trj | 78.60 | 1.30 | 2.20 | 2.64 | 1.07 | -0.03 | -1.74 | 0.54 | 0.03 | 5:59 | rear end | 2.10 | 154.44 | 328 | 4 |
| aljmhori intersection_059.trj | 88.79 | 1.40 | 1.30 | 6.90 | 3.70 | -7.40 | -7.40 | 1.89 | 15.45 | 5:29 | rear end | 5.09 | 149.18 | 328 | 4 |
| aljmhori intersection_059.trj | 68.26 | 1.40 | 2.30 | 4.61 | 0.71 | -1.35 | -4.57 | 0.39 | 0.00 | 5:59 | rear end | 4.22 | 154.46 | 383 | 4 |
| aljmhori intersection_059.trj | 65.90 | 1.30 | 1.90 | 4.55 | 2.88 | -0.01 | -7.23 | 1.44 | 12.87 | 5:34 | lane change | 3.10 | 157.98 | 388 | 4 |
| aljmhori intersection_059.trj | 64.15 | 0.90 | 3.10 | 4.44 | 3.73 | -0.01 | -0.37 | 1.86 | -30.93 | 7:02 | lane change | 1.86 | 160.22 | 389 | 4 |
| aljmhori intersection_059.trj | 65.84 | 1.20 | 3.20 | 4.43 | 3.76 | -6.69 | -6.69 | 1.91 | -1.26 | 6:03 | rear end | 2.18 | 154.54 | 389 | 4 |
| aljmhori intersection_059.trj | 73.26 | 1.20 | 2.10 | 5.39 | 2.99 | -0.02 | -7.31 | 1.64 | -11.07 | 6:22 | lane change | 3.79 | 150.50 | 395 | 4 |
| aljmhori intersection_059.trj | 90.24 | 1.40 | 1.00 | 2.42 | 2.34 | 2.25 | 2.25 | 1.19 | -9.72 | 6:19 | rear end | 1.28 | 154.79 | 379 | 4 |
| aljmhori intersection_059.trj | 98.51 | 1.20 | 2.50 | 3.28 | 0.29 | -0.90 | -7.66 | 0.15 | 4.64 | 5:51 | rear end | 2.80 | 157.15 | 271 | 4 |
| aljmhori intersection_059.trj | 83.08 | 1.50 | 2.30 | 3.87 | 0.16 | -0.18 | -5.50 | 0.08 | 0.00 | 6:00 | rear end | 3.80 | 154.46 | 394 | 4 |
| aljmhori intersection_059.trj | 67.45 | 1.50 | 2.00 | 5.18 | 3.15 | -0.58 | -5.52 | 1.60 | 0.00 | 6:00 | rear end | 3.64 | 154.46 | 409 | 4 |
| aljmhori intersection_059.trj | 81.62 | 0.10 | 0.70 | 1.45 | 0.65 | -0.05 | -0.57 | 0.53 | 2.13 | 5:56 | rear end | 0.62 | 156.54 | 421 | 4 |
| aljmhori intersection_059.trj | 79.88 | 0.80 | 2.80 | 2.96 | 0.69 | -0.04 | -3.82 | 0.37 | 0.01 | 5:59 | rear end | 2.56 | 154.46 | 418 | 4 |
| aljmhori intersection_059.trj | 70.73 | 1.50 | 2.80 | 4.44 | 3.56 | -6.20 | -6.20 | 1.87 | -15.19 | 6:30 | lane change | 2.58 | 157.25 | 571 | 4 |
| aljmhori intersection_059.trj | 77.79 | 1.10 | 0.60 | 5.46 | 2.44 | -3.43 | -7.62 | 1.27 | 0.00 | 6:00 | rear end | 4.17 | 154.46 | 583 | 4 |
| aljmhori intersection_059.trj | 80.67 | 1.10 | 0.60 | 7.16 | 4.06 | -0.38 | -7.42 | 2.03 | 0.00 | 6:00 | rear end | 5.09 | 154.46 | 584 | 4 |
| aljmhori intersection_059.trj | 90.78 | 0.30 | 1.40 | 2.13 | 1.12 | -0.20 | -0.47 | 0.88 | 8.72 | 5:43 | rear end | 0.98 | 163.01 | 403 | 4 |
| aljmhori intersection_059.trj | 73.75 | 1.40 | 2.20 | 5.68 | 0.32 | -0.20 | -7.26 | 0.17 | 0.00 | 5:59 | rear end | 5.52 | 154.46 | 613 | 4 |
| aljmhori intersection_059.trj | 87.75 | 1.40 | 3.00 | 4.16 | 2.65 | -0.28 | -1.85 | 1.42 | -2.36 | 6:05 | rear end | 2.94 | 156.26 | 583 | 4 |
| aljmhori intersection_059.trj | 90.94 | 1.10 | 1.30 | 4.16 | 2.94 | -0.31 | -7.41 | 1.47 | 3.73 | 5:53 | rear end | 2.69 | 157.34 | 403 | 4 |
| aljmhori intersection_059.trj | 72.62 | 1.40 | 2.40 | 5.33 | 1.38 | -0.08 | -7.32 | 0.69 | 0.00 | 6:00 | rear end | 4.26 | 154.46 | 616 | 4 |
| aljmhori intersection_059.trj | 82.35 | 0.70 | 2.90 | 1.49 | 0.74 | -3.89 | -3.89 | 0.39 | 0.00 | 6:00 | rear end | 1.14 | 154.46 | 571 | 4 |
| aljmhori intersection_059.trj | 70.73 | 1.30 | 3.80 | 2.61 | 2.18 | -3.82 | -7.67 | 1.14 | 0.00 | 6:00 | rear end | 1.22 | 154.46 | 607 | 4 |

**Figure (4-9) Screenshot Showing Conflicts at Link no (4) Filtered in Al-jamhori intersection.**

SSAM classifies conflicts into five main categories: Rear End; Lane Change; Crossing; Unclassified; and Total. As can be seen, any conflicts with angles of less than 30° are classified as rear end, between 30° and 85° are classified as lane change, and between 85° and 180° are classified as crossing. Conflicts with angles greater than 180° are shown as unclassified conflicts. In most cases the number of unclassified conflicts was zero. Figure (4-10) shows the classification of conflicts according to the angle of conflict.

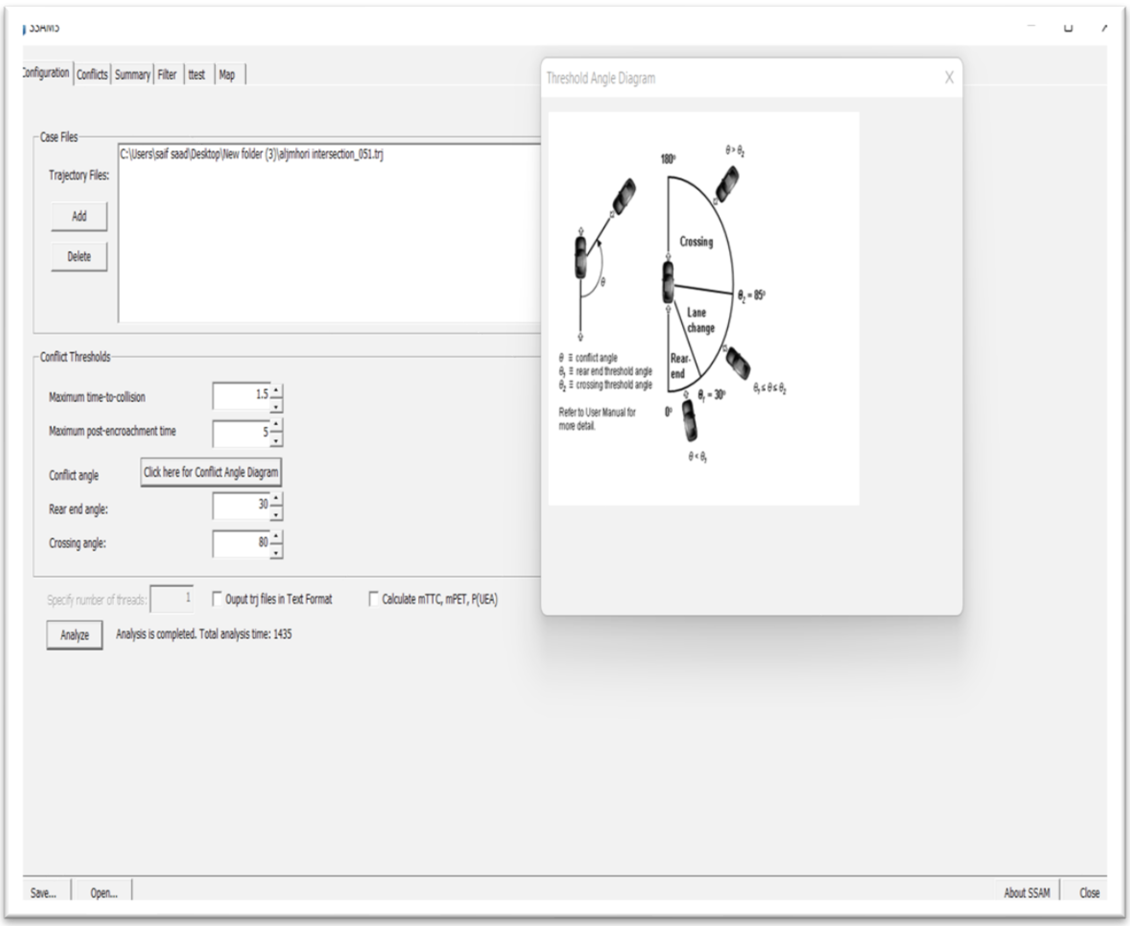



**Figure (4-10) SSAM Software Screenshot Illustrated Conflict Angle Diagram**

The rear end conflict often occurs when the two vehicles are on the same link and the same lane, the lane change conflict occurs in the same link when the vehicle's path changes from one lane to another, while the crossing conflict occurs when the vehicles are on different links on a vertical or semi-vertical angle. Figure (4-11) to Figure (4-13) illustrates the conflicts were recorded by VISSIM and their types were interpreted by SSAM.

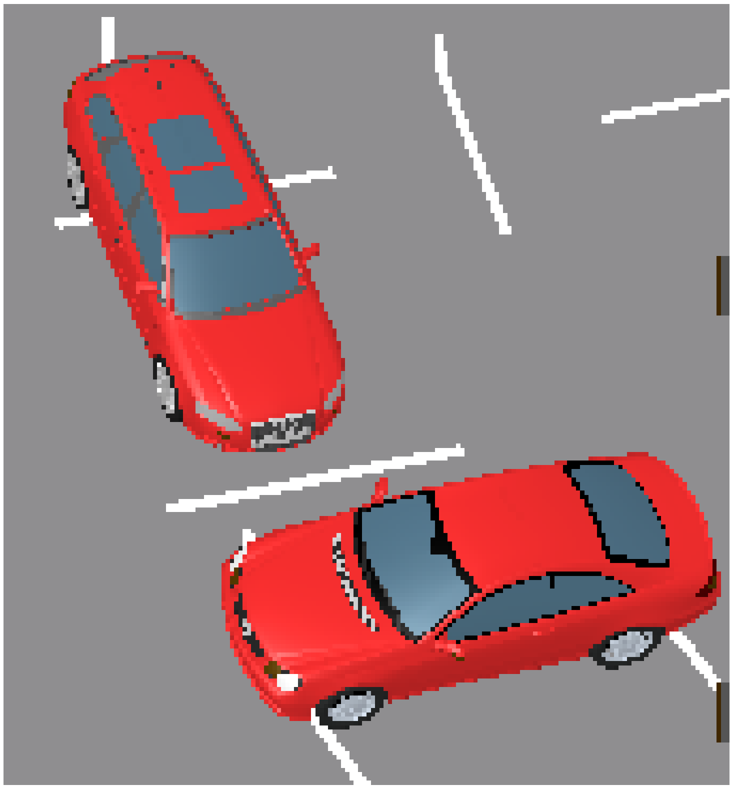


**Figure (4-11) VISSIM Software Screenshot Illustrated Crossing Conflict.**

**Figure (4-12) VISSIM Software Screenshot Illustrated Lane Change Conflict**

**Figure (4-13) VISSIM Software Screenshot Illustrated Rear-End Conflict.**

**Step 5: Finding the Conflicts Severity**

The degree of collision Severity depends on the amount of the TTC, as it starts from zero to greater than 1.5 sec where zero indicates the occurrence of the collision while less than or equal to one high intensity and greater than one and greater each one of the moderate severity class where the collision time is greater than 1.5 sec there is a low risk between the crashing vehicles SSAM's conflict severity rating also corresponds to the conflict severity ratings developed by (**Syed and Zain,1999).** Table (4-2) shows the evaluation of conflict severity according to different ranges of TTC values.

**Table (4-2) Conflicts Risk Correlating with (TTC) Values Ranges [108].**

| Time To Collision (TTC) Range | Risk Of Conflict (ROC) |
|---|---|
| 1.5< TTC <2 s | Low Risk |
| 1< TTC <1.5 s | Moderate Risk |
| 0< TTC <1 s | High Risk |

where the severity of the collision can be displayed on maps by showing them a SSAM software that represents the number of traffic conflicts in the intersection as shown in Figure (4-14)

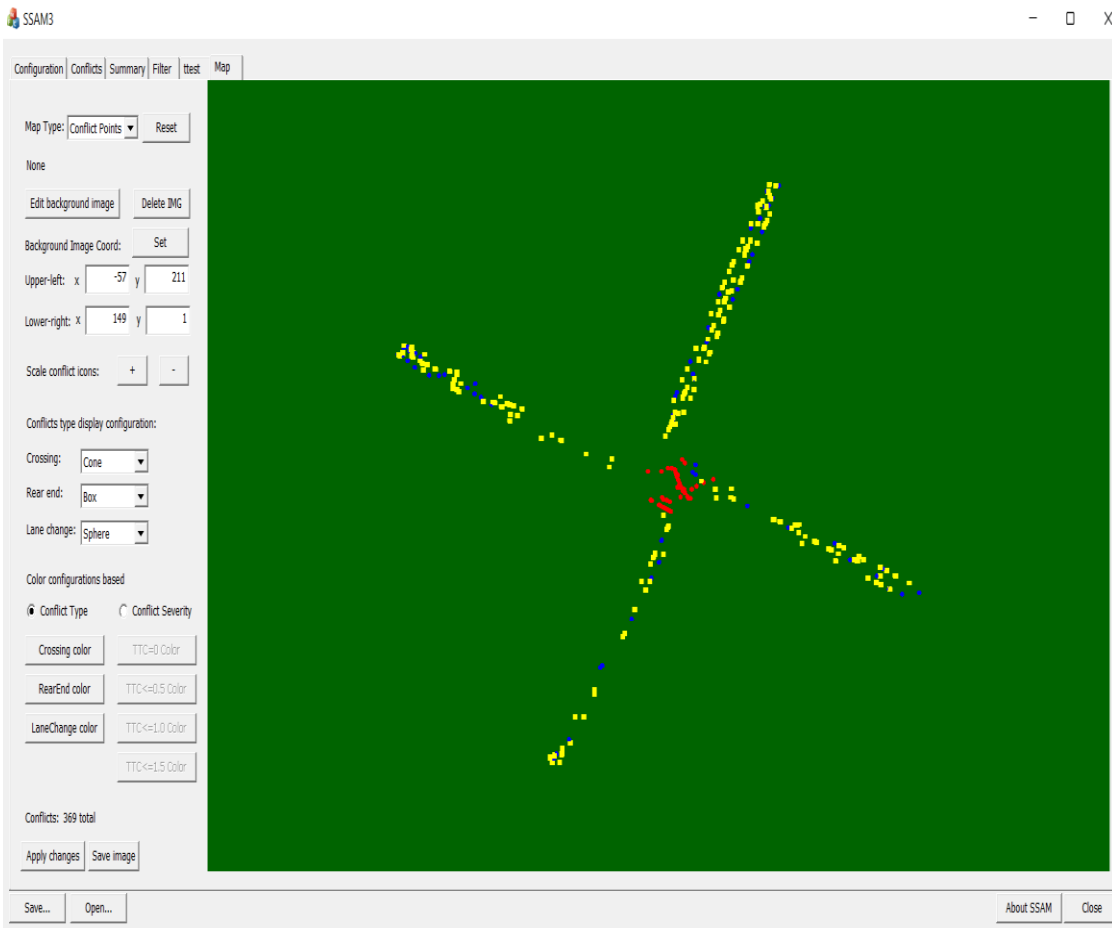
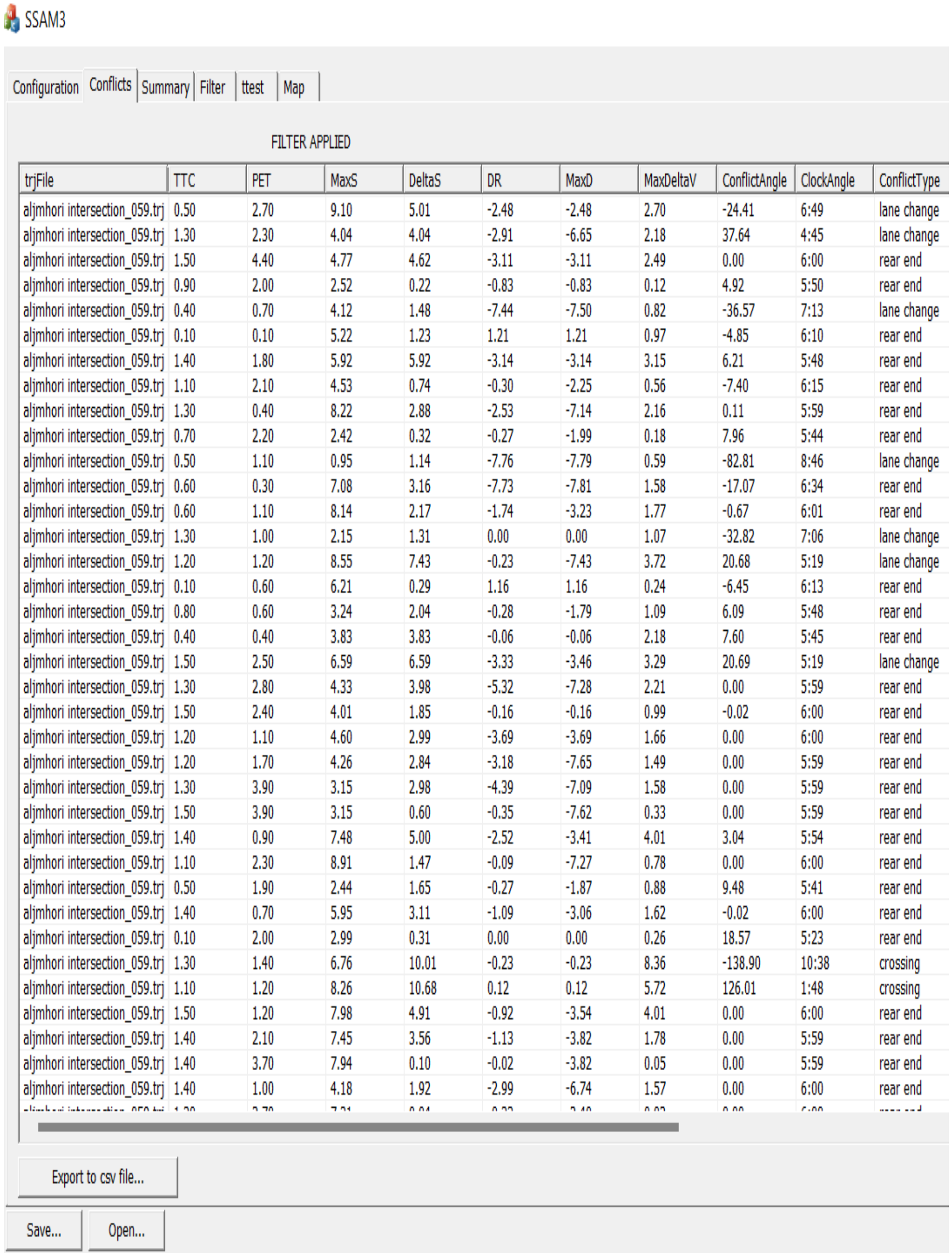



**Figure (4-14) SSAM Screen Showing a Map of The Severity of Conflicts at Al-Jamhori Intersection.**

**Step 6: SAAM Software Results**

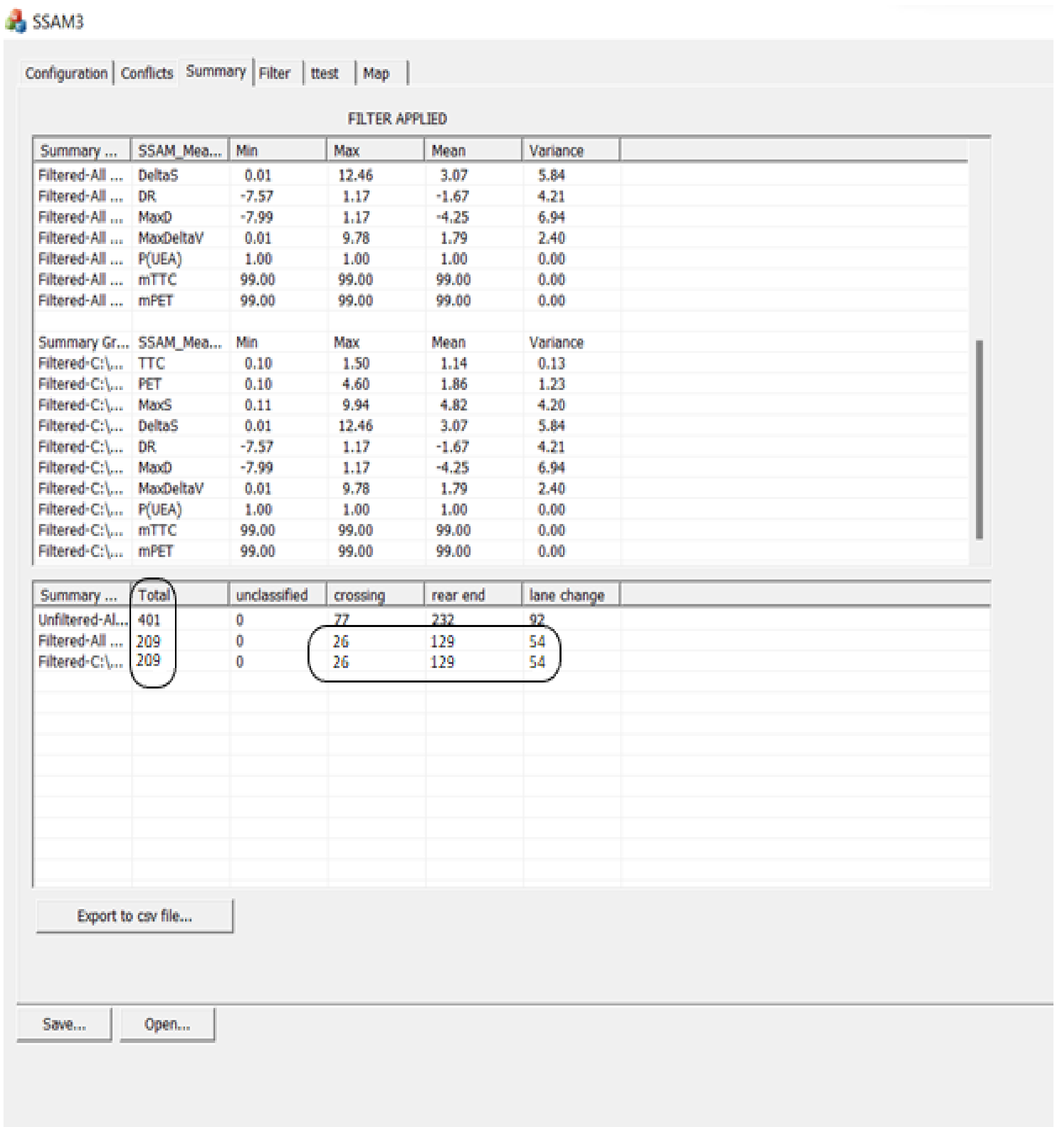
After completing the analysis process for the SSAM software, a Table will appear containing detailed information to the analysis process, the summary two sections make up the Table. The first offers statistical data for the SSAM-measure, including Minimum, Maximum, Mean, and Variance (TTC, PET, MaxS, MaxD, DeltaS, and MaxDeltaV), the data shown in Figure (4-15) are preliminary results.




