ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

MODELING THE CONFLICTS OF CROSSING PEDESTRIAN WITH VEHICLES IN TURNING RIGHT AT SIGNALIZED INTERSECTIONS

By: Michael Asseged Belay

A Thesis submitted to the School of Graduate Studies in Partial Fulfillment of

The Requirements for the Degree of

Master of Science

In

Road and Transport Engineering

Research Advisor: Bikila Teklu Wodajo (PhD)

June, 2019

Addis Ababa, Ethiopia

ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

MODELING THE CONFLICTS OF CROSSING PEDESTRIAN WITH VEHICLES IN TURNING RIGHT AT SIGNALIZED INTERSECTIONS

By: Michael Asseged Belay

A Thesis Submitted to the School of Graduate Studies in Partial Fulfillment of

The Requirements for the Degree of

Master of Science

In

Road and Transport Engineering

Approved by Board of Examiners:

Advisor	Signature	Date
Internal Examiner	Signature	Date
External Examiner	Signature	Date
Chair person	Signature	Date

UNDERTAKING

I certify that research work titled "**Modeling the Conflicts of Crossing Pedestrian with Vehicles in Turning Right at Signalized Intersections**" is my own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged / referred.

Signature: _______________

Undertaker's Full Name: Michael Asseged Belay

Place of Undertaking: Addis Ababa, Ethiopia.

Date: June, 2019

ABSTRACT

A great number of problems persist in Addis Ababa traffic networks for its huge population. The high level of conflict between pedestrians and motor vehicles at intersections is one of the most obvious. It is necessary to study the interaction mechanism of pedestrians and right-turn vehicles in Addis Ababa, Ethiopia. This paper focuses on the development of an empirical model which describes the interaction of pedestrians and motor vehicles at right turns. Four intersections have been selected based on crossing pedestrian volume, right turn vehicle volume, location of crosswalk and right turn vehicle controlling mechanism. Vehicle and pedestrian movement and conflict data were collected at each camera location during the mid-day (11:00am-2:00pm) periods.

In this study multiple linear and Poisson regression analysis techniques employed to model the number of potential conflicts between right turning vehicles and pedestrians. Stepwise model-selection techniques used to screen out predictors. The selected predictor variables are pedestrian volume, right turn volume and number of lanes. It has been found that an increase in right turn vehicle volume significantly affects the number of conflicts more than pedestrian volume and number of lanes has an inverse relationship with number of conflicts. Also a binary logistic regression model has been developed for pedestrian yielding decision. The key predictor variables according to the stepwise regression result are population of pedestrian group, volume of right turn vehicle, turning speed, Direction of pedestrian and Location of cross walk. The result showed that pedestrian yielding is less likely to occur as the people in pedestrian group increases and when the location of cross walk is near to the intersection. Pedestrian yielding is more likely to occur as right turn vehicle volume increases, right turn vehicle turning speed increases and when pedestrian crosses from near side to far side. The results from this analysis can be used in order to evaluate signalized intersections with respect to the risk they impose on pedestrians.

Keywords; pedestrian, right turn vehicle, traffic conflict, conflict area, regression model and signalized intersection

ACKNOWLEDGMENT

First and foremost, I would like to thank the son of the living God, Jesus Christ for giving me the strength, knowledge, ability and opportunity to undertake this research study and to persevere and complete it satisfactorily. Without his blessing, this achievement would not have been possible.

Secondly, I would like to express my sincere gratitude to my advisor Dr. Bikila Teklu for the continuous support of my M.Sc. study and research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of the research and writing of this thesis.

Thirdly, my deep and sincere gratitude to my family for their continuous and unparalleled love, help and support. I am grateful to my mother for always being there for me. I am forever indebted to my parents for giving me the opportunities and experiences that have made me who I am.

Fourthly, I would like to thank my fellow friends Nardos Ashenafi, Habtamu Chalachew and Michael Amare for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis.

The Last but not the least, I would like to thank Ethiopian road authority (ERA) for funding my graduate study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

CBE- Commercial Bank of Ethiopia

RTOR- Right Turn On Red

RTOG- Right Turn On Green

PED- Pedestrian Volume

VEH- Right Turn Vehicle Volume

NL- Number of Lanes

C- Channelization

Pn- Population of Pedestrian

Rn- Number of the RT Vehicles Being Viewed By the Pedestrian At One Time When Crossing

Tt- Turning Speed of Right Turn Vehicles

EPG- Existence of Pedestrian Group

DP- Direction of Pedestrians

LCW- Location of Crosswalk

LC- Location of Conflicts

Pyn- Probability of Pedestrian Yielding

CHAPTER ONE - INTRODUCTION

1.1 General Background

Road traffic injuries claim more than 1.35 million lives each year and have a huge impact on health and development. 26% of all deaths on the world's roads are among those with the least protection – motorcyclists, cyclists and pedestrians. However, the likelihood of dying on the road as a motorcyclist, cyclist or pedestrian varies by region: the African region has the highest proportion of pedestrian and cyclist deaths at 44% of all road traffic deaths(***WHO et al., 2018***).

In Ethiopian; Pedestrian