| trjFile | TTC | PET | MaxS | DeltaS | DR | MaxD | MaxDeltaV | ConflictAngle | ClockAngle | ConflictType |
|---|---|---|---|---|---|---|---|---|---|---|
| aljmhori intersection_059.trj | 0.50 | 2.70 | 9.10 | 5.01 | -2.48 | -2.48 | 2.70 | -24.41 | 6:49 | lane change |
| aljmhori intersection_059.trj | 1.30 | 2.30 | 4.04 | 4.04 | -2.91 | -6.65 | 2.18 | 37.64 | 4:45 | lane change |
| aljmhori intersection_059.trj | 1.50 | 4.40 | 4.77 | 4.62 | -3.11 | -3.11 | 2.49 | 0.00 | 6:00 | rear end |
| aljmhori intersection_059.trj | 0.90 | 2.00 | 2.52 | 0.22 | -0.83 | -0.83 | 0.12 | 4.92 | 5:50 | rear end |
| aljmhori intersection_059.trj | 0.40 | 0.70 | 4.12 | 1.48 | -7.44 | -7.50 | 0.82 | -36.57 | 7:13 | lane change |
| aljmhori intersection_059.trj | 0.10 | 0.10 | 5.22 | 1.23 | 1.21 | 1.21 | 0.97 | -4.85 | 6:10 | rear end |
| aljmhori intersection_059.trj | 1.40 | 1.80 | 5.92 | 5.92 | -3.14 | -3.14 | 3.15 | 6.21 | 5:48 | rear end |
| aljmhori intersection_059.trj | 1.10 | 2.10 | 4.53 | 0.74 | -0.30 | -2.25 | 0.56 | -7.40 | 6:15 | rear end |
| aljmhori intersection_059.trj | 1.30 | 0.40 | 8.22 | 2.88 | -2.53 | -7.14 | 2.16 | 0.11 | 5:59 | rear end |
| aljmhori intersection_059.trj | 0.70 | 2.20 | 2.42 | 0.32 | -0.27 | -1.99 | 0.18 | 7.96 | 5:44 | rear end |
| aljmhori intersection_059.trj | 0.50 | 1.10 | 0.95 | 1.14 | -7.76 | -7.79 | 0.59 | -82.81 | 8:46 | lane change |
| aljmhori intersection_059.trj | 0.60 | 0.30 | 7.08 | 3.16 | -7.73 | -7.81 | 1.58 | -17.07 | 6:34 | rear end |
| aljmhori intersection_059.trj | 0.60 | 1.10 | 8.14 | 2.17 | -1.74 | -3.23 | 1.77 | -0.67 | 6:01 | rear end |
| aljmhori intersection_059.trj | 1.30 | 1.00 | 2.15 | 1.31 | 0.00 | 0.00 | 1.07 | -32.82 | 7:06 | lane change |
| aljmhori intersection_059.trj | 1.20 | 1.20 | 8.55 | 7.43 | -0.23 | -7.43 | 3.72 | 20.68 | 5:19 | lane change |
| aljmhori intersection_059.trj | 0.10 | 0.60 | 6.21 | 0.29 | 1.16 | 1.16 | 0.24 | -6.45 | 6:13 | rear end |
| aljmhori intersection_059.trj | 0.80 | 0.60 | 3.24 | 2.04 | -0.28 | -1.79 | 1.09 | 6.09 | 5:48 | rear end |
| aljmhori intersection_059.trj | 0.40 | 0.40 | 3.83 | 3.83 | -0.06 | -0.06 | 2.18 | 7.60 | 5:45 | rear end |
| aljmhori intersection_059.trj | 1.50 | 2.50 | 6.59 | 6.59 | -3.33 | -3.46 | 3.29 | 20.69 | 5:19 | lane change |
| aljmhori intersection_059.trj | 1.30 | 2.80 | 4.33 | 3.98 | -5.32 | -7.28 | 2.21 | 0.00 | 5:59 | rear end |
| aljmhori intersection_059.trj | 1.50 | 2.40 | 4.01 | 1.85 | -0.16 | -0.16 | 0.99 | -0.02 | 6:00 | rear end |
| aljmhori intersection_059.trj | 1.20 | 1.10 | 4.60 | 2.99 | -3.69 | -3.69 | 1.66 | 0.00 | 6:00 | rear end |
| aljmhori intersection_059.trj | 1.20 | 1.70 | 4.26 | 2.84 | -3.18 | -7.65 | 1.49 | 0.00 | 5:59 | rear end |
| aljmhori intersection_059.trj | 1.30 | 3.90 | 3.15 | 2.98 | -4.39 | -7.09 | 1.58 | 0.00 | 5:59 | rear end |
| aljmhori intersection_059.trj | 1.50 | 3.90 | 3.15 | 0.60 | -0.35 | -7.62 | 0.33 | 0.00 | 5:59 | rear end |
| aljmhori intersection_059.trj | 1.40 | 0.90 | 7.48 | 5.00 | -2.52 | -3.41 | 4.01 | 3.04 | 5:54 | rear end |
| aljmhori intersection_059.trj | 1.10 | 2.30 | 8.91 | 1.47 | -0.09 | -7.27 | 0.78 | 0.00 | 6:00 | rear end |
| aljmhori intersection_059.trj | 0.50 | 1.90 | 2.44 | 1.65 | -0.27 | -1.87 | 0.88 | 9.48 | 5:41 | rear end |
| aljmhori intersection_059.trj | 1.40 | 0.70 | 5.95 | 3.11 | -1.09 | -3.06 | 1.62 | -0.02 | 6:00 | rear end |
| aljmhori intersection_059.trj | 0.10 | 2.00 | 2.99 | 0.31 | 0.00 | 0.00 | 0.26 | 18.57 | 5:23 | rear end |
| aljmhori intersection_059.trj | 1.30 | 1.40 | 6.76 | 10.01 | -0.23 | -0.23 | 8.36 | -138.90 | 10:38 | crossing |
| aljmhori intersection_059.trj | 1.10 | 1.20 | 8.26 | 10.68 | 0.12 | 0.12 | 5.72 | 126.01 | 1:48 | crossing |
| aljmhori intersection_059.trj | 1.50 | 1.20 | 7.98 | 4.91 | -0.92 | -3.54 | 4.01 | 0.00 | 6:00 | rear end |
| aljmhori intersection_059.trj | 1.40 | 2.10 | 7.45 | 3.56 | -1.13 | -3.82 | 1.78 | 0.00 | 5:59 | rear end |
| aljmhori intersection_059.trj | 1.40 | 3.70 | 7.94 | 0.10 | -0.02 | -3.82 | 0.05 | 0.00 | 5:59 | rear end |
| aljmhori intersection_059.trj | 1.40 | 1.00 | 4.18 | 1.92 | -2.99 | -6.74 | 1.57 | 0.00 | 6:00 | rear end |

**Figure (4-15) SSAM Analyses of Surrogate Safety Measures of Conflicts at intersection.**

The second part of the summary Table displays the total number of conflicts for the analyzed trj file and the conflicts number of each type of conflict as shown in Figure (4-16).



SSAM3

Configuration | Conflicts | Summary | Filter | ttest | Map

FILTER APPLIED

| Summary ... | SSAM_Mea... | Min | Max | Mean | Variance |
|---|---|---|---|---|---|
| Filtered-All ... | DeltaS | 0.01 | 12.46 | 3.07 | 5.84 |
| Filtered-All ... | DR | -7.57 | 1.17 | -1.67 | 4.21 |
| Filtered-All ... | MaxD | -7.99 | 1.17 | -4.25 | 6.94 |
| Filtered-All ... | MaxDeltaV | 0.01 | 9.78 | 1.79 | 2.40 |
| Filtered-All ... | P(UEA) | 1.00 | 1.00 | 1.00 | 0.00 |
| Filtered-All ... | mTTC | 99.00 | 99.00 | 99.00 | 0.00 |
| Filtered-All ... | mPET | 99.00 | 99.00 | 99.00 | 0.00 |
| | | | | | |
| Summary Gr... | SSAM_Mea... | Min | Max | Mean | Variance |
| Filtered-C:\... | TTC | 0.10 | 1.50 | 1.14 | 0.13 |
| Filtered-C:\... | PET | 0.10 | 4.60 | 1.86 | 1.23 |
| Filtered-C:\... | MaxS | 0.11 | 9.94 | 4.82 | 4.20 |
| Filtered-C:\... | DeltaS | 0.01 | 12.46 | 3.07 | 5.84 |
| Filtered-C:\... | DR | -7.57 | 1.17 | -1.67 | 4.21 |
| Filtered-C:\... | MaxD | -7.99 | 1.17 | -4.25 | 6.94 |
| Filtered-C:\... | MaxDeltaV | 0.01 | 9.78 | 1.79 | 2.40 |
| Filtered-C:\... | P(UEA) | 1.00 | 1.00 | 1.00 | 0.00 |
| Filtered-C:\... | mTTC | 99.00 | 99.00 | 99.00 | 0.00 |
| Filtered-C:\... | mPET | 99.00 | 99.00 | 99.00 | 0.00 |

| Summary ... | Total | unclassified | crossing | rear end | lane change |
|---|---|---|---|---|---|
| Unfiltered-Al... | 401 | 0 | 77 | 232 | 92 |
| Filtered-All ... | 209 | 0 | 26 | 129 | 54 |
| Filtered-C:\... | 209 | 0 | 26 | 129 | 54 |

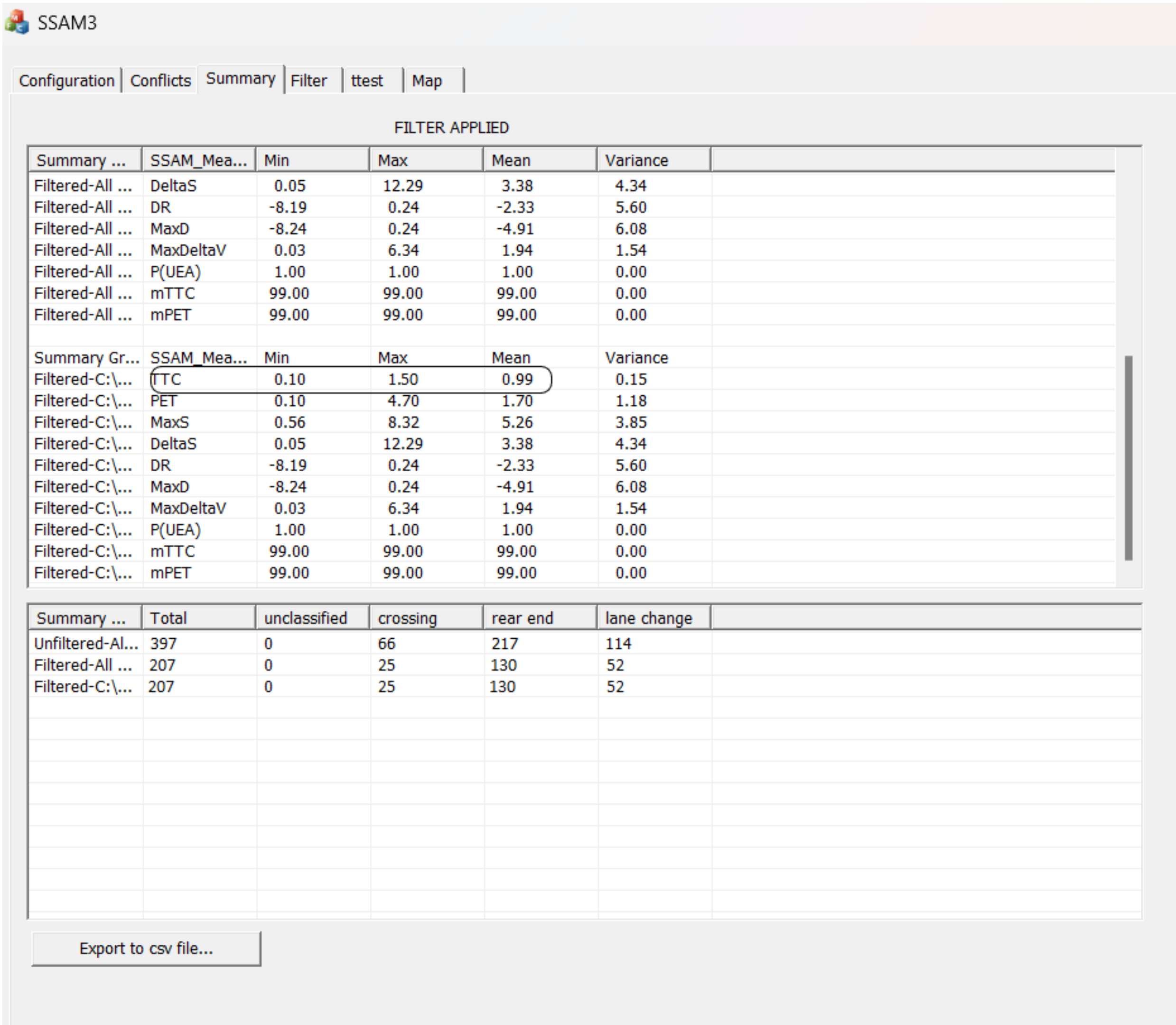
Export to csv file...

Save... Open...

**Figure (4-16) The Total Number of Conflicts of Each Type of Conflicts**

**Step 7: Using (TTC) As an Indicator of Safety Assessment.**

To overcome the shortcomings of crash data several surrogate measures of safety have been developed and proposed by various researchers. One of the most widely used temporal indicators is time-to-collision (TTC) which requires the road users to be on a collision course. (TTC) is used as an indicator of severity at intersections, where it is used to assess safety. Figure (4-17) shows conflicts risk correlating with (TTC) values ranges.




| Summary ... | SSAM_Mea... | Min | Max | Mean | Variance |
|---|---|---|---|---|---|
| Filtered-All ... | DeltaS | 0.05 | 12.29 | 3.38 | 4.34 |
| Filtered-All ... | DR | -8.19 | 0.24 | -2.33 | 5.60 |
| Filtered-All ... | MaxD | -8.24 | 0.24 | -4.91 | 6.08 |
| Filtered-All ... | MaxDeltaV | 0.03 | 6.34 | 1.94 | 1.54 |
| Filtered-All ... | P(UEA) | 1.00 | 1.00 | 1.00 | 0.00 |
| Filtered-All ... | mTTC | 99.00 | 99.00 | 99.00 | 0.00 |
| Filtered-All ... | mPET | 99.00 | 99.00 | 99.00 | 0.00 |
| | | | | | |
| Summary Gr... | SSAM_Mea... | Min | Max | Mean | Variance |
| Filtered-C:\... | TTC | 0.10 | 1.50 | 0.99 | 0.15 |
| Filtered-C:\... | PET | 0.10 | 4.70 | 1.70 | 1.18 |
| Filtered-C:\... | MaxS | 0.56 | 8.32 | 5.26 | 3.85 |
| Filtered-C:\... | DeltaS | 0.05 | 12.29 | 3.38 | 4.34 |
| Filtered-C:\... | DR | -8.19 | 0.24 | -2.33 | 5.60 |
| Filtered-C:\... | MaxD | -8.24 | 0.24 | -4.91 | 6.08 |
| Filtered-C:\... | MaxDeltaV | 0.03 | 6.34 | 1.94 | 1.54 |
| Filtered-C:\... | P(UEA) | 1.00 | 1.00 | 1.00 | 0.00 |
| Filtered-C:\... | mTTC | 99.00 | 99.00 | 99.00 | 0.00 |
| Filtered-C:\... | mPET | 99.00 | 99.00 | 99.00 | 0.00 |

| Summary ... | Total | unclassified | crossing | rear end | lane change |
|---|---|---|---|---|---|
| Unfiltered-Al... | 397 | 0 | 66 | 217 | 114 |
| Filtered-All ... | 207 | 0 | 25 | 130 | 52 |
| Filtered-C:\... | 207 | 0 | 25 | 130 | 52 |

**Figure (4-17) Conflicts Risk Correlating with (TTC) Values Ranges.**

**Step 8: SAAM Maps**

After completing the analysis process, the SSAM software will show the traffic conflicts in the form of maps that represent the number of traffic conflicts at the intersection. SSAM can also show the intersection points for each approach and one or more types of traffic conflicts, as shown in the following Figures for each intersection.

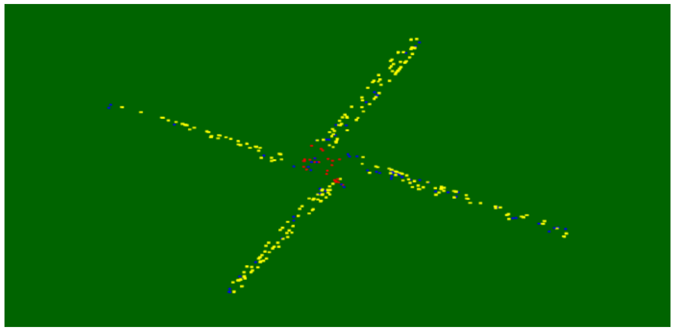


**Figure (4-18) SSAM screenshot Conflicts Results in the Form of Traffic Conflicts**

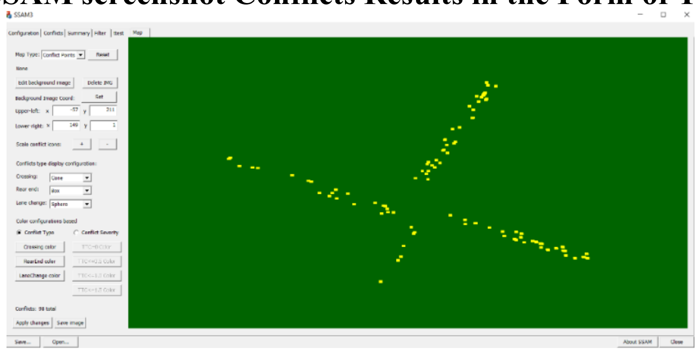


**Figure (4-19) SSAM Screenshot Conflicts Results in The Form of Rear-End Traffic Conflicts.**

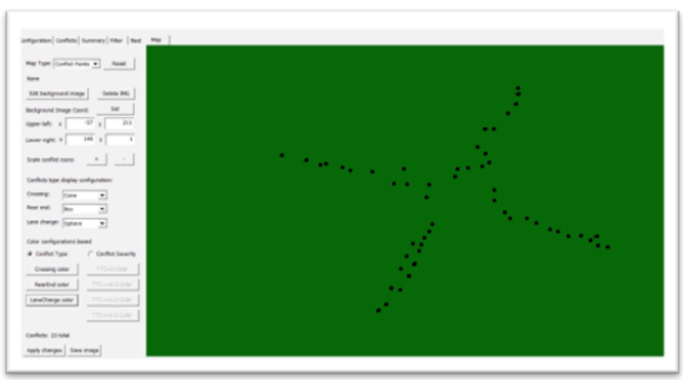


**Figure (4-20) SSAM Screenshot Conflicts Results in The Form of Lane Change**

## 4.5 Countermeasures

To improve the safety of transportation at intersections, there are several countermeasures used for the purpose of reducing traffic conflicts and thus reducing accidents. These countermeasures may contain geometric improvements such as increasing the width of the road or increasing another condition, or they may be traffic improvements such as retiming the length of the traffic cycle or adding a phase to the left.

### 4.5.1 Suggested countermeasures

The chosen intersections have many problems that raise the possibility of collisions and decrease safety, including a large turn volume, the absence of a left-turn phase, poor signal timing, a large overall intersection volume and other issues. In order to increase safety at intersections, a number of countermeasures have been proposed in this study based on the literature review that is presented at Tables (2-1), Table (2-2), and Table (2-3). These countermeasures are summarized as follows.

- Increasing lane widths.
- Increasing numbers of lanes
- Adding left turn phasing.
- Cancelling U-turn
- retiming traffic signal control

To achieve traffic signal retiming, optimization of the cycle time is determined according to Webster Equation made the length of the cycle optimal as a function of the critical flow ratios and lost times. Traffic signal timing optimization is regarded as one of the most cost-effective strategies for lowering vehicle operating expenses and improving traffic flow performance on urban roads. VISSIM contains several optimization types. It optimizes cycle durations, phase sequences, and split timings to reduce delay and stop time.

For each intersection select and identified as a suitable countermeasure, crash reduction ratios (CRR) are calculated. The predicted number of crashes was calculated with and without the countermeasure in place. Details at appendix (I)

The equation (1) is used to calculate the crash reduction ratio **(Tarko et al.,2014).**

$$\text{CRR} = \frac{\text{EOC (without)} - \text{EOC (with)}}{\text{EOC (without)}} * 100\% \qquad (4\text{-}1)$$

Where:

CRR: the crash reduction ratio

ENOC (with): the estimated number of crashes with the countermeasures in site.

ENOC (without): the estimated number of crashes without the countermeasures in site After assessing intersections.

#### 4.5.1.1 Suggested Countermeasures for Al-jamhori Intersection

##### 4.5.1.1.1 First Assessment Before Countermeasures

##### A- The Field Assessment for Al-Jamhori Intersection

According to the field assessment of the Al-jamhori intersection, it is classified as high risk through the severity index of TTC as shown in Table (4-3) before the countermeasures.

**Table (4-3) Field Conflicts Evaluation at Al-Jamhori Intersections Before the Countermeasures**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1}$ (sec) | $ROCR_{APP}$ | $THTC_{I}$ | $TTC_{I}$ (sec) | $ROCR_{I}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-jamhori | NB | 29 | 13 | 5 | 47 | .89 | HR | 188 | **.948** | **HR** |
| | EB | 27 | 18 | 4 | 49 | .99 | HR | | | |
| | SB | 19 | 8 | 3 | 30 | 1.1 | MR | | | |
| | WB | 40 | 16 | 6 | 62 | .86 | HR | | | |

**THTC $_{(APP\ I)}$**: Total hourly traffic conflicts at approach and intersection respectively.
**ROCR $_{(APP\ I)}$**: Risk of collision rating at approach and intersection respectively.

**TTC (APP I)**: Time to collision at approach and intersection respectively.
**HR, MR, LR**: Represents **High risk**, **Moderate risk** respectively.
**ER**: Rear-end conflicts, **C**: crossing conflict, **LC**: lane change conflicts

### B-SSAM's Assessment of Al-Jamhori Intersection.

SSAM's assessment of the Al-jamhori intersection, classified as high risk through the severity index of TTC as shown in Table (4-4) before the countermeasures.

**Table (4-4) SSAM Conflicts Evaluation at Al-Jamhori Intersections Before the Countermeasures**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1}$(sec) | $ROCR_{APP}$ (sec) | $THTC_I$ | $TTC_I$(sec) | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-jamhori | NB | 33 | 11 | 7 | 51 | 1.03 | MR | 207 | **.992** | **HR** |
| | EB | 34 | 15 | 6 | 55 | .97 | HR | | | |
| | SB | 23 | 10 | 4 | 37 | 1.09 | MR | | | |
| | WB | 41 | 17 | 8 | 66 | .93 | HR | | | |

### 4.5.1.1.2 Evaluation After Countermeasures

### 1- Increasing the Width of The Road

When using the countermeasure increasing the width of the road, the percentage of traffic conflicts decreased 39.66%, and when assessing the severity of the risk, the percentage of (TTC) increased 15.62%, as shown at Table (4-5)

**Table (4-5) Evaluation Al-Jamhori Intersection After Increase Width of Lane Countermeasure**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP}$ | $TTC_{APP}$ (sec) | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I(sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-jamhori | NB | 25 | 5 | 2 | 32 | 1.18 | MR | 130 | **1.125** | **MR** |
| | EB | 25 | 3 | 1 | 29 | 1.1 | MR | | | |
| | SB | 20 | 6 | 2 | 28 | 1.14 | MR | | | |
| | WB | 30 | 7 | 4 | 41 | 1.09 | MR | | | |

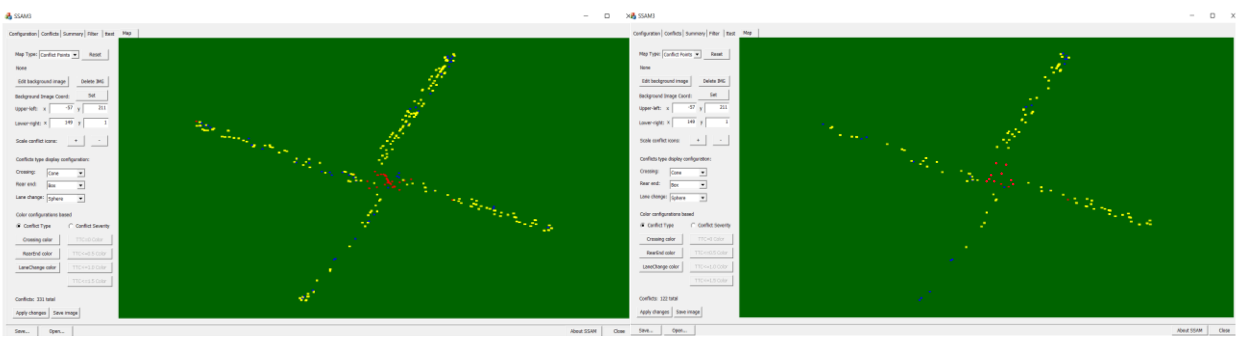


**Figure (4-21) SAAM Conflicts Maps at Al-Jamhori Intersections Before and After Increase Width of Lane Countermeasure**

## 2- Cancel U-turn

One of the reasons for the large number of traffic conflicts the presence of a U-turn at Al-jamhori intersection because one of the causes of collisions at the intersection. One of the solutions to reduce Conflicts points is to cancel the U-turn the vehicles inside the intersection by providing a U-turn outside the intersection, when the procedure is performed the percentage of conflict points reduced 30.9% and the percentage of (TTC) increased 9.6% as shown in Table (4-6).

**Table (4-6) Evaluation Al-jamhori Intersection After Cancel U-Turn Countermeasure**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP}$ | $TTC_{APP\ (sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\ (sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-jamhori | NB | 25 | 5 | 5 | 35 | 1.09 | MR | 144 | 1.085 | MR |
| | EB | 23 | 7 | 4 | 34 | 1.1 | MR | | | |
| | SB | 20 | 5 | 2 | 27 | 1.18 | MR | | | |
| | 28 | 28 | 14 | 6 | 48 | 1.02 | MR | | | |

**3-Increase numbers of lanes**

Increasing the number of lanes reduces conflict points at Al-Jumhouri intersection 38.1% and the percentage of (TTC) increased 10.88% as shown in Table (4-7).

**Table (4-7) Evaluation Al-jamhori Intersection After Increase Numbers of Lanes Countermeasure**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP}$ | $TTC_{APP\ (sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\ (sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-jamhori | NB | 23 | 7 | 4 | 34 | 1.18 | MR | 130 | **1.1** | **MR** |
| | EB | 19 | 4 | 2 | 25 | 1.17 | MR | | | |
| | SB | 30 | 5 | 3 | 38 | 1.2 | MR | | | |
| | WB | 22 | 7 | 4 | 33 | .97 | HR | | | |

**4-Using Protected Left Turn phasing**

Left-turn signal phases facilitate left-turning traffic and improve the safety of the intersection for left-turning vehicles. Therefore, when using the countermeasure, the protected phase, notice that there is a reduction in the percentage of the number of collision points, reached 44.28%, and the percentage of (TTC) increased 10.13%, according to the Table (4-8)

**Table (4-8) Evaluation Al-jamhori Intersection After Using Protected Left Turn Phasing Countermeasure**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP}$ | $TTC_{APP\ (sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\ (sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-jamhori | NB | 9 | 5 | 2 | 16 | 1.02 | MR | 117 | **1.1** | **MR** |
| | EB | 17 | 6 | 1 | 24 | 1.097 | MR | | | |
| | SB | 20 | 7 | 3 | 30 | 1.1 | MR | | | |
| | WB | 30 | 11 | 6 | 47 | 1.11 | MR | | | |

**Table (4-9) SAAM Software Type of Conflicts That Were Filtered Al-jamhori Intersection After Using Protected Left Turn Phasing Countermeasure**

| Summary Group | Total | unclassified | crossing | rear end | lane change |
|---|---|---|---|---|---|
| Unfiltered-All Files | 340 | 0 | 43 | 236 | 61 |
| Filtered-All Files | 117 | 0 | 12 | 76 | 29 |
| Filtered-aljmhori intersection_055.trj | 117 | 0 | 12 | 76 | 29 |

**Table (4-10) Summery Numbers of Conflicts Before and After Countermeasures Al-jamhori Intersection**

| run | Name | Actual conflict by SSAM | | | Type of Countermeasure | Conflicts after countermeasure | | | Reduction conflicts % |
|---|---|---|---|---|---|---|---|---|---|
| | | **C** | **ER** | **LC** | | **C** | **ER** | **LC** | |
| 1 | **jmhori _031.trj** | 27 | 130 | 53 | Increase numbers of lanes | 13 | 94 | 23 | 38.1 |
| 2 | **jmhori _039.trj** | 29 | 127 | 54 | Increase width of lane | 10 | 92 | 23 | 39.61 |
| 3 | **jmhori _038.trj** | 31 | 129 | 54 | Using Protected Left Turn phasing | 12 | 76 | 27 | 44.28 |
| 4 | **jmhori _035.trj** | 30 | 126 | 53 | Cancel U-turn | 17 | 102 | 31 | 30.9 |
| 5 | **jmhori _036.trj** | 28 | 127 | 52 | Improved traffic signal | 9 | 100 | 21 | 37.3 |

#### 4.5.1.2 Suggested Countermeasures for Al-Oruba Intersections

##### 4.5.1.2.1 Field Assessment and SSAM's Assessment

**A- Field Assessment**

According to the field assessment of Al-Oruba intersection, it is classified as high risk through the severity index of the (TTC) as shown in the Table (4-11)

**Table (4-11) Field Conflicts Evaluation at Al-Oruba Intersections Before the Countermeasures**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1}$ (sec) | $ROCR_{APP}$ | $THTC_I$ | $TTC_I$ (sec) | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-Oruba | NB | 20 | 9 | 7 | 36 | 1.03 | MR | 174 | **.911** | **HR** |
| | EB | 16 | 9 | 9 | 34 | .88 | HR | | | |
| | SB | 27 | 18 | 11 | 56 | .94 | HR | | | |
| | WB | 25 | 14 | 9 | 48 | .81 | HR | | | |

**B- SSAM's Assessment Before Countermeasures**

SSAM's assessment of the Al-Oruba intersection, it is classified as high risk through the severity index of TTC as shown in Table (4-12) before the countermeasures.

**Table (4-12) SAAM Conflicts Evaluation at Al-Oruba Intersections before the countermeasures**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1}$ sec | $ROCR_{APP}$ | $THTC_I$ | $TTC_I$ sec | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-Oruba | NB | 23 | 16 | 8 | 47 | .99 | HR | 201 | .98 | HR |
| | EB | 21 | 15 | 9 | 45 | 1.03 | MR | | | |
| | SB | 26 | 20 | 12 | 58 | .94 | HR | | | |
| | WB | 23 | 18 | 10 | 51 | .98 | HR | | | |

**4.5.1.2.2 Evaluation After Countermeasures**

**1-Increasing the Width of The Road**

The countermeasure, increasing the width of the road at Al-Oruba intersection decreased percentage of traffic conflicts 43.3%, and when assessing the severity of the risk, will increases the percentage of TTC 15.63%, as shown in Table (4-13)

**Table (4-13) Evaluation Al-Oruba Intersection After Increase Width of Lane Countermeasure**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APPI}$ | $TTC_{APPI}$ sec | $ROCR_{APP}$ | $THTC_I$ | $TTC_I$ sec | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-Oruba | NB | 19 | 12 | 5 | 36 | 1,15 | MR | 114 | **1.133** | MR |
| | EB | 14 | 8 | 4 | 26 | 1.2 | MR | | | |
| | SB | 19 | 9 | 6 | 34 | 1.14 | MR | | | |
| | WB | 9 | 7 | 2 | 18 | .99 | HR | | | |

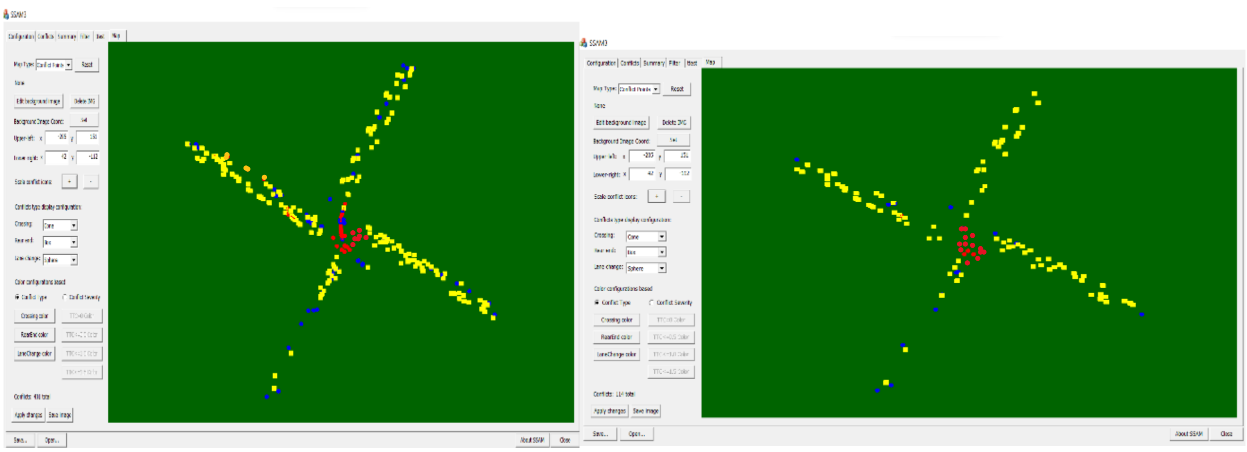


**Figure (4-22) Screenshot Showing the Type of Conflicts That Were Filtered.**

**2-Increase numbers of lanes**

Increasing the number of lanes reduces conflict rates at intersection at Al-Oruba 44.28% and the percentage of (TTC) increased 14.28% as shown in Table (4-14). Figure (4-23) and Figure (4-24) showing evaluation Al-Oruba before and after increase numbers of lanes countermeasure.

## Table (4-14) evaluation Al-Oruba intersection after Increase numbers of lanes countermeasure

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1}$ (sec) | $ROCR_{APP}$ sec | $THTC_{I}$ | $TTC_{I}$ sec (sec) | $ROCR_{I}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-Oruba | NB | 9 | 5 | 2 | 16 | 1.06 | MR | 112 | **1.131** | **MR** |
| | EB | 14 | 7 | 5 | 26 | 1.13 | MR | | | |
| | SB | 23 | 9 | 7 | 39 | 1.13 | MR | | | |
| | WB | 18 | 8 | 5 | 31 | 1.17 | MR | | | |

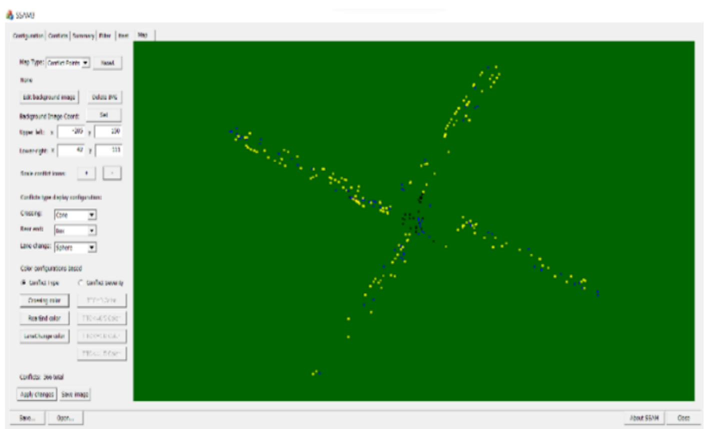


**Figure (4-23) Evaluation Al-Oruba Intersection Before Increase Numbers of Lanes Countermeasure**

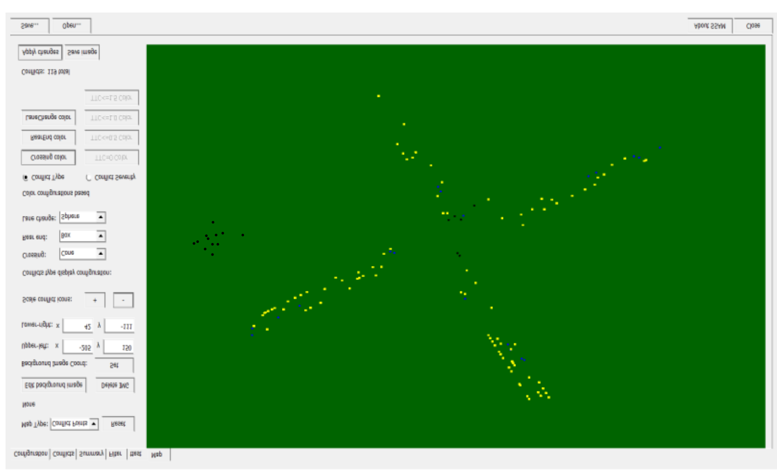


**Figure (4-24) Evaluation Al-Oruba Intersection After Increase Numbers of Lanes Countermeasure**

**3-Using Protected Left Turn phasing**

when using the countermeasure, the protected phase, notice that there is a reduction in the percentage of the number of traffic conflicts, reached 41.8%, and the percentage increasing of TTC reaches 11.92%, according to the Table (4-15)

**Table (4-15) Evaluation Al-Oruba Intersection After Increase Numbers of Lanes Countermeasure**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1\,(sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\,(sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-Oruba | NB | 14 | 4 | 2 | 20 | 1.2 | MR | 117 | **1.097** | **MR** |
| | EB | 19 | 9 | 2 | 30 | 1.19 | MR | | | |
| | SB | 20 | 11 | 3 | 34 | .98 | HR | | | |
| | WB | 20 | 9 | 4 | 33 | 1.07 | MR | | | |

### 4.5.1.3 Al-Fadael Intersection

#### 4.5.1.3.1 Field Assessment and SSAM's Assessment

**A-Field Assessment:** According to the field assessment of the Fadael intersection, it is classified as moderate risk through the severity index of TTC as shown in the Table (4-16) before the countermeasures.

**Table (4-16) Field Evaluation at Al- Fadael Before the Countermeasures**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1(sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\,(sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al- Fadael | NB | 18 | 10 | 6 | 34 | 1.7 | MR | 156 | 1.20 | MR |
| | EB | 24 | 8 | 5 | 37 | 1.2 | MR | | | |
| | SB | 25 | 11 | 2 | 38 | 1.09 | MR | | | |
| | WB | 28 | 17 | 2 | 47 | .96 | HR | | | |

**B- SSAM's Assessment Before Countermeasures**

SSAM's assessment of the Al- Fadael intersection, it is classified as moderate risk through the severity index of TTC as shown in Table (4-17) before the countermeasures.

**Table (4-17) SAAM Conflicts Evaluation at Al- Fadael Intersections Before the Countermeasures**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1\ (sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\ (sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al- Fadael | NB | 25 | 13 | 4 | 42 | 1.20 | MR | 187 | **1.025** | MR |
| | EB | 27 | 15 | 4 | 46 | 1.078 | MR | | | |
| | SB | 31 | 14 | 2 | 47 | .98 | HR | | | |
| | WB | 30 | 19 | 3 | 52 | .88 | HR | | | |

**4.5.1.3.2 Evaluation After Countermeasures**

**1-Increasing the Width of The Road**

the countermeasure, increasing the width of the road at Al- Fadael intersection decreased percentage of conflicts points 36.9%, and when assessing the severity of the risk, will increases the percentage of TTC 12.2%, as shown at Table (4-18)

**Table (4-18) Evaluation Al- Fadael Intersection After Increasing the Width of The Road Countermeasure**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1\ (sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\ (sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al- Fadael | NB | 14 | 7 | 2 | 23 | 1.4 | MR | 118 | **1.15** | MR |
| | EB | 19 | 9 | 3 | 31 | 1.09 | MR | | | |
| | SB | 20 | 6 | 1 | 27 | 1.1 | MR | | | |
| | WB | 23 | 13 | 1 | 37 | 1.085 | MR | | | |

**2-Increase numbers of lanes**

Increasing the number of lanes reduces conflict rates at intersections, at Al-Fadael 45.77% and the percentage of time increased 8.44% as shown in Table (4-19).

**Table (4-19) Evaluation Al- Fadael Intersection After Increase numbers of lanes Countermeasure**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1\ (sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\ (sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al- Fadael | NB | 8 | 5 | 1 | 14 | 1.53 | LR | 101 | **1.11** | MR |
| | EB | 13 | 8 | 1 | 22 | 1.42 | MR | | | |
| | SB | 18 | 9 | 3 | 31 | 1.092 | MR | | | |
| | WB | 27 | 6 | 2 | 23 | 1.12 | MR | | | |

**3-Using Protected Left Turn phasing**

When using the countermeasure, the protected phase, notice that there is a reduction in the percentage of the number of conflicts points, reached 28.34%, and the percentage of (TTC) reached 24%, according to the Table (4-20).

**Table (4-20) Evaluation Al- Fadael Intersection After Using Protected Left Turn Phasing Countermeasure**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1}$ (sec) | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\ (sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al- Fadael | NB | 13 | 6 | 2 | 21 | 1.46 | MR | 134 | **1.27** | MR |
| | EB | 21 | 10 | 4 | 35 | 1.32 | MR | | | |
| | SB | 25 | 10 | 1 | 36 | 1.22 | MR | | | |
| | WB | 27 | 16 | 1 | 42 | 1.18 | MR | | | |

### 4.5.1.4 Al-Nesser Intersection

A major intersection in the of Al-Qadisiya defined by coordinate 32°0'39"N and 44°54'57"E with four directions and four legs approaches have four lanes. Each approach transfers different types of traffic movement such as passenger car unit, heavy vehicle, and buses. The intersection is equipped with a traffic light signal.

#### 4.5.1.4.1 Field Assessment and SSAM's Assessment

**A-Field Assessment**

According to the field assessment and SSAM's assessment of the Al-nesser intersection, it is rated as moderate risk based on the severity index of the (TTC), as indicated in the Table (4-21) before countermeasures.

**Table (4-21) Field Conflicts Evaluation at Al-Nesser Intersections Before the Countermeasures**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1\ (sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\ (sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-nisser | NB | 39 | 17 | 5 | 61 | .82 | HR | 186 | **1.052** | **MR** |
| | EB | 15 | 10 | 2 | 27 | 1.48 | MR | | | |
| | SB | 38 | 26 | 4 | 68 | .85 | HR | | | |
| | WB | 21 | 8 | 1 | 30 | 1.6 | LR | | | |

**B- SSAM's Assessment Before Countermeasures**

SSAM's assessment of Al-nesser intersection, it is classified as moderate risk through the severity index of TTC as shown in the Table (4-22) before the countermeasures.

**Table (4-22) SAAM Conflicts Evaluation at Al-nesser Intersections Before the Countermeasures**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1\ (sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\ (sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-nesser | NB | 47 | 22 | 6 | 75 | .903 | HR | 209 | **1.116** | MR |
| | EB | 20 | 13 | 2 | 35 | 1.52 | LR | | | |
| | SB | 41 | 23 | 3 | 67 | .88 | HR | | | |
| | WB | 20 | 10 | 2 | 32 | 1.67 | LR | | | |

### 4.5.1.4.2 Evaluation After Countermeasures

### 1-Increasing the Width of The Road

When assessing the severity of the risk, the countermeasure of widening the road at the Al-nesser intersection will decrease the percentage of conflicts points 45.93% and raise the percentage of TTC 16.75%, as shown in the Table (4-23)

**Table (4-23) Evaluation Al-nesser Intersection After Increase numbers of lanes Countermeasure**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1\ (sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I(sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-nesser | NB | 25 | 11 | 3 | 39 | 1.02 | MR | 113 | **1.303** | **MR** |
| | EB | 11 | 7 | 1 | 19 | 1.8 | LR | | | |
| | SB | 20 | 16 | 1 | 37 | .99 | HR | | | |
| | WB | 10 | 8 | 0 | 18 | 2.04 | LR | | | |

### 2-Increase numbers of lanes

When using the countermeasure, increase numbers of lanes notice that there is a reduction in the percentage of the number of traffic conflicts, reached 53.11%, and the percentage of TTC reaches 27.2%, according to the Table (4-24)

**Table (4-24) Evaluation Al-nesser Intersection After Increase numbers of lanes Countermeasure**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1(sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I(sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-nesser | NB | 22 | 10 | 3 | 35 | 1.1 | MR | 98 | **1.42** | **MR** |
| | EB | 13 | 4 | 0 | 17 | 2.1 | LR | | | |
| | SB | 20 | 10 | 1 | 31 | 1.14 | MR | | | |
| | WB | 8 | 5 | 2 | 15 | 1.98 | LR | | | |

### 3-Using Protected Left Turn phasing

When using the countermeasure, the protected phase, notice that there is a reduction in the percentage of the number of traffic conflicts, reached to 45%, and the percentage of collision time reaches 12%, according to the Table (4-25).

**Table (4-25) Evaluation Al-nesser Intersection After Using Protected Left Turn Phasing Countermeasure**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1\ (sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\ (sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-nesser | NB | 23 | 13 | 5 | 40 | .99 | HR | 115 | **1.25** | **MR** |
| | EB | 11 | 8 | 2 | 21 | 1.63 | LR | | | |
| | SB | 19 | 15 | 1 | 35 | 1.09 | MR | | | |
| | WB | 11 | 5 | 3 | 19 | 1.68 | LR | | | |

### 4- Cancel U-turn

One of the reasons for the large number of crashes is the presence of a U-turn at Al-nesser intersection because one of the causes of collisions at the intersection. One of the solutions to reduce Conflicts points is to cancel the U-turn the vehicles inside the intersection by providing a U-turn outside the intersection, when the procedure is performed the percentage of conflicts points reduced 21.5% and the percentage TTC increased 9.36% as shown at Table (4-26)

**Table (4-26) evaluation Al-nesser intersection after Cancel U-turn countermeasure**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1\ (sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I(sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-nesser | NB | 40 | 11 | 2 | 53 | .98 | HR | 164 | **1.22** | MR |
| | EB | 20 | 9 | 1 | 30 | 1.61 | LR | | | |
| | SB | 35 | 17 | 0 | 52 | .94 | HR | | | |
| | WB | 21 | 7 | 1 | 29 | 1.76 | LR | | | |

## 4.5.2 Traffic Signal Timing Optimization

### 4.5.2.1 Field Traffic Signal Timing Optimization

For a long time, fixed time traffic signals have been utilized to control traffic in ad diwaniya City. Unfortunately, rather than using traffic engineering knowledge, traffic cops timed these signals based only on random judgment. As a result, they lost their ability to perform the function effectively and efficiently. As a result, this study assumed that the selected intersection had four phase signals (each approach with one phase) and used the maximum actual green time.

VISSIM contains several optimization types. It optimizes cycle durations, phase sequences, and split timings to reduce delay and stop time.

By Webster Equation made the length of the cycle optimal as a function of the critical flow ratios and lost times. The Webster Equation is considered as the basis for the design of many design brochures. The results of Webster's equation are displayed.

Calculations The Webster method is used for Signal design **(Salim et al.,2019)**

The optimum signal cycle is given $C_0 = (1.5\ L + 5) / 1\text{-}Y$ (4-1)

Where,

Co = optimum cycle time in seconds

L = total lost time

$Y = y_1 + y_2 + y_3 + \ldots\ldots\ldots\ldots\ldots + y_n$ (4-2)

$y_1, y_2, y_3 \ldots. y_n$ are the ratios of flow to saturation flow.

$y_i = q_i / S_i$ (4-3)

Where, q = total flow in pcu/hr

S = saturation flow

Max. Flow Ratio $Y = Y_1 + Y_2 + Y_3$ (4-4)

Yellow=3 sec No. of phases, n=4

The Tables below show Traffic signal timing optimization using the Webster method at Al- Fadael Intersection. Details at appendixes (C)

**Table (4-27) Actual Volume at Al- Fadael Intersection**

| From | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1<br>(WB) | 0 | 376<br>Right | 519<br>Through | 502<br>Left |
| 2<br>(SB) | 405<br>Left | 0 | 475<br>Right | 527<br>Through |
| 3<br>(EB) | 398<br>Through | 551<br>Left | 0 | 438<br>Right |
| 4<br>(NB) | 411<br>Right | 454<br>Through | 567<br>Left | 0 |

$$PHF = \frac{\text{Hourly volume}}{\text{Peak rate of flow within the hour}}$$ **(Salim et al.,2019)** ( (4-5)

$$PHF = V / \left[4 \times V_{15}\right]$$ (4-6)

V = peak-hour volume (vph)

$V_{15}$ = volume during the peak 15 minutes of flow (veh /15 minutes)

**Table (4-28) PHF Values Calculation at Al- Fadael Intersection**

| | Left | Through | Right |
|---|---|---|---|
| 1-(WB) | .95 | .901 | .83 |
| 2-(SB) | .946 | .91 | .92 |
| 3-(EB) | .937 | .88 | .912 |
| 4-(NB) | .941 | .93 | .85 |

**Table (4-29) The Results of DHV Values Calculation at Al- Fadael Intersection**

| For | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| **1**<br>**(WB)** | 0 | 480<br>Right | 611<br>Through | 561<br>Left |
| **2**<br>**(SB)** | 459<br>Left | 0 | 558<br>Right | 626<br>Through |
| **3**<br>**(EB)** | 503<br>Through | 654<br>Left | 0 | 535<br>Right |
| **4**<br>**(NB)** | 533<br>Right | 538<br>Through | 615<br>Left | 0 |

For example, the calculations of west approach (1) are done as follow:

RT

376/0.83=453

453- (0.051*453) +(0.0531*453*2.2) =480

**Table (4-30) (Vi, Si and Yi) Values Calculations for Each Phase at Al- Fadael Intersection**

| | **WB** | | | **EB** | | | **SB** | | | **NB** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **LT.** | **Th.** | **RT.** | **LT.** | **Th.** | **RT.** | **LT.** | **Th.** | **RT.** | **LT.** | **Th.** | **RT.** |
| ***Vi*** | 561 | 611 | 480 | 654 | 503 | 535 | 459 | 626 | 558 | 615 | 538 | 533 |
| ***Si*** | 2940 | 2940 | 2940 | 2940 | 2940 | 2940 | 2442 | 2442 | 2442 | 2442 | 2442 | 2442 |
| ***Vi/Si*** | 0.2 | 0.2 | 0.2 | 0.3 | 0.19 | 0.06 | 0.03 | - | 0.07 | 0.18 | - | 0.105 |
| ***Yi*** | 0.207 | | | 0.222 | | | 0.256 | | | 0.252 | | |

Yi=.937

$C_o$ = ((1.5*8) +5)/ (1-.937) ≈95

$G_1 = Y_1$*(Co-L)/Y = 0. 207*(95-8)/0. 937= 20 sec

$G_2 = Y_2$*(Co-L)/Y = 0.2 22*(95-8)/0. 937=20 sec

$G_3 = Y_3$*(Co-L)/Y 0.2 56*(95-8)/0. 937= 24 sec

$G_4 = Y_4$*(Co-L)/Y = 0.2 52*(95-8)/0. 937= 24 sec

### 4.5.2.2 Evaluation after Traffic Signal Timing Optimization

**1- Al- Fadael intersection.**

**A- Field Evaluation after Traffic Signal Timing Optimization**

According to retiming the cycle length at Al- Fadael intersection, field traffic signal timing optimization reduced the traffic conflicts 23.94% while the percentage of TTC increased 10.8%, as shown in Table (4-31)

**Table (4-31) Field Evaluation Al- Fadael Intersection After Traffic Signal Timing Optimization**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1\ (sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\ (sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| **Al- Fadael** | NB | 17 | 7 | 4 | 28 | 1.82 | LR | 119 | **1.33** | **MR** |
| | EB | 20 | 10 | 2 | 32 | 1.309 | MR | | | |
| | SB | 20 | 8 | 1 | 29 | 1.08 | MR | | | |
| | WB | 18 | 10 | 2 | 30 | 1.09 | MR | | | |

**B- SSAM’s Evaluation after Traffic Signal Timing Optimization**

According SSAM’s assessment after retiming the cycle length at Al- Fadael intersection, traffic signal timing optimization reduced the traffic conflicts 28.84% while the percentage of TTC increased 19.8%, as shown in Table (4-32)

**Table (4-32) SSAM Evaluation Al- Fadael Intersection After Traffic Signal Timing Optimization**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1\ (sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\ (sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| **Al- Fadael** | NB | 20 | 8 | 4 | 32 | 1.3 | MR | 133 | 1.22 | HR |
| | EB | 21 | 11 | 2 | 34 | 1.30 | MR | | | |
| | SB | 23 | 9 | 2 | 34 | 1.19 | MR | | | |
| | WB | 19 | 13 | 1 | 33 | 1.1 | MR | | | |

## 2- Al-Oruba

### A- Field Evaluation after Traffic Signal Timing Optimization

According to retiming the cycle length at Al-Oruba intersection, field traffic signal timing optimization reduced the traffic conflicts 25.3% while the percentage of TTC increased 18.5%, as shown in Table (4-33)

**Table (4-33) Field Evaluation Al-Oruba Intersection After Traffic Signal Timing Optimization**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1\ (sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\ (sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-Oruba | NB | 17 | 6 | 6 | 29 | 1.2 | MR | 130 | 1.08 | HR |
| | EB | 13 | 5 | 5 | 23 | 1.03 | MR | | | |
| | SB | 22 | 13 | 5 | 40 | .99 | HR | | | |
| | WB | 17 | 15 | 6 | 38 | 1.1 | MR | | | |

**B- SSAM's Evaluation after Traffic Signal Timing Optimization**

According SSAM's assessment after retiming the cycle length at Al-Oruba intersection, traffic signal timing optimization reduced the traffic conflicts 29.9% while the percentage of TTC increased 10.2%, as shown in Table (4-34)

**Table (4-34) SSAM Evaluation Al-Oruba Intersection After Traffic Signal Timing Optimization**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1\ (sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\ (sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-Oruba | NB | 22 | 7 | 4 | 33 | 1.1 | MR | 131 | **1.08** | **HR** |
| | EB | 11 | 7 | 5 | 23 | 1.08 | MR | | | |
| | SB | 20 | 12 | 6 | 38 | 1.02 | MR | | | |
| | WB | 19 | 14 | 4 | 37 | 1.13 | MR | | | |

## 3- Al-jamhori Intersection

**A- Field Evaluation after Traffic Signal Timing Optimization**

According to retiming the cycle length at Al-jamhori intersection, field traffic signal timing optimization reduced the traffic conflicts 36,7% while the percentage of TTC increased 28.7%, as shown in Table (4-35)

**Table (4-35) Field Evaluation Al-jamhori Intersection After Traffic Signal Timing Optimization**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1\,(sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\,(sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-jamhori | NB | 19 | 8 | 3 | 30 | 1.17 | MR | 119 | **1.22** | **HR** |
| | EB | 16 | 10 | 3 | 29 | 1.3 | MR | | | |
| | SB | 20 | 5 | 2 | 27 | 1.23 | MR | | | |
| | WB | 20 | 9 | 4 | 33 | 1.2 | MR | | | |

## B- SSAM's Evaluation after Traffic Signal Timing Optimization

SSAM's assessment According to retiming the cycle length at Al-jamhori intersection, traffic signal timing optimization reduced the traffic conflicts 32.4% while the percentage of TTC increased 23%, as shown in Table (4-36)

**Table (4-36) SSAM Evaluation Al-jamhori Intersection After Traffic Signal Timing Optimization**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1\,(sec)}$ | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\,(sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-jamhori | NB | 21 | 8 | 2 | 31 | 1.17 | MR | 127 | **1.22** | **HR** |
| | EB | 17 | 11 | 3 | 31 | 1.3 | MR | | | |
| | SB | 19 | 4 | 2 | 25 | 1.23 | MR | | | |
| | WB | 23 | 10 | 6 | 39 | 1.2 | MR | | | |

## 4- Al-Nesser

### A- Field Evaluation after Traffic Signal Timing Optimization

According to retiming the cycle length at Al-nesser intersection, field traffic signal timing optimization reduced the traffic conflicts 13% while the percentage of TTC increased 32.8%, as shown in Table (4-37)

**Table (4-37) Field Evaluation Al-Nesser Intersection After Traffic Signal Timing Optimization**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1\ (sec)}$ | $ROCR_{APP}$ | $THTC_{I}$ | $TTC_{I\ (sec)}$ | $ROCR_{I}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-Nesser | NB | 32 | 13 | 2 | 47 | 1.04 | MR | 162 | **1.37** | MR |
| | EB | 22 | 9 | 2 | 33 | 1.37 | MR | | | |
| | SB | 26 | 17 | 1 | 48 | .98 | HR | | | |
| | WB | 11 | 11 | 2 | 34 | 1.72 | LR | | | |

### B- SSAM's Evaluation after Traffic Signal Timing Optimization

SSAM's assessment According to retiming the cycle length at Al-Nesser intersection, traffic signal timing optimization reduced the traffic conflicts 22.4% while the percentage of TTC increased 22.8%, as shown in Table (4-38)

**Table (4-38) SSAM Evaluation Al-Nesser Intersection After Traffic Signal Timing Optimization**

| Intersection | Approach | (No. of Conflict/ hr.) / App. | | | $THTC_{APP1}$ | $TTC_{APP1}$ (sec) | $ROCR_{APP}$ | $THTC_I$ | $TTC_{I\,(sec)}$ | $ROCR_I$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RE | LC | C | | | | | | |
| Al-Nesser | NB | 32 | 13 | 2 | 47 | 1.04 | HR | 162 | **1.37** | MR |
| | EB | 22 | 9 | 2 | 33 | 1.37 | LR | | | |
| | SB | 26 | 17 | 1 | 48 | .98 | HR | | | |
| | WB | 11 | 11 | 2 | 34 | 1.72 | LR | | | |

Simulation of traffic signal timing optimization as a countermeasure reveal that the total traffic conflicts can be reduced (23, 29.9, 28.84, 32.8)% at Al-jamhori, Al-Oruba, Al- Fadael and AL-nesser intersections respectively, while field observation for traffic signal timing optimization shows that the total traffic conflicts can be reduced (36,7, 25.3, 23.94, 13) % at Al-jamhori, Al- Oruba, Al- Fadael and AL-nesser intersections respectively.

Hence, it can be concluded that in general simulation process overestimate total traffic conflicts. Table (4-39) shows the summary of results field and simulation of traffic signal timing optimization as a countermeasure.

**Table (4-39) Summary of results field and simulation After traffic signal timing optimization as a countermeasure.**

| Intersection | Traffic Signal Timing Optimization % | |
|---|---|---|
| | Simulation Optimization | Field Optimization |
| Al-Jamhori | 23 | 36.7 |
| Al-Oruba | 29.9 | 25.3 |
| Al- Fadael | 28.84 | 23.94 |
| Al-Nesser | 32.8 | 13 |

After traffic signal timing optimization necessary to validate simulation by comparing actual conflict and simulated conflict in order to determine the degree of correlation between the simulation approach and the field approach and to support the capacity of the (VISSIM &SSAM) model. Pearson correlation coefficient (PCC) was used for validation of the conflicts extracted from SSAM by calculating the correlation between the field and simulated conflicts. According to Table (4-40) and Table (4-41) the linear regression results at Al- Fadael indicating that number of simulated conflicts is significantly correlated with the number of observed conflicts. with $R^2$ value was .938, which indicates that 93.8% of the variation in observed conflicts can be explained by the variation in simulated conflicts. Details at (G) and (H)

**Table (4-40) Correlation between Simulation and Field Conflicts After Traffic signal timing optimization**

| Correlations | | | |
|---|---|---|---|
| | | OB. T | SIM.T |
| Pearson Correlation | OB. T | 1.000 | .962 |
| | SIM. T | .962 | 1.000 |
| Sig. (1-tailed) | OB. T | . | .019 |
| | SIM. T | .019 | . |
| N | OB. T | 4 | 4 |
| | SIM. T | 4 | 4 |
| OB: Observed, SIM: Simulated | | | |

**Table (4-41) Statistical Description of Correlation between Simulation and Field Conflicts at Al- Fadael Intersection After Traffic signal timing optimization**

| Model Summary[b] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics | | | | |
| | | | | | R Square Change | F Change | df1 | df2 | Sig. F Change |
| 1 | .968[a] | .938 | .906 | .58554 | .938 | 30.083 | 1 | 2 | .032 |
| a. OBSEVED | | | | | | | | | |
| b.: SIMULATED | | | | | | | | | |

Most of the results agreed with Table (2-2) and Table (2-3) of previous studies. Some of the results were less than what are found in the Tables for reasons including the difference in the conditions of the study sites and some of the problems that the selected intersections suffer from, such as an increase in the of traffic volumes over the design volumes of the intersections and non-compliance with the laws, as well as not taking into account the effects of pedestrians on the intersections. Table (4-42) shows the summary results of the countermeasures at the selected intersections.

**Table (4-42) Summary of Type Countermeasures and Percentage Reduction Hourly Traffic Conflict After Applied the Estimated Countermeasure at The Selected Intersections**.

| intersection | Type of countermeasures and reduction % | | | |
|---|---|---|---|---|
| | Increase lane widths | Increase numbers of lanes | Add left turn phasing | Cancel U-turn |
| Al-jamhori | 39.66 | 38.1 | 44.28 | 30.9 |
| Al-Oruba | 43.3 | 44.28 | 41.8 | / |
| Al- Fadael | 36.9 | 45.77 | 28.34 | / |
| Al-nesser | 45.93 | 53.11 | 45 | 21.5 |

From the Table above for most the results of the countermeasures are agrees with reported of previous studies at Table (2-2) and Table (2-3).

### 4.6 Calibrating VISSIM Simulation Model

Calibration is the process in which various parameters of the simulation model are adjusted till the model accurately represents field conditions to get an understanding about the level of calibration needed. Driving behavior parameters consist of default values that allow users to change their scope in line with the conditions of the site to be studied. Since the drivers' behavior differs greatly from geographical location to another, therefore, the default values for driving behavior parameters seldom match the domestic traffic characteristics and conditions of traffic for a specific zone **(Siddharth, & Ramadurai, 2013). (Park et al. 2006**) used travel time and queue length as the calibration measures, where the difference with the obtained and simulated values were compared. In another calibration study, saturation flow rate and queue discharge headway were used for the calibration measures in obtaining optimum values for calibrated parameters. Further to this, minimizing the error between observed and simulated queue length has been considered as the objective functions, in most of the research due to the simplicity and practicality of obtaining data (Siddharth, & Ramadurai,2013). In calibration processes, most of the researches first target to obtain the discrepancy between the simulated results and the field results by using the default parameters in VISSIM **(Arafat et al. 2020**) Thus, the default parameter values should be calibrated as shown in the Table (4-43) to obtain a simulation that represents the real world as closely as possible.

**Table (4-43) Parameters Selected for the Calibration of the Simulation Model**

| Parameter | Definition | Range | Calibrated value |
|---|---|---|---|
| Average standstill distance | The average desired distance between stopped cars | (1-3) m | .9-1.2 |
| Lock ahead distance | Max & Min forward distance that the vehicle driver can see within the same link. | (0 Min.- 250Max) m | 27-100 |
| Lock back distance | Max & Min back distance that the vehicle driver can see in order that reacts to other vehicles behind- within the same link. | (0 Min.- 150Max) m | 2-12 |
| Driving behavior on adjacent lanes distance | The minimum distance between adjacent vehicles when vehicles are approaching the stop line. | - | 1.10 |
| Car following Model | Models of how vehicles behave within the network.<br>- No interaction<br>- Wiedemann 74<br>- Wiedemann 99 | NO<br>W 99<br>W74 | W 74 |

The calibrated models are then validated with a new data set under untested conditions, including input volumes, traffic compositions, and other necessary data.

The Geoffrey E. Heaver (GEH) statistic is used to compare field traffic volumes with simulation data. As a basic general principle for calibration and validation, GEH Less than 5 values indicate an acceptable **(Laureshyn & Várhelyi, 2018).** For confirmation, several simulations with varied parameters are done. Table (4-44) reveals that at al-Oruba intersection the microscopic model's GEH value is 18.888 before calibration, while GEH value is 2.62 after calibration as shown in Table (4-45) indicating that it is adequately calibrated and accurately depicts the field traffic condition. Figure (4-25) and Figure (4-26) also illustrates the least amount of difference between the actual and validated flows, details in Appendix D

**Table (4-44) GEH Values of Al-Oruba Intersection Before Calibration**

| | Actual | Simulation | Actual-Simulation difference | % Difference | GEH |
|---|---|---|---|---|---|
| NB | 1444 | 1289 | 155 | 10.73 | 4.2 |
| EB | 1529 | 1780 | -251 | -16.41 | 6.1 |
| SB | 1503 | 1310 | 193 | 12.8 | 5.14 |
| WB | 1554 | 1421 | 133 | 8.55 | 3.448 |
| SUM | | | | 15.67 | 18.888 |

**GEH;** The Geoffrey E. Heaver statistic

**Table (4-45) GEH Values of Al-Oruba Intersection After Calibration**

| Approach | Actual | Simulation | Actual-Simulation difference | % Difference | GEH |
|---|---|---|---|---|---|
| NB | 1444 | 1425 | 19 | 1.3 | .5 |
| EB | 1529 | 1551 | -22 | -1.43 | .56 |
| SB | 1503 | 1522 | -19 | -1.26 | .488 |
| WB | 1554 | 1511 | 43 | 2.7 | 1.098 |
| SUM | | | | 1.34 | 2.65 |

Tables (D) presents the results of GEH for Aljamhori, Al-Oruba and Al-nesser intersections trj file, respectively.

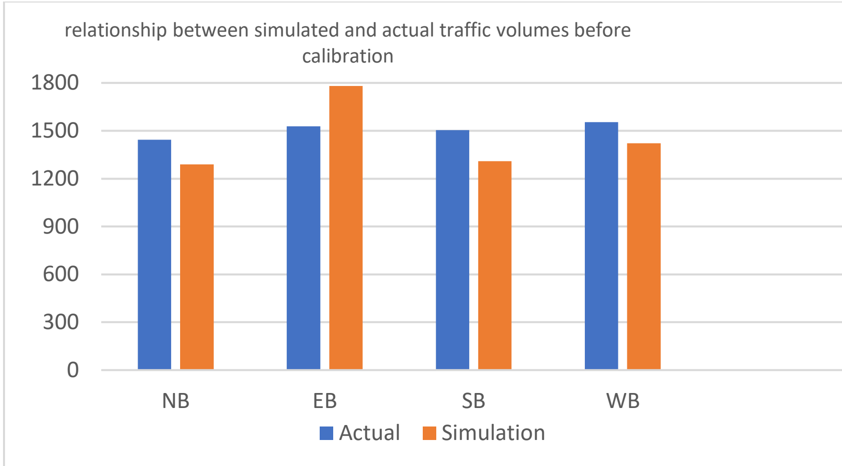



**Figure (4-25) The Difference of Number of Discharged Vehicles Between Actual Field and VISSIM Model at Al-Oruba Intersection before Calibration**

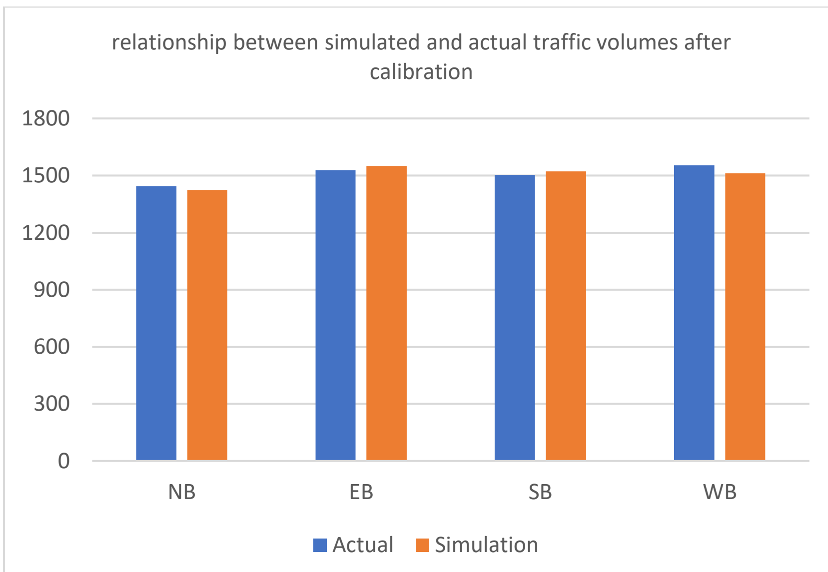



**Figure (4-26): -The Difference of Number of Discharged Vehicles Between Actual Field and VISSIM Model at Al-Oruba Intersection after Calibration**

## 4.7 Validation of Observed and Simulated of VISSIM Model.

After confirming the success of the model calibration, the complete validity of the model to simulate the real network is confirmed. This is done by placing special counters in the model at the same points whose values were measured on site and compared. The observed queue length at the practical site was compared to the queue length obtained using the VISSIM traffic micro simulation software for profiling validation. The mean percentage error obtained was 11.6% at Al-Oruba Intersection as shown in Table (4-46).

**Table (4-46) Observed and VISSIM Queue Length (M) At Al-Oruba Intersection After Calibration**

| approach | Queue Length (m) | | % Error |
|---|---|---|---|
| | Observed | VISSIM | |
| NB | 140 | 130.45 | 7 |
| EB | 147 | 145.44 | 1.6 |
| SB | 135 | 139.15 | -3 |
| WB | 127 | 123.85 | 3 |
| | | Sum % Error | 11.6 |

Based on the mean percentage values obtained for the intersections considered, the error obtained for all the intersections were less than acceptable values according to literature should be less than 22% [110]. Therefore, this successfully validates the values for calibrated parameters.

## 4.8 Validation of Observed and Simulated Traffic Conflicts

The effect of the calibration procedure on the goodness of the safety assessment, the extent of the correlation between the simulation approach and the field approach and substantiate the capability of the (VISSIM &SSAM) models to produce a surrogate approach that is symmetric with the real, it requires validation of simulation has been performed by compared with observed conflict. According to the linear regression results at Al-Oruba, it is found that the p-value of independent variable is 0.011 indicating that number of simulated conflicts is significantly correlated with the number of observed conflicts. In addition, the $R^2$ value for the model was 0.954, which means that 95.4% of the variability in the observed conflicts can be explained by the variation in the simulated conflicts. Table (4-47) shows all types of conflicts (crossing, lane-change, and rear end) as well as clarified two simulation scenarios, which are the default and after calibration.

**Table (4-47) Numbers All Types of Conflicts for Both Observed and Simulated Before and After Calibration**

| Inter-section | App. | Crossing Conflicts | | | Rear-end Conflicts | | | Lane-change Conflicts | | | Total Conflicts | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ob. | $Si^{a.}$ | $Si^{b}$. | Ob. | $Si^{a}$. | $Si^{b}$. | Ob. | $Si.^{a}$ | $Si^{b}$. | Ob. | $Si.^{a}$ | $Si^{b}$. |
| Al-jamhori | NB | 5 | 9 | 8 | 30 | 39 | 33 | 13 | 9 | 11 | 48 | 57 | 52 |
| | EB | 6 | 8 | 7 | 31 | 41 | 34 | 17 | 24 | 14 | 54 | 73 | 55 |
| | SB | 4 | 7 | 4 | 19 | 35 | 23 | 7 | 14 | 9 | 32 | 56 | 36 |
| | WB | 8 | 7 | 10 | 40 | 27 | 38 | 15 | 19 | 19 | 63 | 53 | 67 |
| Al-Oroba | NB | 7 | 8 | 8 | 25 | 42 | 23 | 9 | 20 | 16 | 41 | 70 | 47 |
| | EB | 9 | 13 | 9 | 29 | 36 | 21 | 9 | 19 | 15 | 47 | 68 | 45 |
| | SB | 11 | 9 | 12 | 33 | 47 | 26 | 18 | 23 | 20 | 62 | 79 | 58 |
| | WB | 9 | 11 | 10 | 37 | 51 | 23 | 14 | 13 | 18 | 60 | 75 | 51 |
| Al-Fadael | NB | 4 | 3 | 4 | 20 | 30 | 25 | 9 | 13 | 13 | 33 | 46 | 42 |
| | EB | 4 | 6 | 4 | 25 | 26 | 27 | 11 | 17 | 15 | 40 | 49 | 46 |
| | SB | 1 | 2 | 2 | 25 | 32 | 31 | 11 | 13 | 14 | 37 | 47 | 47 |
| | WB | 2 | 3 | 3 | 37 | 34 | 30 | 17 | 21 | 19 | 56 | 58 | 52 |
| Al-nisser | NB | 5 | 7 | 6 | 41 | 52 | 47 | 23 | 25 | 22 | 75 | 84 | 69 |
| | EB | 2 | 3 | 2 | 20 | 31 | 20 | 11 | 14 | 13 | 35 | 47 | 33 |
| | SB | 4 | 3 | 3 | 36 | 40 | 41 | 25 | 19 | 23 | 67 | 62 | 65 |
| | WB | 1 | 2 | 2 | 18 | 30 | 20 | 10 | 17 | 10 | 32 | 42 | 29 |

**Ob./** Observed conflicts.
**$Si^a$./** Simulated conflicts extracted from VISSIM simulation models before calibrated.
**$Si^b$./** Simulated conflicts extracted from calibrated VISSIM simulation models.

The results indicate that calibration process decreased the Mean Absolute Prevent Error (MAPE) and enhanced compatibility between observed and simulated.

The values are calculated based on equations [111].

$$\text{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{c_s^i - c_f^i}{c_f^i}\right| \qquad (4\text{-}7)$$

Where:

n= The observations number.

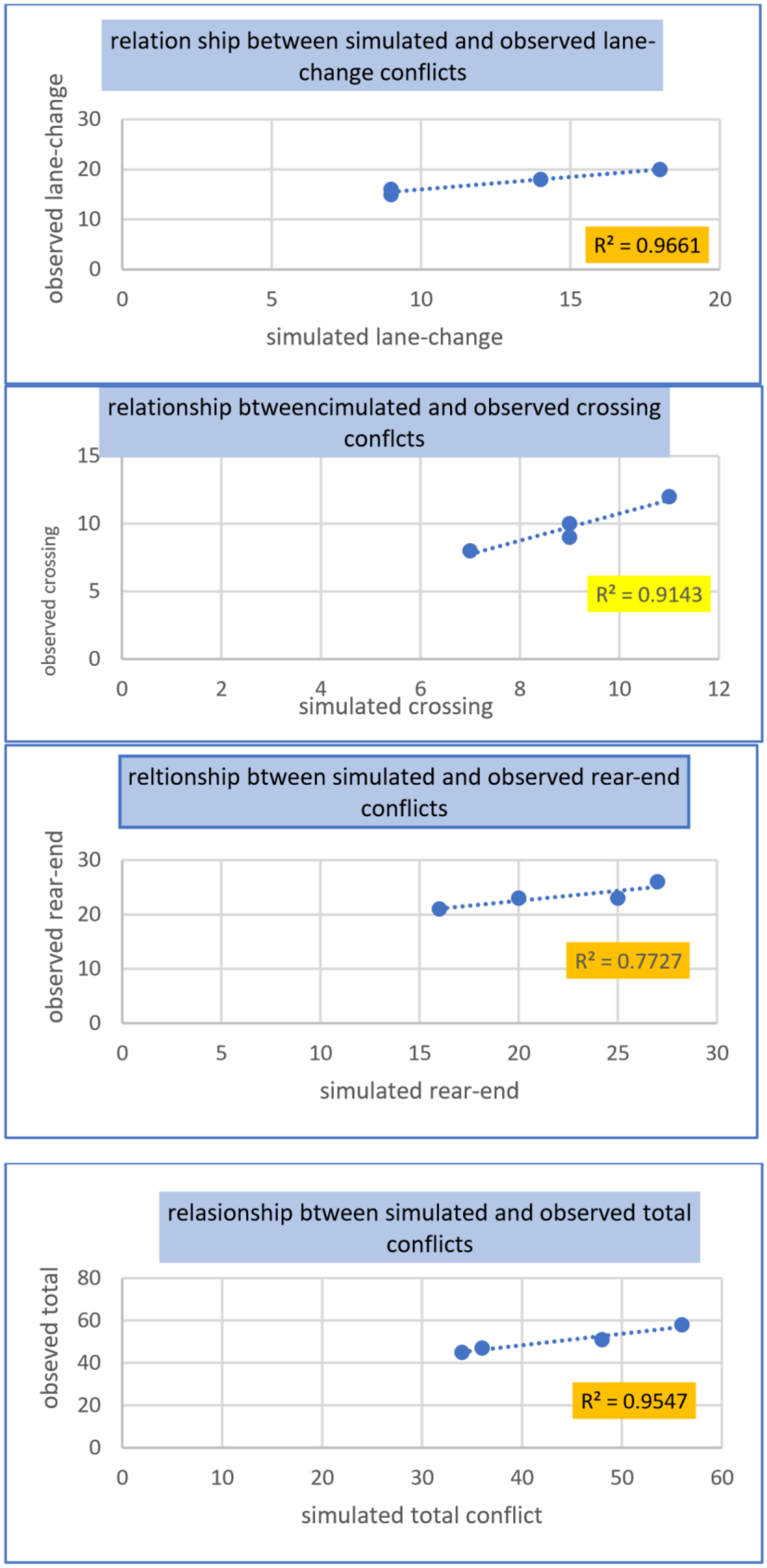
$c_s^i$=The simulated conflicts number at time interval i.

$c_f^i$=The field observed conflicts number at time interval i.

MAPE values were reduced from 43% to 24% for the rear-end conflicts, from 25% to 9% for the crossing conflicts, from 71.9% to 45.6% for the crossing conflicts and from 41.9% to 10.6% for the total conflicts. Table (4-48) show the linear relationship between the two approaches conflicts at al-oruba intersection after calibration. conducting along with the observed conflicts for ranged from strong with the lowest correlation coefficient (0.773) for rear-end conflicts, strong for crossing conflicts and lane changes, with two correlation coefficient values (0.914 and 0.966) respectively. Followed by total conflicts with the highest correlation (0.954) that classified strong correlation. details in Appendix (H)

**Table (4-48) Statistical Description of Correlation between Simulation and Field Conflicts at Al-Oruba Intersection After Calibration**

| Model Summary[b] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics | | | | |
| | | | | | R Square Change | F Change | df1 | df2 | Sig. F Change |
| 1 | .977[a] | .955 | .932 | 2.70583 | .955 | 42.117 | 1 | 2 | .023 |
| a. simulated | | | | | | | | | |
| b.observed | | | | | | | | | |




**Figure( 4-27) Relationship between Simulated and Observed Conflict**

# Chapter Five
# Conclusions and Recommendations

# CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Conclusions

1-Rear-end conflicts at the intersections represented the highest percentage among the conflict's points reached (62%46%, 60%,61%), of the total traffic conflicts at Al-Jamhori , Al-Oruba, Al-Fadael and Al-Nesser Intersections respectively, while the crossing conflicts was the lowest reached (12%,20%,7%and6.4% ) of the total conflicts at Al- Jamhori, Al-Oruba ,Al-Fadael and Al-Nesser Intersections respectively

2- Al-Jamhori and Al-Oruba intersections were classified as high-risk intersections that TTC (0.992, 0.98) s respectively, while Al-Fadael and intersections and Alnesser were classified as a moderate risk intersection that TTC (1.025, 1.116) s respectively.

3-Retiming the cycle length at Al-Jamhori intersection reduced the traffic conflicts 38%, while Al-Oruba and Al-Fadael intersections 27%,30% respectively

4-Increasing the road width reduced the rates of conflict at the intersections of Al-Jamhori, Al-Oruba, Al-Fadael and Al-Nesser respectively 40%,44%, 39% and 46% respectively

5-The removal of U-turn at Al-Jamhori intersection reduced the proportion of the conflict to 31% and (TTC=1.09) sec while the removal of U-turn at Al-Nesser intersection reduced the proportion of the conflict to 22% and the percentage of TTC increased 10%

6-Increasing the number of lanes reduces conflict rates at intersections, at Al-Jamhori 38%, while Al-Oruba, Al-Fadael and Al-Nesser intersections to 45%, 46% and 27%respectively

7-Before making countermeasures the severity of the conflicts at Al-Jamhori intersection and Al-Oruba (TTC=0.992,.984) sec respectively as a high-risk collision. As Al-Fadael intersection (TTC=1.03 sec), it is classified as moderate risk.

After using the countermeasures, the severity of the conflicts at Al-Jamhori intersection, Al-Oruba and Al-Fadael intersection are classified as moderate risk.

8-lowest percentage of traffic conflict reduction was the elimination of U-turn, where the percentage was reduced to 22% at Al-Nesser intersection while the highest percentage was 53% increasing the number of lanes at Al-Nesser intersection

9- The results indicate that calibration process decreased the (MAPE) and enhanced compatibility between observed and simulated.

10- MAPE values were reduced from 43% to 24% for the rear-end conflicts, from 25% to 9% for the crossing conflicts, from 72% to 46% for the crossing conflicts and from 42% to 11% for the total traffic conflicts.

11- according to validation test it was found Pearson correlation coefficient (PCC) between observed conflicts and simulated conflicts were (0.84, 0.773, 0.71 and 0.94) for rear-end conflicts, (0.71,0.7,0.96,0.84) for lane changes,(0.96, 0.914, 0.85and 0.901) and (0.97,0.954,0.941,0. and 0.908) for total traffic conflicts at Al- jamhori, Al-Oruba, Al-Fadael and Al-Nesser respectively.

12- Simulation of traffic signal timing optimization as a countermeasure reveal that the total traffic conflicts can be reduced (23, 29.9, 28.84, 32.8)% at Al-Jamhori, Al-Oruba, Al- Fadael and AL-Nesser intersections respectively, while field observation for traffic signal timing optimization shows that the total traffic conflicts can be reduced (36,7, 25.3, 23.94, 13) % at Al-jamhori, Al- Oruba, Al- Fadael and AL-Nesser intersections respectively.

## 5.2 Recommendations

1-A study of the effect of pedestrians on safety at intersections using VISSIM and SSAM software's, where the study focused on the impact of vehicles on each other on safety at intersections.

2-Periodic maintenance of road networks, including intersections, to find out the problems they suffer from, to fix them and to make the roads safer

3-Emphasizing the implementation of the traffic law and educating users to abide by it

4-Reconsidering the design of traffic lights as a result of the increase in traffic loads and designing them according to accurate scientific methods by using programs such as SSAM and other specialized programs

5-The study showed that there is an urgent need to develop the existing intersections in the city of Diwaniyah

## 5.3Future Recommendations

1-Use other software's such as SIDRA and SINGRO with SSAM and VISSIM to compare between software's and obtain results of higher accuracy and reliability

2-The use of the SSAM and VISSIM software in other traffic facilities to assess safety in the various road network in the city of Diwaniyah, as well as their use at unsignalized intersections, as well as the roundabouts in the governorate.

3-Evaluating intersections through other parameters in addition to traffic conflicts such as travel time, queue length, delay time, as well as studying engineering characteristics on safety at intersections and proposing countermeasures to reduce congestion at intersections and delay time.

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# Appendices

# Appendix (A)

## Tables, Figures and Data Related to Traffic Safety in Iraq

**Table(A-1) The number of recorded traffic accidents by governorate and the nature of the accident for the year 2020**

| Governorate | Total | Type of accident | | | |
|---|---|---|---|---|---|
| | | Others | Run over | Overturn | Crash |
| Nineveh | 232 | 0 | 142 | 21 | 69 |
| salah - Alden | 228 | 0 | 89 | 36 | 103 |
| Kirkuk | 259 | 0 | 96 | 35 | 128 |
| Diala | 631 | 50 | 167 | 51 | 363 |
| Al - Anbar | 416 | 0 | 43 | 44 | 329 |
| Baghdad | 871 | 0 | 488 | 37 | 346 |
| Babylon | 830 | 0 | 233 | 107 | 490 |
| Kerbela | 409 | 0 | 191 | 14 | 204 |
| Najaf | 778 | 0 | 316 | 38 | 424 |
| Qadisiya | 587 | 31 | 135 | 54 | 367 |
| Muthanna | 341 | 0 | 95 | 38 | 208 |
| Thi - Qar | 575 | 0 | 159 | 84 | 332 |
| Wasit | 708 | 0 | 200 | 139 | 369 |
| Missan | 298 | 15 | 106 | 38 | 139 |
| Basra | 1,023 | 0 | 333 | 37 | 653 |
| Total | 8,186 | 96 | 2,793 | 773 | 4,524 |

**Table(A-2) The number of recorded traffic accidents by accident type and governorate and the danger of accident for the year 2020**

| severity of the accident | Total | Type of accident | | | |
|---|---|---|---|---|---|
| | | Others | Run over | Overturn | Crash |
| Deadly | 91 | 1 | 32 | 14 | 44 |
| Death with injury | 29 | 0 | 3 | 1 | 25 |
| Injuries only | 423 | 24 | 95 | 36 | 268 |
| Non | 44 | 6 | 5 | 3 | 30 |
| Total | 587 | 31 | 135 | 54 | 367 |

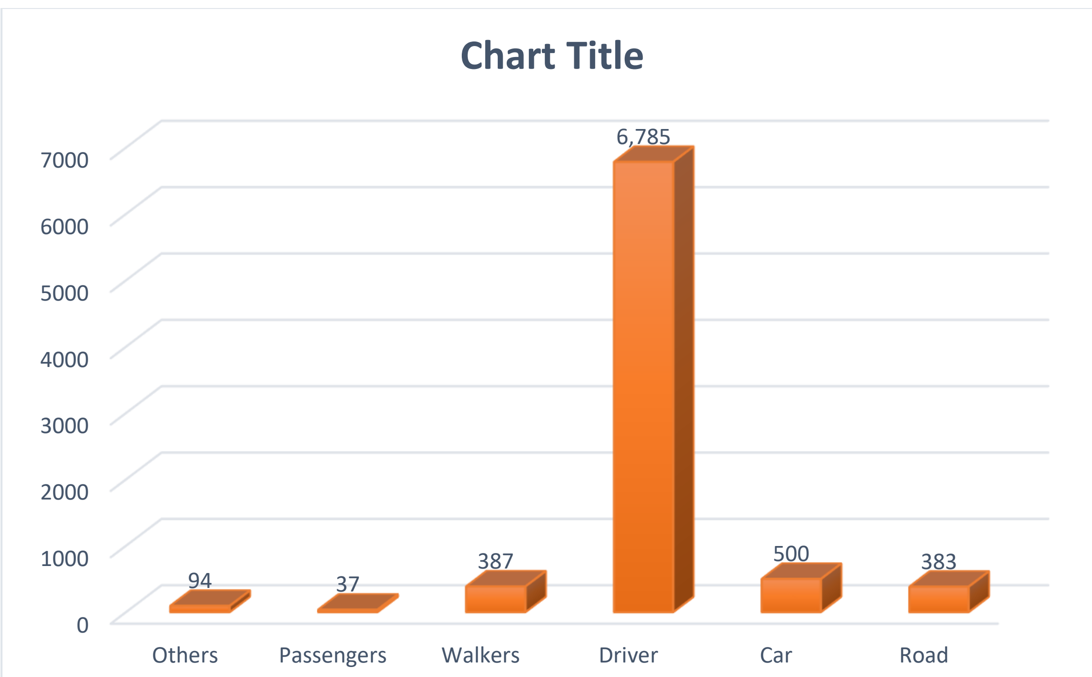



**Figure (A-1) The number of traffic accidents recorded by governorate and the causes of accidents for the year 2020.**

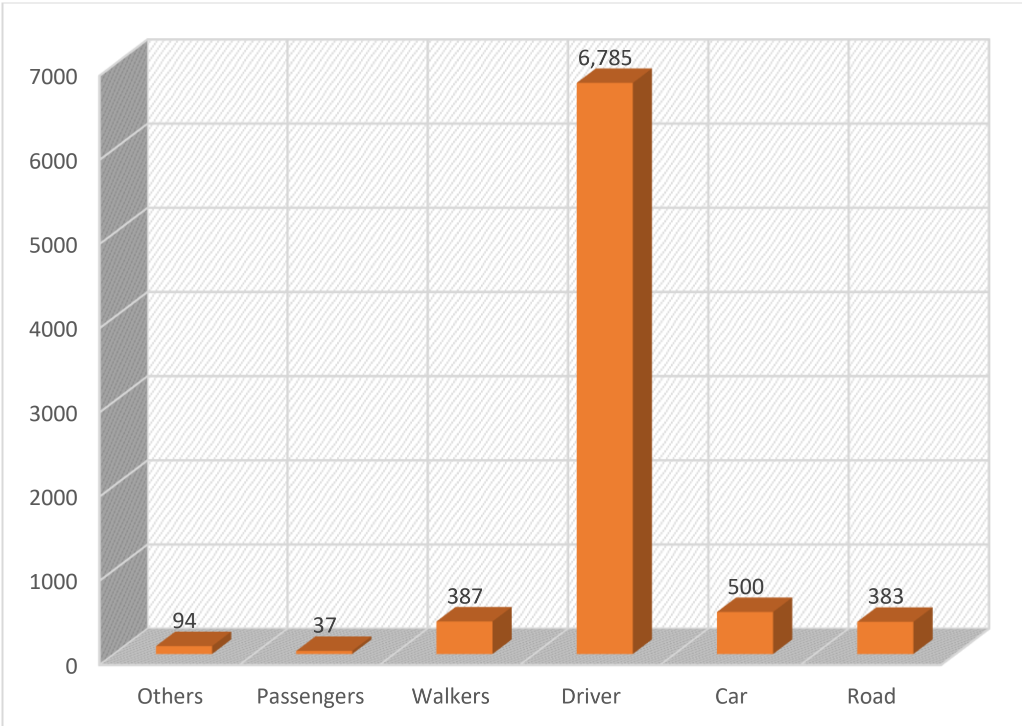



**Figure (A-2) The number of traffic accidents recorded by governorate and the causes of accidents for the year 2020.**

# Appendix (B)

## Data Collect

### Table (B-1) Traffic Volume Data at Al-Dubbad Approach at Each Five Minutes

| Time | Left | Through | Right | U-Turn |
|---|---|---|---|---|
| 12:30-12:35 | 30 | 29 | 31 | 6 |
| 12:35-12:40 | 28 | 34 | 33 | 5 |
| 12:40-12:45 | 33 | 33 | 32 | 7 |
| 12:45-12:50 | 34 | 33 | 35 | 10 |
| 12:50-12:55 | 38 | 38 | 33 | 11 |
| 12:55-1:00 | 36 | 41 | 31 | 8 |
| 1:00-1:05 | 37 | 40 | 30 | 12 |
| 1:05-1:10 | 40 | 43 | 32 | 13 |
| 1:10-1:15 | 38 | 40 | 36 | 10 |
| 1:15-1:20 | 36 | 43 | 38 | 9 |
| 1:20-1:25 | 41 | 45 | 37 | 11 |
| 1:25-1:30 | 40 | 42 | 39 | 17 |
| 1:30-1:35 | 38 | 40 | 28 | 10 |
| 1:35-1:40 | 37 | 42 | 29 | 9 |
| 1:40-1:45 | 35 | 38 | 27 | 8 |
| 1:45-1:50 | 37 | 40 | 30 | 11 |
| 1:50-1:55 | 35 | 35 | 30 | 7 |
| 1:55-2:00 | 37 | 33 | 33 | 10 |
| 2:00-2:05 | 37 | 34 | 32 | 12 |
| 2:05-2:10 | 39 | 33 | 34 | 10 |
| 2:10-2:15 | 37 | 31 | 35 | 8 |
| 2:15-2:20 | 32 | 32 | 36 | 6 |
| 2:20-2:25 | 33 | 27 | 34 | 5 |
| 2:25-2:30 | 28 | 29 | 33 | 9 |

## Table (B-2) Traffic Volume Data at Al- Mutaqadeen Approach at Each Five Minutes

| Time | Left | Through | Right | U-Turn |
|---|---|---|---|---|
| 12:30-12:35 | 36 | 31 | 23 | 3 |
| 12:35-12:40 | 34 | 29 | 25 | 7 |
| 12:40-12:45 | 36 | 28 | 24 | 5 |
| 12:45-12:50 | 38 | 32 | 27 | 2 |
| 12:50-12:55 | 35 | 35 | 31 | 9 |
| 12:55-1:00 | 33 | 35 | 34 | 7 |
| 1:00-1:05 | 34 | 38 | 36 | 4 |
| 1:05-1:10 | 37 | 41 | 34 | 6 |
| 1:10-1:15 | 32 | 37 | 37 | 5 |
| 1:15-1:20 | 29 | 35 | 38 | 7 |
| 1:20-1:25 | 34 | 34 | 35 | 6 |
| 1:25-1:30 | 36 | 36 | 34 | 4 |
| 1:30-1:35 | 35 | 39 | 35 | 1 |
| 1:35-1:40 | 37 | 37 | 33 | 3 |
| 1:40-1:45 | 38 | 41 | 34 | 7 |
| 1:45-1:50 | 36 | 38 | 31 | 8 |
| 1:50-1:55 | 32 | 31 | 32 | 3 |
| 1:55-2:00 | 37 | 33 | 33 | 10 |
| 2:00-2:05 | 38 | 21 | 32 | 7 |
| 2:05-2:10 | 35 | 27 | 33 | 5 |
| 2:10-2:15 | 32 | 28 | 31 | 3 |
| 2:15-2:20 | 34 | 25 | 27 | 4 |
| 2:20-2:25 | 33 | 23 | 27 | 1 |
| 2:25-2:30 | 33 | 24 | 24 | 3 |

**Table (B-3) Traffic Volume Data at Al- Jamhori Approach At Each Five Minutes**

| Time | Left | Through | Right | U-Turn |
|---|---|---|---|---|
| 12:30-12:35 | 32 | 42 | 25 | 14 |
| 12:35-12:40 | 37 | 47 | 30 | 12 |
| 12:40-12:45 | 35 | 44 | 29 | 13 |
| 12:45-12:50 | 36 | 49 | 32 | 10 |
| 12:50-12:55 | 38 | 53 | 34 | 12 |
| 12:55-1:00 | 40 | 51 | 37 | 12 |
| 1:00-1:05 | 39 | 47 | 39 | 9 |
| 1:05-1:10 | 41 | 49 | 37 | 10 |
| 1:10-1:15 | 38 | 45 | 38 | 12 |
| 1:15-1:20 | 40 | 49 | 36 | 11 |
| 1:20-1:25 | 43 | 47 | 41 | 8 |
| 1:25-1:30 | 39 | 44 | 38 | 10 |
| 1:30-1:35 | 38 | 45 | 34 | 12 |
| 1:35-1:40 | 39 | 47 | 31 | 14 |
| 1:40-1:45 | 36 | 44 | 33 | 10 |
| 1:45-1:50 | 34 | 46 | 28 | 12 |
| 1:50-1:55 | 36 | 42 | 27 | 9 |
| 1:55-2:00 | 33 | 40 | 23 | 14 |
| 2:00-2:05 | 35 | 36 | 24 | 12 |
| 2:05-2:10 | 35 | 33 | 21 | 8 |
| 2:10-2:15 | 34 | 34 | 21 | 5 |
| 2:15-2:20 | 32 | 31 | 22 | 6 |
| 2:20-2:25 | 34 | 30 | 23 | 8 |
| 2:25-2:30 | 36 | 32 | 20 | 6 |

**Table (B-4) Traffic Volume Data at Al- Jamhori Sharqi Approach at Each Five minutes**

| Time | Left | Through | Right | U-Turn |
|---|---|---|---|---|
| 12:30-12:35 | 27 | 37 | 30 | 13 |
| 12:35-12:40 | 32 | 40 | 35 | 11 |
| 12:40-12:45 | 34 | 37 | 31 | 10 |
| 12:45-12:50 | 29 | 40 | 33 | 9 |
| 12:50-12:55 | 33 | 47 | 40 | 14 |
| 12:55-1:00 | 35 | 45 | 41 | 11 |
| 1:00-1:05 | 34 | 41 | 44 | 8 |
| 1:05-1:10 | 36 | 44 | 45 | 10 |
| 1:10-1:15 | 33 | 38 | 43 | 12 |
| 1:15-1:20 | 35 | 43 | 46 | 10 |
| 1:20-1:25 | 38 | 41 | 45 | 7 |
| 1:25-1:30 | 34 | 38 | 41 | 9 |
| 1:30-1:35 | 33 | 39 | 40 | 11 |
| 1:35-1:40 | 34 | 41 | 39 | 15 |
| 1:40-1:45 | 31 | 38 | 35 | 12 |
| 1:45-1:50 | 29 | 40 | 38 | 12 |
| 1:50-1:55 | 31 | 37 | 31 | 8 |
| 1:55-2:00 | 27 | 33 | 28 | 13 |
| 2:00-2:05 | 30 | 31 | 29 | 11 |
| 2:05-2:10 | 33 | 28 | 26 | 7 |
| 2:10-2:15 | 27 | 29 | 26 | 4 |
| 2:15-2:20 | 24 | 26 | 27 | 5 |
| 2:20-2:25 | 29 | 25 | 28 | 7 |
| 2:25-2:30 | 32 | 27 | 25 | 6 |

**Table (B-5) Total Traffic Volume Data at Al-Dubbad Approach At Each Five Minutes**

| Time | Left | Through | Right | U-Turn | Total |
|---|---|---|---|---|---|
| 12:30-1:30 | 431 | 461 | 407 | 109 | 1408 |
| 12:35-1:35 | 439 | 472 | 404 | 113 | 1428 |
| 12:40-1:40 | 448 | 480 | 400 | 117 | 1445 |
| 12:45-1:45 | 450 | 485 | 395 | 118 | 1448 |
| 12:50-1:50 | 453 | 492 | 392 | 119 | 1456 |
| 12:55-1:55 | 450 | 489 | 389 | 115 | 1443 |
| 1:00-2:00 | 451 | 481 | 391 | 114 | 1437 |
| 1:05-2:05 | 451 | 475 | 393 | 112 | 1431 |
| 1:10-2:10 | 450 | 465 | 395 | 113 | 1423 |
| 1:15-2:15 | 449 | 456 | 394 | 115 | 1414 |
| 1:20-2:20 | 447 | 445 | 392 | 112 | 1396 |
| 1:25-2:25 | 439 | 429 | 389 | 106 | 1362 |
| 1:30-2:30 | 424 | 416 | 383 | 108 | 1334 |

**Table (B-6) Total Traffic Volume Data at Al-Jamhori Sharqi Approach At Each Five Minutes**

| Time | Left | Through | Right | U-Turn | |
|---|---|---|---|---|---|
| 12:30-1:30 | 400 | 493 | 474 | 123 | 1490 |
| 12:35-1:35 | 406 | 496 | 484 | 119 | 1504 |
| 12:40-1:40 | 408 | 494 | 488 | 123 | 1513 |
| 12:45-1:45 | 402 | 495 | 493 | 123 | 1516 |
| 12:50-1:50 | 405 | 495 | 497 | 128 | 1525 |
| 12:55-1:55 | 404 | 485 | 488 | 123 | 1499 |
| 1:00-2:00 | 396 | 477 | 475 | 125 | 1473 |
| 1:05-2:05 | 392 | 465 | 460 | 128 | 1445 |
| 1:10-2:10 | 391 | 449 | 441 | 125 | 1406 |
| 1:15-2:15 | 385 | 434 | 424 | 117 | 1360 |
| 1:20-2:20 | 379 | 423 | 405 | 112 | 1319 |
| 1:25-2:25 | 368 | 405 | 388 | 112 | 1273 |
| 1:30-2:30 | 366 | 396 | 372 | 109 | 1243 |

**Table (B-7) Total Traffic Volume Data At Al- Jamhori Approach At Each Five Minutes**

| Time | Left | Through | Right | U-Turn | |
|---|---|---|---|---|---|
| 12:30-1:30 | 458 | 567 | 416 | 133 | 1574 |
| 12:35-1:35 | 464 | 570 | 425 | 131 | 1590 |
| 12:40-1:40 | 465 | 571 | 425 | 135 | 1594 |
| 12:45-1:45 | 467 | 573 | 428 | 133 | 1601 |
| 12:50-1:50 | 465 | 567 | 426 | 132 | 1590 |
| 12:55-1:55 | 463 | 556 | 419 | 133 | 1571 |
| 1:00-2:00 | 457 | 545 | 405 | 135 | 1542 |
| 1:05-2:05 | 453 | 534 | 390 | 138 | 1515 |
| 1:10-2:10 | 446 | 518 | 374 | 144 | 1482 |
| 1:15-2:15 | 442 | 504 | 353 | 130 | 1432 |
| 1:20-2:20 | 434 | 489 | 343 | 121 | 1387 |
| 1:25-2:25 | 426 | 470 | 330 | 124 | 1349 |
| 1:30-2:30 | 461 | 460 | 307 | 120 | 1348 |

**Table (B-8) Total Traffic Volume Data at Al-Dubbad Approach At Each Five Minutes**

| time | left | through | right | U-turn | total |
|---|---|---|---|---|---|
| 12:30-1:30 | 414 | 406 | 378 | 67 | 1265 |
| 12:35-1:35 | 413 | 419 | 390 | 63 | 1285 |
| 12:40-1:40 | 416 | 427 | 398 | 59 | 1300 |
| 12:45-1:45 | 418 | 399 | 408 | 54 | 1279 |
| 12:50-1:50 | 416 | 446 | 412 | 59 | 1333 |
| 12:55-1:55 | 413 | 442 | 414 | 59 | 1341 |
| 1:00-2:00 | 417 | 440 | 417 | 54 | 1346 |
| 1:05-2:05 | 423 | 427 | 417 | 60 | 1342 |
| 1:10-2:10 | 421 | 413 | 416 | 61 | 1326 |
| 1:15-2:15 | 421 | 404 | 410 | 61 | 1311 |
| 1:20-2:20 | 426 | 394 | 399 | 57 | 1291 |
| 1:25-2:25 | 425 | 383 | 391 | 54 | 1268 |
| 1:30-2:30 | 422 | 371 | 381 | 51 | 1241 |

## Table (B-9) Total Traffic Volume Data at Al-Jamhori Intersection at Each One Hour

| Time | Mutaqadeen | Al-Dubbad | Jamhori Sharqi | Al-Jamhori | Total |
|---|---|---|---|---|---|
| 12:30-1:30 | 1265 | 1408 | 1490 | 1574 | 5737 |
| 12:35-1:35 | 1285 | 1428 | 1504 | 1590 | 5807 |
| 12:40-1:40 | 1300 | 1445 | 1513 | 1594 | 5852 |
| 12:45-1:45 | 1279 | 1448 | 1516 | 1601 | 5844 |
| 12:50-1:50 | 1333 | 1456 | 1525 | 1590 | 5904 |
| 12:55-1:55 | 1330 | 1443 | 1499 | 1571 | 5843 |
| 1:00-2:00 | 1326 | 1437 | 1473 | 1542 | 5778 |
| 1:05-2:05 | 1326 | 1431 | 1445 | 1515 | 5718 |
| 1:10-2:10 | 1327 | 1423 | 1406 | 1482 | 5637 |
| 1:15-2:15 | 1311 | 1414 | 1360 | 1434 | 5519 |

| | | | | | |
|---|---|---|---|---|---|
| 1:20-2:20 | 1291 | 1396 | 1319 | 1384 | 5393 |
| 1:25-2:25 | 1268 | 1363 | 1273 | 1349 | 5253 |
| 1:30-2:30 | 1241 | 1334 | 1243 | 1348 | 5166 |

**Table (B-10) Traffic Volume Data and Vehicle Compositions at Al-jamhori Approach of Al-jamhori intersection**

| Time | Left | Through | Right | U-Turn |
|---|---|---|---|---|
| 12:50-1:05 | 117 | 151 | 110 | 33 |
| 1:05-1:20 | 119 | 143 | 111 | 33 |
| 1:20-1:35 | 120 | 136 | 113 | 30 |
| 1:35-1:50 | 109 | 137 | 92 | 36 |
| total | 465 | 567 | 366 | 132 |

| Vehicle Compositions | Number of Vehicles | | | | Proportion |
|---|---|---|---|---|---|
| | Left | Through | Right | U-Turn | |
| Car | 515 | 502 | 320 | 103 | 87.3 |
| HGV | 22 | 28 | 20 | 6 | 5.59 |
| Bus | 28 | 37 | 26 | 9 | 7.11 |

**Table (B-11) Traffic Volume Data and Vehicle Compositions at Al-mutaqadeen Approach of Al-jamhori intersection**

| Time | Left | Through | Right | U-Turn |
|---|---|---|---|---|
| 12:50-1:05 | 102 | 108 | 101 | 20 |
| 1:05-1:20 | 98 | 113 | 109 | 18 |
| 1:20-1:35 | 105 | 109 | 104 | 11 |
| 1:35-1:50 | 111 | 116 | 98 | 10 |
| total | 416 | 446 | 412 | 57 |

| Vehicle Compositions | Number of Vehicles | | | | Proportion % |
|---|---|---|---|---|---|
| | Left | Through | Right | U-Turn | |
| Car | 369 | 396 | 367 | 51 | 88.78 |
| HGV | 20 | 21 | 18 | - | 4.71 |
| Bus | 27 | 29 | 27 | 6 | 6.51 |

**Table (B-12) Traffic Volume Data and Vehicle Compositions at Al- Dubbad Approach of Al-Jamhori Intersection**

| Time | Left | Through | Right | U-Turn |
|---|---|---|---|---|
| 12:50-1:05 | 111 | 119 | 94 | 31 |
| 1:05-1:20 | 114 | 123 | 106 | 32 |
| 1:20-1:35 | 119 | 130 | 104 | 28 |
| 1:35-1:50 | 109 | 120 | 86 | 28 |
| total | 453 | 492 | 390 | 119 |

| Vehicle Compositions | Number of Vehicles | | | | Proportion % |
|---|---|---|---|---|---|
| | Left | Through | Right | U-Turn | |
| Car | 418 | 457 | 377 | 112 | 93.72 |
| HGV | 14 | 16 | 12 | 2 | 3.0 |
| Bus | 15 | 20 | 13 | 5 | 3.28 |

**Table (B-13) Traffic Volume Data and Vehicle Compositions at Al-Jamhori Sharqi Approach of Al-Jamhori Intersection**

| Time | Left | Through | Right | U-Turn |
|---|---|---|---|---|
| 12:50-1:05 | 102 | 133 | 124 | 33 |
| 1:05-1:20 | 104 | 126 | 128 | 32 |
| 1:20-1:35 | 105 | 118 | 122 | 27 |
| 1:35-1:50 | 94 | 119 | 105 | 37 |
| Total | 405 | 496 | 497 | 128 |

| Vehicle Compositions | Number of Vehicles | | | | Proportion % |
|---|---|---|---|---|---|
| | Left | Through | Right | U-Turn | |
| Car | 370 | 453 | 455 | 117 | 91.43 |
| HGV | 13 | 16 | 11 | - | 3.24 |
| Bus | 22 | 26 | 31 | 11 | 5.33 |

## Table (B-14) Speed Data at at Al-jamhori Approach Approach Al-Jamhori Intersection

| Vehicle No. | Time (sec) | Spot Speed (kph) | Vehicle No. | Time (sec) | Spot Speed (kph) | Vehicle No. | Time (sec) | Spot Speed (kph) |
|---|---|---|---|---|---|---|---|---|
| 1 | 4.82 | 22.4 | 35 | 6.05 | 17.8 | 69 | 5.75 | 18.8 |
| 2 | 4.73 | 22.88 | 36 | 4.15 | 26 | 70 | 5.55 | 19.46 |
| 3 | 4.93 | 21.95 | 37 | 5.81 | 18.6 | 71 | 4.87 | 22.2 |
| 4 | 5.29 | 20.41 | 38 | 4.43 | 24.4 | 72 | 4.43 | 24.4 |
| 5 | 5.18 | 20.85 | 39 | 5.8 | 18.8 | 73 | 3.74 | 28.87 |
| 6 | 5.39 | 20 | 40 | 4.89 | 22.1 | 74 | 5.16 | 20.9 |
| 7 | 5.02 | 21.5 | 41 | 5.88 | 18.4 | 75 | 5.43 | 19.9 |
| 8 | 5.64 | 19.15 | 42 | 5.2 | 20.8 | 76 | 5.03 | 21.5 |
| 9 | 6.03 | 18 | 43 | 5.27 | 20.5 | 77 | 4.53 | 19.53 |
| 10 | 4.03 | 26.8 | 44 | 4.79 | 22.6 | 78 | 4.18 | 25.84 |
| 11 | 4.89 | 22.1 | 45 | 4.91 | 23 | 79 | 4.63 | 23.3 |
| 12 | 4.34 | 24.9 | 46 | 5.48 | 19.7 | 80 | 5.18 | 20.85 |
| 13 | 5.42 | 20 | 47 | 5.44 | 19.9 | 81 | 5.45 | 19.81 |
| 14 | 5.29 | 20.4 | 48 | 4.04 | 26.54 | 82 | 5.97 | 18.1 |
| 15 | 5.5 | 19.6 | 49 | 4.26 | 25.4 | 83 | 4.62 | 23.3 |
| 16 | 4.33 | 25 | 50 | 4.5 | 24 | 84 | 5.37 | 20.11 |
| 17 | 4.81 | 22.5 | 51 | 5.8 | 18.6 | 85 | 5.46 | 19.8 |
| 18 | 4.71 | 22.93 | 52 | 6.1 | 17.7 | 86 | 6.2 | 17.41 |
| 19 | 5.29 | 20.41 | 53 | 4.74 | 22.8 | 87 | 4.52 | 23.9 |
| 20 | 6.06 | 17.82 | 54 | 6.06 | 17.8 | 88 | 4.13 | 26.15 |
| 21 | 4.97 | 21.67 | 55 | 4.8 | 22.5 | 89 | 5.11 | 21.14 |
| 22 | 4.33 | 24.94 | 56 | 4.74 | 22.8 | 90 | 5.6 | 19.3 |
| 23 | 6.1 | 17.7 | 57 | 6.1 | 17.7 | 91 | 5.88 | 18.4 |
| 24 | 5.6 | 21.3 | 58 | 5.39 | 20 | 92 | 5.47 | 19.7 |
| 25 | 5.08 | 19.3 | 59 | 4.83 | 22.4 | 93 | 4.48 | 24.1 |
| 26 | 4.53 | 23.8 | 60 | 4.48 | 24.1 | 94 | 4.59 | 23.6 |
| 27 | 4.36 | 24.8 | 61 | 4.15 | 26 | 95 | 4.77 | 22.64 |
| 28 | 5.31 | 20.34 | 62 | 4.48 | 24.1 | 96 | 4.57 | 23.7 |
| 29 | 5.10 | 21 | 63 | 4.73 | 22.8 | 97 | 5.43 | 19.99 |
| 30 | 5.05 | 21.4 | 64 | 5.25 | 20.57 | 98 | 5.12 | 21.09 |
| 31 | 4.91 | 22 | 65 | 4.99 | 21.6 | 99 | 4.9 | 23 |
| 32 | 4.61 | 23.4 | 66 | 5.17 | 20.9 | 100 | 4.36 | 24.6 |
| 33 | 4.87 | 22.2 | 67 | 5.34 | 20.22 | | | |
| 34 | 6.17 | 17.5 | 68 | 4.34 | 24.9 | | | |

## Table (B-15) Speed Data at Al- Dubbad Approach

| Vehicle No. | Time (sec) | Spot Speed (kph) | Vehicle No. | Time (sec) | Spot Speed (kph) | Vehicle No. | Time (sec) | Spot Speed (kph) |
|---|---|---|---|---|---|---|---|---|
| 1 | 5.64 | 19.15 | 35 | 5.17 | 21 | 69 | 4.96 | 21.77 |
| 2 | 5.22 | 20.7 | 36 | 5.91 | 18.27 | 70 | 4.29 | 25.17 |
| 3 | 4.39 | 24.6 | 37 | 6.09 | 17.73 | 71 | 5.34 | 20.22 |
| 4 | 4.64 | 23.28 | 38 | 4.82 | 22.4 | 72 | 4.64 | 23.27 |
| 5 | 4.56 | 23.7 | 39 | 4.99 | 21.6 | 73 | 4.53 | 23.84 |
| 6 | 4.84 | 22.31 | 40 | 4.77 | 22.64 | 74 | 6.1 | 17.7 |
| 7 | 5.35 | 20.12 | 41 | 4.66 | 23.17 | 75 | 5.01 | 21.6 |
| 8 | 5.12 | 21.1 | 42 | 4 | 27 | 76 | 4.56 | 23.6 |
| 9 | 4.6 | 23.5 | 43 | 3.89 | 21.95 | 77 | 4.84 | 22.31 |
| 10 | 5.27 | 20.49 | 44 | 6.31 | 17.11 | 78 | 5.42 | 20 |
| 11 | 4.93 | 22 | 45 | 6.17 | 17.5 | 79 | 5.04 | 21.43 |
| 12 | 4.22 | 25.6 | 46 | 5 | 21.6 | 80 | 4.89 | 22.1 |
| 13 | 5 | 21.6 | 47 | 5.04 | 21.42 | 81 | 6.51 | 16.6 |
| 14 | 5.05 | 21.4 | 48 | 4.41 | 24.5 | 82 | 6.3 | 17.14 |
| 15 | 6.08 | 17.8 | 49 | 4.91 | 22 | 83 | 5.54 | 19.5 |
| 16 | 6.2 | 17.41 | 50 | 4.2 | 25.71 | 84 | 5.28 | 20.45 |
| 17 | 4.84 | 22.31 | 51 | 5.6 | 19.3 | 85 | 5.32 | 20.3 |
| 18 | 4.44 | 24.32 | 52 | 5.88 | 18.36 | 86 | 5.48 | 19.7 |
| 19 | 4.34 | 24.88 | 53 | 4.82 | 22.6 | 87 | 5.04 | 21.43 |
| 20 | 5.37 | 20.11 | 54 | 3.91 | 27.3 | 88 | 4.52 | 23.9 |
| 21 | 5.2 | 20.8 | 55 | 4.33 | 25 | 89 | 3.97 | 27.2 |
| 22 | 5.09 | 21.21 | 56 | 5.21 | 20.74 | 90 | 3.9 | 27.7 |
| 23 | 4.25 | 25.41 | 57 | 5.62 | 19.21 | 91 | 4.9 | 22.02 |
| 24 | 4.65 | 23.22 | 58 | 5.78 | 18.7 | 92 | 5.34 | 20.22 |
| 25 | 3.99 | 27.1 | 59 | 4.2 | 25.71 | 93 | 4.91 | 22 |
| 26 | 4.27 | 25.3 | 60 | 4.72 | 22.88 | 94 | 5.1 | 21.17 |
| 27 | 4.59 | 23.53 | 61 | 4.97 | 21.73 | 95 | 4.99 | 21.56 |
| 28 | 5.55 | 19.45 | 62 | 4.09 | 26.4 | 96 | 4.49 | 23.8 |
| 29 | 5.9 | 18.3 | 63 | 4.95 | 21.81 | 97 | 5.33 | 18.99 |
| 30 | 6.01 | 17.97 | 64 | 5.21 | 20.73 | 98 | 5.22 | 21 |
| 31 | 6.31 | 17.11 | 65 | 5.7 | 18.94 | 99 | 5.46 | 19.76 |
| 32 | 4.47 | 24.16 | 66 | 6.18 | 17.48 | 100 | 4.22 | 26.8 |
| 33 | 4.81 | 24.5 | 67 | 4.52 | 23.9 | | | |
| 34 | 4.97 | 21.77 | 68 | 5.09 | 21.21 | | | |

# Table (B-16) Speed Data at Al-Jamhori Sharqi Approach

| Vehicle No. | Time (sec) | Spot Speed (kph) | Vehicle No. | Time (sec) | Spot Speed (kph) | Vehicle No. | Time (sec) | Spot Speed (kph) |
|---|---|---|---|---|---|---|---|---|
| 1 | 4.68 | 23.1 | 35 | 4.24 | 25.47 | 69 | 4.17 | 25.9 |
| 2 | 3.94 | 27.1 | 36 | 4.65 | 23.22 | 70 | 3.88 | 27.83 |
| 3 | 4.03 | 26.8 | 37 | 5.38 | 20.1 | 71 | 4.95 | 21.81 |
| 4 | 4.1 | 26.3 | 38 | 5.82 | 18.56 | 72 | 5.75 | 18.8 |
| 5 | 3.89 | 27.8 | 39 | 4.79 | 22.55 | 73 | 5.76 | 18.75 |
| 6 | 4.74 | 22.8 | 40 | 4.75 | 22.7 | 74 | 5.28 | 20.5 |
| 7 | 5.28 | 20.5 | 41 | 4.5 | 24 | 75 | 4.72 | 22.9 |
| 8 | 5.4 | 20 | 42 | 5.83 | 18.52 | 76 | 4.14 | 26.1 |
| 9 | 4.96 | 18.12 | 43 | 5.21 | 20.73 | 77 | 5.44 | 19.9 |
| 10 | 4.66 | 23.18 | 44 | 5.14 | 21 | 78 | 4.63 | 23.33 |
| 11 | 5.57 | 19.4 | 45 | 3.83 | 28.2 | 79 | 3.9 | 27.7 |
| 12 | 5.18 | 20.9 | 46 | 4.18 | 26.1 | 80 | 3.97 | 27.8 |
| 13 | 4.98 | 21.7 | 47 | 4.55 | 23.71 | 81 | 5.6 | 19.3 |
| 14 | 4.04 | 26.7 | 48 | 4.89 | 22.1 | 82 | 4.94 | 21.9 |
| 15 | 5.15 | 21 | 49 | 5.47 | 19.74 | 83 | 5.35 | 20.19 |
| 16 | 5.93 | 18.21 | 50 | 6 | 18 | 84 | 5 | 21.7 |
| 17 | 5.05 | 21.4 | 51 | 4.75 | 22.73 | 85 | 4.59 | 23.53 |
| 18 | 4.36 | 20.15 | 52 | 4.13 | 26.15 | 86 | 5.09 | 21.21 |
| 19 | 3.96 | 27.27 | 53 | 3.84 | 28.12 | 87 | 5.74 | 18.18 |
| 20 | 3.74 | 28.7 | 54 | 4.02 | 26.9 | 88 | 4.32 | 25 |
| 21 | 5.4 | 20 | 55 | 4.88 | 22.13 | 89 | 5.76 | 18.75 |
| 22 | 4.31 | 25.05 | 56 | 5 | 21.6 | 90 | 5.11 | 21.13 |
| 23 | 4.6 | 23.4 | 57 | 5.89 | 18.22 | 91 | 5.25 | 20.5 |
| 24 | 5.28 | 20.45 | 58 | 4.5 | 24 | 92 | 6.1 | 17.7 |
| 25 | 5.21 | 20.73 | 59 | 5.76 | 18.75 | 93 | 4.7 | 23 |
| 26 | 4.21 | 25.7 | 60 | 4.99 | 21.64 | 94 | 3.99 | 27.1 |
| 27 | 4.26 | 25.35 | 61 | 4.87 | 22.18 | 95 | 4.33 | 24.94 |
| 28 | 3.73 | 28.9 | 62 | 4.04 | 26.73 | 96 | 4.7 | 23 |
| 29 | 3.79 | 28.5 | 63 | 4.33 | 24.956 | 97 | 5.07 | 21.3 |
| 30 | 5.9 | 18.3 | 64 | 3.86 | 28 | 98 | 5.27 | 20.44 |
| 31 | 6.01 | 18 | 65 | 5.85 | 18.45 | 99 | 4.7 | 23 |
| 32 | 6.09 | 17.73 | 66 | 6.03 | 17.91 | 100 | 4.45 | 23.67 |
| 33 | 4.7 | 23 | 67 | 4.27 | 25.3 | | | |
| 34 | 4.34 | 24.88 | 68 | 4.74 | 22.8 | | | |

## Table (B-17) Speed Data at Al- mutaqadeen Approach

| Vehicle No. | Time (sec) | Spot Speed (kph) | Vehicle No. | Time (sec) | Spot Speed (kph) | Vehicle No. | Time (sec) | |
|---|---|---|---|---|---|---|---|---|
| 1 | 4.73 | 22.83 | 35 | 5.05 | 21.39 | 69 | 3.99 | 27.06 |
| 2 | 4.55 | 23.74 | 36 | 4.19 | 25.77 | 70 | 4.58 | 23.58 |
| 3 | 4.61 | 23.42 | 37 | 4.43 | 24.38 | 71 | 5.13 | 21.05 |
| 4 | 4.3 | 25.1126 | 38 | 3.97 | 27.2 | 72 | 5.77 | 18.71 |
| 5 | 4.22 | 25.6 | 39 | 5.31 | 20.33 | 73 | 4.92 | 21.95 |
| 6 | 3.9 | 27.7 | 40 | 4.97 | 21.73 | 74 | 5.01 | 21.55 |
| 7 | 3.81 | 28.35 | 41 | 4.77 | 22.64 | 75 | 5.2 | 20.73 |
| 8 | 5.1 | 21.17 | 42 | 4.84 | 22.31 | 76 | 4.44 | 24.32 |
| 9 | 5.05 | 21.39 | 43 | 5.1 | 21.17 | 77 | 4.28 | 25.23 |
| 10 | 5.91 | 18.27 | 44 | 5.52 | 19.56 | 78 | 4.39 | 24.6 |
| 11 | 4.81 | 22.45 | 45 | 3.97 | 27.2 | 79 | 4.92 | 21.95 |
| 12 | 4.77 | 22.6 | 46 | 3.99 | 27.06 | 80 | 5.13 | 21.05 |
| 13 | 4.32 | 25 | 47 | 4 | 27 | 81 | 3.98 | 27.13 |
| 14 | 4.89 | 22.1 | 48 | 4.87 | 22.17 | 82 | 3.79 | 28.5 |
| 15 | 4.11 | 26.26 | 49 | 4.75 | 22.73 | 83 | 5.44 | 19.85 |
| 16 | 4.12 | 26.21 | 50 | 5.4 | 21.03 | 84 | 5.47 | 19.74 |
| 17 | 5.01 | 21.55 | 51 | 4.55 | 23.77 | 85 | 5.92 | 18.24 |
| 18 | 5.16 | 20.93 | 52 | 4.49 | 24.05 | 86 | 4.87 | 22.17 |
| 19 | 5.55 | 19.46 | 53 | 4.72 | 22.88 | 87 | 4.41 | 24.48 |
| 20 | 5.4 | 20 | 54 | 4.91 | 21.99 | 88 | 5.16 | 20.93 |
| 21 | 4.98 | 21.7 | 55 | 3.98 | 27.13 | 89 | 5.72 | 18.88 |
| 22 | 4.47 | 22.6 | 56 | 4.89 | 22.08 | 90 | 4.12 | 26.21 |
| 23 | 4.01 | 24.43 | 57 | 4.21 | 25.65 | 91 | 4.13 | 26.15 |
| 24 | 4.2 | 24.16 | 58 | 4.27 | 25.29 | 92 | 4.32 | 25 |
| 25 | 3.9 | 27.62 | 59 | 3.88 | 27.83 | 93 | 4.12 | 26.21 |
| 26 | 3.8 | 27.9 | 60 | 4.65 | 23.22 | 94 | 4.84 | 22.35 |
| 27 | 5.11 | 21 | 61 | 4.42 | 24.43 | 95 | 4.96 | 21.88 |
| 28 | 5.38 | 20.09 | 62 | 4.66 | 23.17 | 96 | 4.32 | 24.89 |
| 29 | 5.59 | 19.32 | 63 | 3.92 | 27.55 | 97 | 4.22 | 26.09 |
| 30 | 5.01 | 21.55 | 64 | 5.1 | 21.17 | 98 | 5.11 | 21 |
| 31 | 4.1 | 26.34 | 65 | 5.44 | 19.85 | 99 | 4.88 | 22.11 |
| 32 | 4.37 | 24.7 | 66 | 5.37 | 20.11 | 100 | 5.76 | 18.66 |
| 33 | 3.77 | 28.64 | 67 | 4.79 | 22.55 | | | |
| 34 | 5.12 | 21.1 | 68 | 4.84 | 22.31 | | | |

## Appendix (C)

## Data needed for Traffic signal timing optimization.

**Table (c-1) Actual Volume at Al- nesser Intersection**

| From | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **1 (WB)** | 44 | 159 Right | 952 Through | 646 Left |
| **2 (SB)** | 258 Left | 59 | 161 Right | 497 Through |
| **3 (EB)** | 985 Through | 461 Left | 72 | 320 Right |
| **4 (NB)** | 113 Right | 377 Through | 312 Left | 132 |

**Table (c-2) PHF Values Calculation at Al- nesser Intersection**

| | Left | Through | Right |
|---|---|---|---|
| **1 (WB)** | .81 | .915 | .96 |
| **2 (SB)** | .9 | .98 | .914 |
| **3 (EB)** | .96 | .936 | .919 |
| **4 (NB)** | .928 | .915 | .84 |

**Table (c-3)** ***The Results of DHV Values*** **Al- nesser Intersection**

| From | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| **1 (WB)** | 0 | 187 Right | 1147 Through | 903 Left |
| **2 (SB)** | 337 Left | 0 | 207 Right | 596 Through |
| **3 (EB)** | 1171 Through | 533 Left | 0 | 387 Right |
| **4 (NB)** | 314 Right | 287 Through | 168 Left | 0 |

**Table (c-4) (*Vi*, *Si and Yi*) Values Calculations for Each Phase Al- nesser Intersection**

| | **WB** | | | **EB** | | | **SB** | | | **NB** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **LT.** | **Th.** | **RT.** | **LT.** | **Th.** | **RT.** | **LT.** | **Th.** | **RT.** | **LT.** | **Th.** | **RT.** |
| ***Vi*** | 903 | 1147 | 187 | 533 | 1171 | 387 | 337 | 596 | 207 | 382 | 287 | 314 |
| ***Si*** | 3465 | 3465 | 3465 | 3465 | 3465 | 3465 | 3255 | 3255 | 3255 | 3255 | 3255 | 3255 |
| ***Vi/Si*** | | | | | | | | | | | | |
| ***Yi*** | .33 | | | .33 | | | .18 | | | .117 | | |

**Table (c-5) Actual Volume at Al- jamhori Intersection**

| From | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| **1 (WB)** | 132 | 366 Right | 567 Through | 465 Left |
| **2 (SB)** | 405 Left | 128 | 497 Right | 495 Through |
| **3 (EB)** | 490 Through | 453 Left | 119 | 390 Right |
| **4 (NB)** | 412 Right | 446 Through | 416 Left | 57 |

**Table (C-6)** ***The Results of DHV Values*** **at Al- jamhori Intersection**

| From | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| **1 (WB)** | 0 | 516 Right | 700 Through | 512 Left |
| **2 (SB)** | 465 Left | 0 | 559 Right | 586 Through |
| **3 (EB)** | 553 Through | 511 Left | 0 | 431 Right |
| **4 (NB)** | 494 Right | 525 Through | 505 Left | 0 |

**Table (C-7) PHF Values at Al- jamhori Intersection**

| | **Left** | **Through** | **Right** |
|---|---|---|---|
| **1 (WB)** | .95 | .898 | .929 |
| **2 (SB)** | .916 | .923 | .905 |
| **3 (EB)** | .888 | .918 | .941 |
| **4 (NB)** | .951 | .93 | .942 |

**Table (C-8) (*Vi*, *Si and Yi*) Values Calculations for Each Phase at Al- jamhori Intersection**

| | **WB** | | | **EB** | | | **SB** | | | **NB** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **LT.** | **Th.** | **RT.** | **LT.** | **Th.** | **RT.** | **LT.** | **Th.** | **RT.** | **LT.** | **Th.** | **RT.** |
| ***Vi*** | 512 | 700 | 516 | 553 | 511 | 431 | 465 | 586 | 559 | 505 | 525 | 494 |
| ***Si*** | 2361 | 2361 | 2361 | 2361 | 2361 | 2361 | 2520 | 2520 | 2520 | 2520 | 2520 | 2520 |
| ***Vi/Si*** | | | | | | | | | | | | |
| ***Yi*** | .29 | | | .23 | | | .23 | | | .2 | | |

# Appendix (D)

## Tables Related to GEH statistics before and after the calibration.

### (D-1) GEH statistics before the calibration at Al- jamhori Intersection

| | Actual | Simulation | Actual-Simulation difference | % Difference | GEH |
|---|---|---|---|---|---|
| NB | 1455 | 1621 | -166 | -11.4 | 4.23 |
| EB | 1525 | 1211 | 112 | 7.34 | 8.48 |
| SB | 1330 | 1112 | 71 | 5.33 | 6.23 |
| WB | 1590 | 1501 | 81 | 5.1 | 2.263 |
| SUM | | | | 6.37 | 21.2 |

### (D-2) GEH statistics after the calibration at Al- jamhori Intersection

| | Actual | Simulation | Actual-Simulation difference | % Difference | GEH |
|---|---|---|---|---|---|
| NB | 1455 | 1466 | -11 | -0.756 | .287 |
| EB | 1525 | 1510 | 15 | 0.9836 | .385 |
| SB | 1330 | 1299 | 31 | 2.3308 | .854 |
| WB | 1590 | 1556 | 34 | 2.1384 | .857 |
| SUM | | | | 4.6968 | 2.383 |

**(D-3) GEH statistics before the calibration at Al- Fadael Intersection**

| | Actual | Simulation | Actual-Simulation difference | % Difference | GEH |
|---|---|---|---|---|---|
| NB | 1491 | 1233 | 136 | 9.12 | 6.99 |
| EB | 1387 | 1139 | 86 | 6.2 | 6.97 |
| SB | 1405 | 1320 | 85 | 6.05 | 2.3 |
| WB | 1344 | 1089 | -57 | -4.2 | 7.31 |
| SUM | | | | 17.1 | 23.57 |

**(D-4) GEH statistics after the calibration at Al- Fadael Intersection**

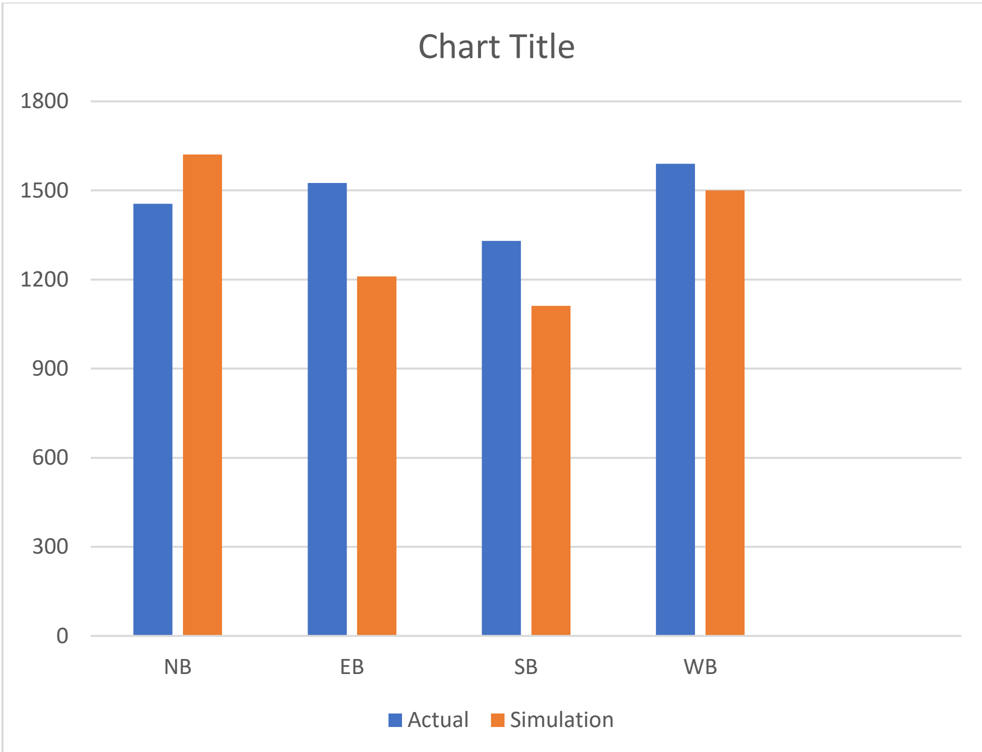
| | Actual | Simulation | Actual-Simulation difference | % Difference | GEH |
|---|---|---|---|---|---|
| NB | 1491 | 1444 | 47 | 0.0315 | 1.23 |
| EB | 1387 | 1352 | 35 | 0.0252 | .94 |
| SB | 1405 | 1433 | -83 | -0.02 | .74 |
| WB | 1344 | 1299 | 45 | 0.0335 | 1.237 |
| SUM | | | | 0.07031 | 4.147 |

**(D-5) GEH statistics before the calibration at Al- nesser Intersection**

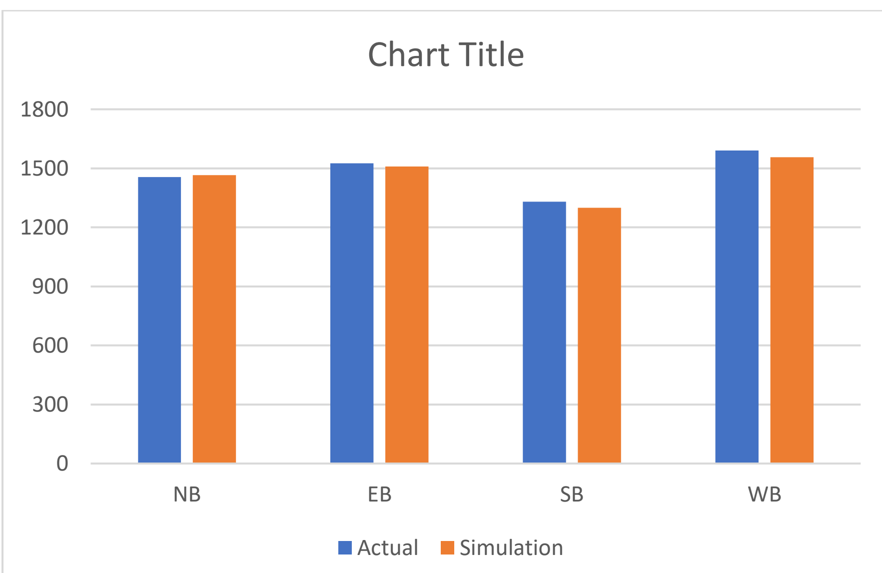
| | Actual | Simulation | Actual-Simulation difference | % Difference | GEH |
|---|---|---|---|---|---|
| NB | 936 | 1003 | -67 | -7.15 | 2.15 |
| EB | 1838 | 1677 | 161 | 8.75 | 3.84 |
| SB | 975 | 888 | 87 | 8.92 | 2.85 |
| WB | 1801 | 1643 | 158 | 8.77 | 3.8 |
| SUM | | | | 19.3 | 12.64 |

**(D-6) GEH statistics after the calibration at Al- nesser Intersection**

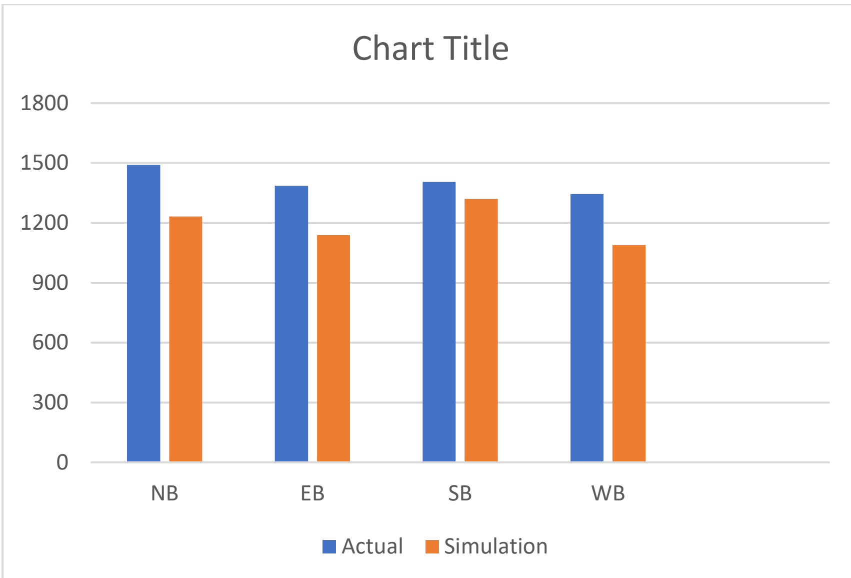
| | Actual | Simulation | Actual-Simulation difference | % Difference | GEH |
|---|---|---|---|---|---|
| NB | 936 | 931 | 5 | 0.005342 | .164 |
| EB | 1838 | 1833 | 5 | 0.00272 | .117 |
| SB | 975 | 927 | 48 | 0.049231 | 1.55 |
| WB | 1801 | 1855 | -54 | -0.02998 | 1.26 |
| SUM | | | | 0.02731 | 3.091 |



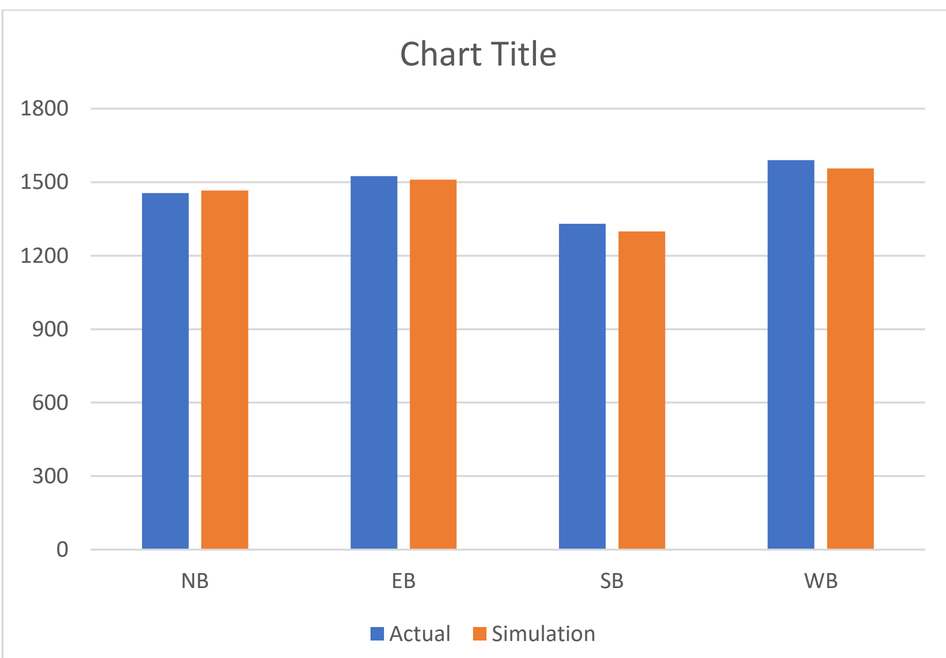

**Figure(D-1)The Difference of Number of Discharged Vehicles Between Actual Field and VISSIM Model**



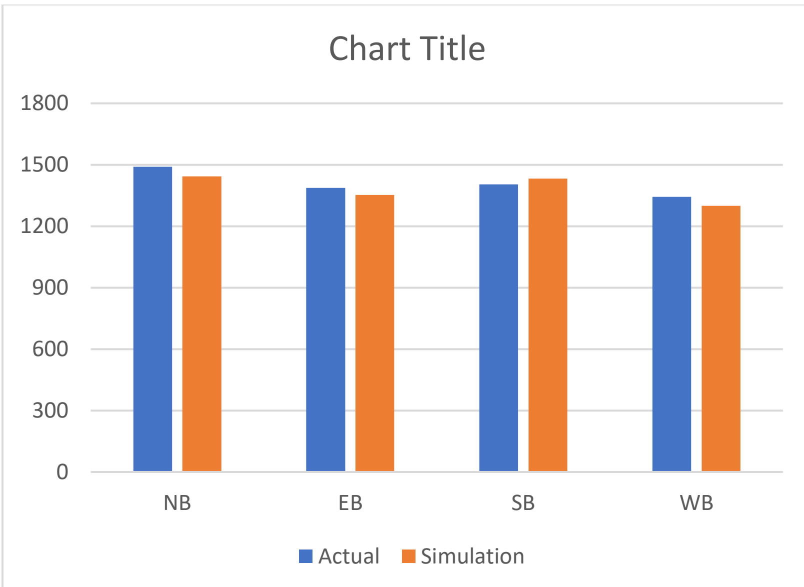

**Figure(D-2) The Difference of Number of Discharged Vehicles Between Actual Field and VISSIM Model**



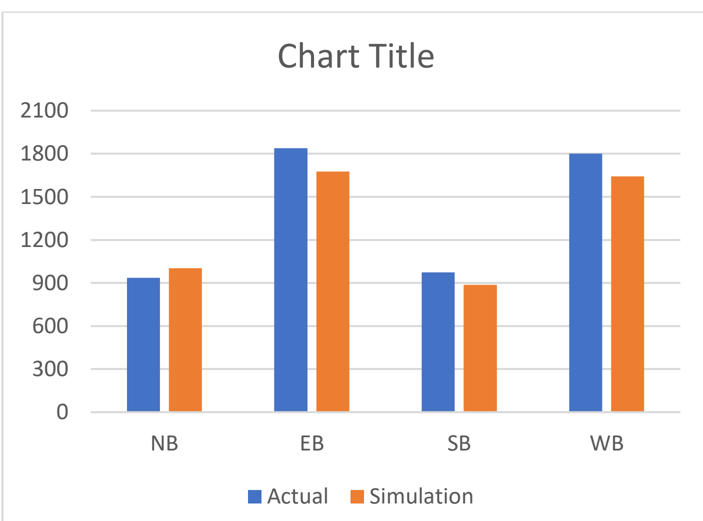

**Figure(D-3) The Difference of Number of Discharged Vehicles Between Actual Field and VISSIM Model**




**Figure(D-4) The Difference of Number of Discharged Vehicles Between Actual Field and VISSIM Model**




**Figure(D-5) The Difference of Number of Discharged Vehicles Between Actual Field and VISSIM Model**




**Figure(D-6) The Difference of Number of Discharged Vehicles Between Actual Field and VISSIM Model**

# Appendix (E)

## Conflict Data

### Table (E-1) Conflict Data at al-jamhori Intersection

| Time | App. | Traffic Conflict /h | | | | | | | | Total TC/h |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Rear-end Conflict | | | | Lane-change Conflict | | | Crossing Conflict | |
| | | C1 | C2 | C3 | Total | C4 | C5 | Total | C6 | |
| 12:50-1:50 | NB | 14 | 9 | 6 | 29 | 9 | 4 | 13 | 5 | 188 |
| | EB | 14 | 10 | 3 | 27 | 11 | 7 | 18 | 4 | |
| | SB | 9 | 7 | 2 | 19 | 6 | 2 | 8 | 3 | |
| | WB | 20 | 14 | 6 | 40 | 9 | 6 | 16 | 6 | |

### Table (E-2) Conflict Data at al-Oruba Intersection

| Time | App. | Traffic Conflict /h | | | | | | | | Total TC/h |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Rear-end Conflict | | | | Lane-change Conflict | | | Crossing Conflict | |
| | | C1 | C2 | C3 | Total | C4 | C5 | Total | C6 | |
| 7:45 -8:45 | NB | 6 | 11 | 3 | 20 | 4 | 5 | 9 | 7 | 174 |
| | EB | 10 | 6 | - | 16 | 2 | 7 | 9 | 9 | |
| | SB | 13 | 7 | 7 | 27 | 11 | 7 | 18 | 11 | |
| | WB | 10 | 13 | 2 | 25 | 6 | 2 | 14 | 9 | |

**Table (E-3) Conflict Data at al-Fadael Intersection**

| Time | App. | Traffic Conflict /h | | | | | | | | Total TC/h |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Rear-end Conflict | | | | Lane-change Conflict | | | Crossing Conflict | |
| | | C1 | C2 | C3 | Total | C4 | C5 | Total | C6 | |
| 8:05 -9:05 | NB | 6 | 8 | 4 | 18 | 3 | 7 | 10 | 6 | 156 |
| | EB | 13 | 9 | 2 | 24 | 5 | 3 | 8 | 5 | |
| | SB | 11 | 13 | 1 | 25 | 6 | 5 | 11 | 2 | |
| | WB | 9 | 14 | 5 | 28 | 11 | 6 | 17 | 2 | |

**Table (E-4) Conflict Data at al-Nesser Intersection**

| Time | App. | Traffic Conflict /h | | | | | | | | Total TC/h |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Rear-end Conflict | | | | Lane-change Conflict | | | Crossing Conflict | |
| | | C1 | C2 | C3 | Total | C4 | C5 | Total | C6 | |
| 7:35 -8:35 | NB | 18 | 14 | 7 | 39 | 11 | 6 | 17 | 5 | 186 |
| | EB | 10 | 5 | - | 15 | 7 | 3 | 10 | 2 | |
| | SB | 21 | 9 | 8 | 38 | 17 | 9 | 26 | 4 | |
| | WB | 9 | 11 | 1 | 21 | 4 | 4 | 8 | 1 | |

# Appendix (F)
## SSAM's Analysis of Trajectory Files
### Table (F-1) SSAM Outputs of Surrogate Safety Measures of Conflicts at AL-orouba Intersection

| | TTC | PET | MaxS | Delta S | DR | Max D | Max Delta V | Conflict Angle | Conflict Type |
|---|---|---|---|---|---|---|---|---|---|
| AL-orouba _050.trj | 1.3 | 1.2 | 4.88 | 4.67 | -1.8 | -2.33 | 2.66 | -1.12 | rear end |
| AL-orouba _050.trj | 1.5 | 1.4 | 6.63 | 6.27 | -1.52 | -2.12 | 3.28 | 46.49 | rear end |
| AL-orouba _050.trj | 1.2 | 2.6 | 6.3 | 4.7 | -2.55 | -3.2 | 2.46 | 16.54 | lane change |
| AL-orouba _050.trj | 0.8 | 2.2 | 8.98 | 4.96 | -0.8 | -5.51 | 3.84 | 0 | rear end |
| AL-orouba _050.trj | 0.8 | 3.5 | 8.38 | 4.42 | -0.54 | -6.99 | 3.42 | -5.34 | rear end |
| AL-orouba _050.trj | 1.1 | 1 | 4.01 | 2.17 | -5.31 | -5.31 | 1.09 | 5.17 | rear end |
| AL-orouba _050.trj | 0.9 | 2 | 7.56 | 7.55 | -2.17 | -2.91 | 4.13 | 0 | rear end |
| AL-orouba _050.trj | 0.5 | 1.3 | 5.47 | 1.81 | -7.5 | -7.64 | 0.91 | 19.89 | lane change |
| AL-orouba _050.trj | 1.5 | 0.8 | 2.99 | 1.39 | -1.08 | -1.08 | 0.72 | -0.36 | rear end |
| AL-orouba _050.trj | 1.5 | 1 | 3.58 | 1.82 | -2.15 | -2.62 | 0.91 | -17.07 | rear end |
| AL-orouba _050.trj | 1 | 3.5 | 2.99 | 2.94 | -3.45 | -3.45 | 1.49 | 0.02 | rear end |
| AL-orouba _050.trj | 0.8 | 1.8 | 5.69 | 2.49 | -1.3 | -7.86 | 1.24 | 0 | rear end |
| AL-orouba _050.trj | 0.9 | 0.9 | 5.58 | 1.83 | -4.22 | -7.2 | 0.96 | 0 | rear end |
| AL-orouba _050.trj | 1 | 2.1 | 5.91 | 3.91 | -7.48 | -7.5 | 1.99 | 0 | rear end |
| AL-orouba _050.trj | 1.5 | 4.5 | 6.07 | 1.08 | -0.43 | -7.94 | 0.56 | 0 | rear end |
| AL-orouba _050.trj | 1.1 | 2.3 | 6.63 | 7.05 | -0.88 | -6.55 | 3.75 | 89.6 | crossing |
| AL-orouba _050.trj | 0.9 | 1.2 | 5.23 | 2.21 | -2.09 | -4.61 | 1.12 | 0 | rear end |
| AL-orouba _050.trj | 1.2 | 3.1 | 1.89 | 1.31 | -0.27 | -2.03 | 0.72 | -0.13 | rear end |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| AL-orouba _050.trj | 1.3 | 3 | 1.37 | 1.33 | -1.61 | -1.72 | 0.7 | 0 | rear end |
| AL-orouba _050.trj | 1.5 | 0.9 | 5.08 | 2.27 | -2.78 | -3.01 | 1.19 | -14.27 | lane change |
| AL-orouba _050.trj | 1.4 | 2.3 | 5.81 | 5.23 | -2.22 | -2.97 | 2.67 | 15.68 | lane change |
| AL-orouba _050.trj | 1.2 | 3.7 | 2.34 | 2.34 | -2.38 | -2.38 | 1.22 | 34.74 | lane change |
| AL-orouba _050.trj | 1.3 | 2 | 7.89 | 4.8 | -2.03 | -3.4 | 2.48 | 0 | rear end |
| AL-orouba _050.trj | 1.4 | 1.3 | 6.91 | 6.02 | -2.84 | -2.84 | 3.08 | 19.69 | rear end |
| AL-orouba _050.trj | 1.2 | 2.6 | 5.05 | 4.62 | -3.19 | -3.19 | 2.38 | -0.18 | rear end |
| AL-orouba _050.trj | 1.5 | 3.8 | 7.38 | 0.44 | -1.06 | -1.17 | 0.24 | 0.48 | rear end |
| AL-orouba _050.trj | 1.2 | 1.6 | 3.93 | 2.61 | -1.28 | -4.86 | 1.41 | -16.39 | lane change |
| AL-orouba _050.trj | 1.3 | 1.5 | 6.04 | 5.28 | -2.09 | -3.13 | 2.81 | 0 | rear end |
| AL-orouba _050.trj | 1.3 | 3.5 | 6.14 | 2.4 | -2.09 | -2.53 | 1.24 | 0 | rear end |
| AL-orouba _050.trj | 1.3 | 3.1 | 7.33 | 2.36 | -1.43 | -4.46 | 1.35 | 0 | rear end |
| AL-orouba _050.trj | 1 | 1.2 | 7.9 | 7.6 | -0.54 | -7.02 | 4.04 | 0 | rear end |
| AL-orouba _050.trj | 1 | 1.6 | 5.97 | 5.68 | -2.12 | -4.97 | 3.06 | 30.57 | lane change |
| AL-orouba _050.trj | 1.2 | 1.5 | 5.36 | 5.23 | -0.01 | -0.78 | 2.62 | 29.09 | rear end |
| AL-orouba _050.trj | 1.2 | 3.7 | 3.47 | 3.47 | -1.78 | -1.78 | 1.78 | 4.22 | rear end |
| AL-orouba _050.trj | 1 | 2.7 | 5.38 | 4.71 | -0.76 | -5.33 | 2.42 | 0 | rear end |
| AL-orouba _050.trj | 1.1 | 0.7 | 4.36 | 1.59 | -1.24 | -5.49 | 0.82 | 0 | rear end |
| AL-orouba _050.trj | 0.2 | 3.6 | 4.41 | 0.4 | -0.22 | -7.85 | 0.2 | 0 | rear end |
| AL-orouba _050.trj | 0.9 | 1.7 | 3.68 | 2.41 | -0.14 | -2.28 | 1.24 | 0 | rear end |
| AL-orouba _050.trj | 1.5 | 0.6 | 3.6 | 1.38 | -0.29 | -1.35 | 0.69 | 0 | rear end |
| AL-orouba _050.trj | 1.2 | 1.5 | 5.61 | 4.55 | 0 | 0 | 2.45 | 20.54 | rear end |
| AL-orouba _050.trj | 1.5 | 0.8 | 3.82 | 3.82 | 0 | 0 | 2.8 | -10.37 | lane change |
| AL-orouba _050.trj | 1.2 | 0.4 | 5.37 | 1.77 | -0.73 | -3.84 | 1.01 | 0 | rear end |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| AL-orouba _050.trj | 0.1 | 0.4 | 9.14 | 9.11 | -1.52 | -7.79 | 4.69 | 25.93 | rear end |
| AL-orouba _050.trj | 0.9 | 0.5 | 7.83 | 5.23 | -0.39 | -3.29 | 2.8 | 0 | rear end |
| AL-orouba _050.trj | 1.3 | 0.7 | 5.86 | 2.63 | -2.28 | -2.81 | 2.15 | -12.69 | lane change |
| AL-orouba _050.trj | 1.4 | 1.1 | 7.09 | 2.67 | -1.77 | -2.11 | 1.4 | 11.69 | lane change |
| AL-orouba _050.trj | 1.3 | 0.8 | 5.58 | 1.49 | -2.82 | -2.82 | 1.24 | 0 | rear end |
| AL-orouba _050.trj | 1.1 | 4.1 | 4.14 | 3.72 | 3.05 | 3.05 | 2.99 | 177.77 | crossing |
| AL-orouba _050.trj | 0.9 | 4.7 | 9.3 | 3.33 | -5.62 | -5.62 | 2.72 | -0.02 | rear end |
| AL-orouba _050.trj | 1.4 | 1 | 7.46 | 6.95 | -0.1 | -1.21 | 5.68 | 0.69 | rear end |
| AL-orouba _050.trj | 0.3 | 2.9 | 6.77 | 6.77 | -0.76 | -7.53 | 3.39 | -3.98 | rear end |
| AL-orouba _050.trj | 0.8 | 1.4 | 5.36 | 0.68 | -0.51 | -0.57 | 0.55 | 6.22 | rear end |
| AL-orouba _050.trj | 0.5 | 1.4 | 7.47 | 6.97 | -0.34 | -0.85 | 5.82 | -5.59 | rear end |
| AL-orouba _050.trj | 0.8 | 1.6 | 5.45 | 5.26 | -1.66 | -5.14 | 2.92 | 0 | rear end |
| AL-orouba _050.trj | 1.3 | 0.1 | 6.83 | 3.17 | -0.2 | -2.1 | 1.73 | 0 | rear end |
| AL-orouba _050.trj | 1.3 | 0.7 | 7.42 | 4.98 | -2.5 | -2.5 | 4.03 | 7.28 | lane change |
| AL-orouba _050.trj | 1.4 | 1.4 | 4.96 | 4.91 | -1 | -1.39 | 2.68 | -0.23 | rear end |
| AL-orouba _050.trj | 1.5 | 2 | 2.67 | 1.18 | -0.55 | -3.6 | 0.96 | 0 | rear end |
| AL-orouba _050.trj | 1.4 | 2.3 | 7.81 | 4.07 | -1.36 | -2.89 | 2.07 | -3.36 | rear end |
| AL-orouba _050.trj | 1.4 | 1.7 | 3.65 | 1.4 | -0.4 | -1.82 | 1.13 | -0.1 | rear end |
| AL-orouba _050.trj | 0.1 | 3.6 | 7.46 | 0.79 | -0.51 | -6.96 | 0.62 | -10.68 | rear end |
| AL-orouba _050.trj | 1.4 | 1.3 | 2.72 | 1.32 | -0.15 | -0.49 | 1.06 | 0.06 | rear end |
| AL-orouba _050.trj | 1.5 | 1.1 | 2.21 | 2.21 | -2.16 | -5.66 | 1.32 | -73.92 | lane change |
| AL-orouba _050.trj | 1.1 | 3.4 | 4.45 | 1.58 | -0.3 | -7.84 | 0.79 | -4.92 | rear end |
| AL-orouba _050.trj | 1.3 | 2.4 | 7.76 | 0.21 | -0.2 | -4.17 | 0.1 | 0 | rear end |
| AL-orouba _050.trj | 1.3 | 1.4 | 3.06 | 1.31 | -0.79 | -3.8 | 0.68 | 0 | rear end |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| AL-orouba _050.trj | 1.2 | 2.3 | 2.63 | 2.61 | -0.31 | -6.06 | 1.35 | 0 | rear end |
| AL-orouba _050.trj | 1 | 3.6 | 4.24 | 2.46 | -5.64 | -5.64 | 1.31 | -1.45 | rear end |
| AL-orouba _050.trj | 1.3 | 3.7 | 3.64 | 2.23 | -1.72 | -4.36 | 1.27 | 0 | rear end |
| AL-orouba _050.trj | 0.1 | 0.8 | 7.58 | 0.82 | -1.46 | -5.66 | 0.61 | 3.42 | rear end |
| AL-orouba _050.trj | 0.9 | 2.8 | 8.27 | 5.99 | -0.43 | -5.89 | 2.99 | 0 | rear end |
| AL-orouba _050.trj | 0.9 | 0.6 | 5.97 | 5.35 | -0.79 | -7.12 | 2.84 | 0 | rear end |
| AL-orouba _050.trj | 1.4 | 0.7 | 5.85 | 5.85 | -2.56 | -2.98 | 3.07 | 9.49 | rear end |
| AL-orouba _050.trj | 1.4 | 1 | 2.97 | 2.07 | -1.46 | -3.12 | 1.18 | -0.94 | rear end |
| AL-orouba _050.trj | 1.5 | 0.8 | 3.21 | 2.66 | -1.03 | -1.03 | 1.41 | -50.81 | lane change |
| AL-orouba _050.trj | 1.2 | 0.4 | 3.2 | 3.12 | -7.62 | -7.62 | 1.56 | -6.97 | rear end |
| AL-orouba _050.trj | 1.3 | 3.2 | 8.01 | 1.77 | -0.45 | -7.04 | 0.95 | 0 | rear end |
| AL-orouba _050.trj | 1.2 | 2.4 | 5.68 | 1.25 | -0.26 | -5.21 | 0.64 | -10.05 | rear end |
| AL-orouba _050.trj | 1.3 | 0.4 | 2.84 | 2.6 | -1.34 | -4.36 | 1.4 | 15.42 | rear end |
| AL-orouba _050.trj | 1.3 | 2.5 | 7.43 | 7.33 | -0.9 | -3.04 | 3.78 | 0 | rear end |
| AL-orouba _050.trj | 1.2 | 0.9 | 2.24 | 0.54 | -2.29 | -2.29 | 0.29 | 6.73 | rear end |
| AL-orouba _050.trj | 1.1 | 2.8 | 1.28 | 0.97 | -4.53 | -4.53 | 0.5 | -43.35 | rear end |
| AL-orouba _050.trj | 1.4 | 0.9 | 4.82 | 2.54 | -7.19 | -7.19 | 1.35 | -6.79 | rear end |
| AL-orouba _050.trj | 0.8 | 0.7 | 6.3 | 6.06 | -1.31 | -7.5 | 3.26 | -5.74 | lane change |

# Appendix (G)

**Statistics And The Normal The Speed Distribution Test.**

**Table (G-1) The Speed Descriptive Statistics And The Normal Distribution Test. at AL-orouba Intersection**

| Intersection | | Minimum | Maximum | Range | Mean | Std. Deviation |
|---|---|---|---|---|---|---|
| Al-jamhori | NB | 15.1 | 25 | 9.9 | 20.23 | 2.30 |
| | EB | 16.36 | 28.5 | 12.14 | 20.45 | 2.94 |
| | SB | 16.61 | 27.8 | 11.19 | 22.5 | 2.67 |
| | WB | 16.11 | 26.34 | 10.23 | 19.94 | 2.48 |

**Table (G-2) The Speed Descriptive Statistics And The Normal Distribution Test at Al- Fadael Intersection**

| Intersection | | Minimum | Maximum | Range | Mean | Std. Deviation |
|---|---|---|---|---|---|---|
| Al-jamhori | NB | 17.5 | 29.8 | 12.3 | 22.305 | 2.8 |
| | EB | 16.89 | 30.02 | 13.13 | 22.044 | 3.63 |
| | SB | 19.24 | 33.4 | 14.16 | 23.32 | 3.11 |
| | WB | 18.55 | 31.55 | 13 | 23.745 | 3.085 |

# Appendix (H)

## Statistical Analyses of SSAM Outputs

## Table (H-1) Descriptive Statistics Analyses Related to validation the Simulation Approach in Estimation Safety at Signalized Intersections

**ANOVA[a]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 504.987 | 1 | 504.987 | 77.612 | .013[b] |
| | Residual | 13.013 | 2 | 6.507 | | |
| | Total | 518.000 | 3 | | | |

a. Dependent Variable: OB.T

b. Predictors: (Constant), SIM.T

## Table (H-2) Statistical Description of Correlation between Simulation and Field Conflicts After Calibration

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | R Square Change | F Change | df1 | df2 | Sig. F Change |
| 1 | .987[a] | .975 | .962 | 2.55079 | .975 | 77.612 | 1 | 2 | .013 |

a. Predictors: (Constant), SIM.T

## Table (H-3) Descriptive Statistics Analyses Related to validation the Simulation Approach in Estimation Safety at Signalized Intersections

**ANOVA[a]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 308.357 | 1 | 308.357 | 42.117 | .023[b] |
| | Residual | 14.643 | 2 | 7.322 | | |
| | Total | 323.000 | 3 | | | |

a. Dependent Variable: OB.T

b. Predictors: (Constant), SIM.T

## Table (H-4) Statistical Description of Correlation between Simulation and Field Conflicts After Calibration

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | R Square Change | F Change | df1 | df2 | Sig. F Change |
| 1 | .977[a] | .955 | .932 | 2.70583 | .955 | 42.117 | 1 | 2 | .023 |

a. Predictors: (Constant), SIM.T

## Table (H-5) Descriptive Statistics Analyses Related to validation the Simulation Approach in Estimation Safety at Signalized Intersections

**ANOVA[a]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 88.453 | 1 | 88.453 | 31.893 | .030[b] |
| | Residual | 5.547 | 2 | 2.773 | | |
| | Total | 94.000 | 3 | | | |

a. Dependent Variable: OB.T

b. Predictors: (Constant), SIM.T

## Table (H-6) Statistical Description of Correlation between Simulation and Field Conflicts After Calibration

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | R Square Change | F Change | df1 | df2 | Sig. F Change |
| 1 | .970[a] | .941 | .911 | 1.66535 | .941 | 31.893 | 1 | 2 | .030 |

a. Predictors: (Constant), SIM.T

# Appendix (I)

## Intersections After and before Countermeasure

### Table (I-1) traffic signal of Al- Fadael Intersection After and before retiming traffic signal Countermeasure

| | Phase1 sec | | Phase2 sec | | Phase3 sec | | Phase4 sec | | |
|---|---|---|---|---|---|---|---|---|---|
| | before | after | before | after | before | after | before | after | |
| Al-Fadael | 113 | 56 | 113 | 57 | 111 | 55 | 111 | 57 | red |
| | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | yellow |
| | 33 | 31 | 33 | 30 | 35 | 32 | 35 | 30 | green |

### Table (I-2) traffic signal of Al-Oruba Intersection After and before retiming traffic signal Countermeasure

| | Phase1 sec | | Phase2 sec | | Phase3 sec | | Phase4 sec | | |
|---|---|---|---|---|---|---|---|---|---|
| | before | after | before | after | before | after | before | after | |
| Al-Oruba | 104 | 71 | 98 | 74 | 99 | 70 | 109 | 80 | red |
| | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | yellow |
| | 27 | 50 | 33 | 57 | 32 | 61 | 22 | 51 | green |

### Table (I-3) traffic signal of Al-Jamhori Intersection After and before retiming traffic signal Countermeasure

| | Phase1 sec | | Phase2 sec | | Phase3 sec | | Phase4 sec | | |
|---|---|---|---|---|---|---|---|---|---|
| | before | after | before | after | before | after | before | after | |
| Al-Jamhori | 111 | 85 | 111 | 77 | 109 | 87 | 110 | 85 | red |
| | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | yellow |
| | 27 | 32 | 27 | 40 | 29 | 30 | 28 | 32 | green |

### Table (I-4) traffic signal of Al-nesser Intersection After and before retiming traffic signal Countermeasure

| | Phase1 sec | | Phase2 sec | | Phase3 sec | | Phase4 sec | | |
|---|---|---|---|---|---|---|---|---|---|
| | before | after | before | after | before | after | before | after | |
| Alnesser | 124 | 85 | 125 | 85 | 124 | 85 | 126 | 85 | red |
| | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | yellow |
| | 31 | 35 | 30 | 35 | 31 | 35 | 29 | 35 | green |

**Table (I-5) Al-jamhori Intersection After and before Increase Width of Lane Countermeasure**

| Aljamhori | Approach1 meter | | Approach2 meter | | Approach3 meter | | Approach4 meter | |
|---|---|---|---|---|---|---|---|---|
| | before | after | before | after | before | after | before | after |
| | 3.2 | 3.6 | 3 | 3.3 | 3.2 | 3.6 | 3 | 3.3 |
| | 3.2 | 3.6 | 3 | 3.3 | 3.2 | 3.6 | 3 | 3.3 |
| | 3.2 | 3.6 | 3 | 3.3 | 3.2 | 3.6 | 3 | 3.3 |

**Table (I-6) Al-nesser Intersection After and before Increase Width of Lane Countermeasure**

| Alnesser | Approach1 meter | | Approach2 meter | | Approach3 meter | | Approach4 meter | |
|---|---|---|---|---|---|---|---|---|
| | before | after | before | after | before | after | before | after |
| | 3.3 | 3.6 | 3.1 | 3.4 | 3.3 | 3.6 | 3.1 | 3.4 |
| | 3.3 | 3.6 | 3.1 | 3.4 | 3.3 | 3.6 | 3.1 | 3.4 |
| | 3.3 | 3.6 | 3.1 | 3.4 | 3.3 | 3.6 | 3.1 | 3.4 |
| | 3.3 | 3.6 | 3.1 | 3.4 | 3.3 | 3.6 | 3.1 | 3.4 |

**Table (I-7) Al-nesser Intersection After and before Increase Width of Lane Countermeasure**

| | Approach1 meter | | Approach2 meter | | Approach3 meter | | Approach4 meter | |
|---|---|---|---|---|---|---|---|---|
| | before | after | before | after | before | after | before | after |
| Alnisser | 3.1 | 3.65 | 3 | 3.65 | 3.1 | 3.65 | 3 | 3.65 |
| | 3.1 | 3.65 | 3 | 3.65 | 3.1 | 3.65 | 3 | 3.65 |
| | 3.1 | 3.65 | 3 | 3.65 | 3.1 | 3.65 | 3 | 3.65 |
| | 3.1 | 3.65 | | | 3.1 | 3.65 | | |

**Table (I-8) Al-Oruba Intersection After and before Increase Width of Lane Countermeasure**

| | Approach1 meter | | Approach2 meter | | Approach3 meter | | Approach4 meter | |
|---|---|---|---|---|---|---|---|---|
| | before | after | before | after | before | after | before | after |
| Al-Fadael | 2.8 | 3.4 | 3.3 | 3.65 | 2.8 | 3.4 | 3.3 | 3.65 |
| | 2.8 | 3.4 | 3.3 | 3.65 | 2.8 | 3.4 | 3.3 | 3.65 |
| | 2.8 | 3.4 | 3.3 | 3.65 | 2.8 | 3.4 | 3.3 | 3.65 |

**Table (I-9) Traffic Signal of Al- Fadael Intersection After and Before Optimization Traffic Signal Countermeasure**

| | Phase1 sec | | Phase2 sec | | Phase3 sec | | Phase4 sec | | |
|---|---|---|---|---|---|---|---|---|---|
| | before | after | before | after | before | after | before | after | |
| Al- Fadael | 113 | 63 | 113 | 73 | 111 | 63 | 111 | 73 | red |
| | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | yellow |
| | 33 | 24 | 33 | 20 | 35 | 24 | 35 | 20 | green |

**Table (I-10) traffic signal of Al-Oruba Intersection After and before Optimization traffic signal Countermeasure**

| | Phase1 sec | | Phase2 sec | | Phase3 sec | | Phase4 sec | | |
|---|---|---|---|---|---|---|---|---|---|
| | before | after | before | after | before | after | before | after | |
| Al- Oruba | 104 | 81 | 98 | 87 | 99 | 75 | 109 | 89 | red |
| | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | yellow |
| | 27 | 35 | 33 | 29 | 32 | 41 | 22 | 27 | green |

**Table (I-11) traffic signal of Al-Jamhori Intersection After and before Optimization traffic signal Countermeasure**

| | Phase1 sec | | Phase2 sec | | Phase3 sec | | Phase4 sec | | |
|---|---|---|---|---|---|---|---|---|---|
| | before | after | before | after | before | after | before | after | |
| Al-Jamhori | 111 | 77 | 111 | 83 | 109 | 77 | 110 | 87 | red |
| | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | yellow |
| | 27 | 32 | 27 | 26 | 29 | 32 | 28 | 22 | green |

**Table (I-12) traffic signal of Al-nesser Intersection After and before Optimization traffic signal Countermeasure**

| | Phase1 sec | | Phase2 sec | | Phase3 sec | | Phase4 sec | | |
|---|---|---|---|---|---|---|---|---|---|
| | before | after | before | after | before | after | before | after | |
| Alnesser | 124 | 104 | 125 | 91 | 124 | 101 | 126 | 94 | red |
| | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | yellow |
| | 31 | 27 | 30 | 40 | 31 | 30 | 29 | 37 | green |

خلاصة

تعتمد الطريقة التقليدية لتقييم حالة السلامة عند التقاطعات المزودة بإشارات على بيانات الحوادث التاريخية. تمثل الصعوبة والانتظار الطويل لجمع البيانات بالإضافة إلى عدم الموثوقية بعض القيود. نتيجة لتقييم السلامة بالطريقة التقليدية، قد يتم اقتراح تدابير مضادة لتحسين درجة السلامة. تهدف هذه الدراسة إلى تقييم فعالية التدابير المضادة عند التقاطعات ذات الإشارات باستخدام برنامج نموذج المحاكاة الدقيقة (VISSIM10) ونموذج تقييم السلامة البديل (SSAM) للتعامل مع النزاعات المرورية كتدابير بديلة بدلاً من بيانات الأعطال.

اعتمدت الدراسة على برنامج (VISSIM10) لإنشاء ملف المسار(trj) كمدخلات لـSSAM لغرض إجراء تقييم السلامة المرورية باستخدام الصراعات المرورية ووقت الاصطدام (TTC) كمؤشرات للسلامة. تم اختيار أربعة تقاطعات ذات إشارات ضوئية في مدينة الديوانية لتقييم السلامة ومن ثم اقتراح الإجراءات المضادة المناسبة. يتم اختبار التدابير المضادة المختلفة من خلال المحاكاة لتقدير فعاليتها باستخدام مقياسين: زيادة الوقت اللازم للاصطدام (TTC) وتقليل النسبة المئوية للتعارضات المرورية. يكشف التقييم قبل الإجراءات المضادة أن تقاطعي الجمهوري والعروبة تصنف بانها عالية المخاطر حيث تبلغ (TTC) 0.992 و0.984 ثانية على التوالي، في حين أن تقاطعي الفضائل والنسر متوسطة الخطورة مع (1.023,1.116) TTC ثانية على التوالى. أظهرت محاكاة تنفيذ الإجراءات المضادة أن زيادة عرض الحارات قلل من التعارضات المرورية (39.66،43.3،36.945.93)% عند تقاطعات الجمهوري والعروبة والفضائل والنسر على التوالي، كما أدت زيادة أعداد المسارات إلى انخفاض الصراعات المرورية. (44.28،38.1، 45.77، 53.11) عند تقاطعات الجمهوري والعروبة والفضائل والنسر على التوالي. أدت إضافة مراحل الانعطاف لليسار إلى تقليل التعارضات المرورية (44.28،41.8،28.34،45) عند تقاطعات الجمهوري والعروبة والفضائل والنسر على التوالي، بينما أدى إلغاء U-turn إلى تقليل التعارضات المرورية (30.9،21.5). ) عند تقاطعي الجمهوري والنسر على التوالي.

محاكاة تحسين توقيت الإشارات المرورية ادت  إلى تقليل التعارضات المرورية بنسبة (23، 29.9، 28.84، 32.8)% عند تقاطعات الجمهوري، العروبة، الفضائل والنسر على التوالي، في حين أدى تحسين توقيت الإشارات المرورية الميدانية إلى تقليل التعارضات المرورية بنسبة (36، 7، 25.3، 23.94، 13)% عند تقاطعات الجمهوري والعروبة والفضائل والنسر على التوالي.. أظهرت النتائج أن معايرة النموذج قللت من متوسط الخطأ المطلق (MAPE)وحسنت التوافق بين كل من التعارضات المرصودة والمحاكاة.

أظهرت محاكاة تحسين توقيت الإشارات المرورية كإجراء مضاد أنه يمكن تقليل إجمالي التعارضات المرورية (23، 29.9، 28.84، 32.8)% عند تقاطعات الجمهوري، العروبة، الفضائل والنسر على التوالي، بينما التحسينات الميدانية لتوقيت الإشارات المرورية تبين أنه يمكن تقليل إجمالي التعارضات المرورية (36،7، 25.3، 23.94، 13)٪ عند تقاطعات الجمهوري والعروبة والفضائل والنسر على التوالي.

وبالتالي، يمكن أن نستنتج أنه في عملية المحاكاة كانت اعلى في تقدير إجمالي تعارضات حركة المرور.

تم تخفيض قيم MAPE من 43% إلى 24% لتعارضات النهاية الخلفية(RE)، من 25% إلى 9% لتعارضات العبور(C)، من 71.9% إلى 45.6% لتعارضات تغير مسار (LC ) ومن 41.9% إلى 10.6% لإجمالي التعارضات الكلية. تم التحقق من صحة المحاكاة مقارنة بالتعارض الحقلي. وفقا للانحدار الخطي يرتبط عدد الصراعات المحاكاة بشكل كبير بعدد الصراعات المرصودة حقليا. بالإضافة إلى ذلك، يمكن تفسير النتائج الحقلية من خلال قيمة $R^2$ للنموذج من خلال الاختلاف في محاكاة الصراعات

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قسم الهـندسة المدنيـــة

# محاكاة معايير بديلة لتقييم كفاءة المعالجات في التقاطعات المرورية

رسالة

مقدمة الى كلية الهندسة ـ جامعة بابل وهي جزء من متطلبات نيل درجة الماجستير في الهندسة/ الهندسة المدنية/ المواصلات

من قبل
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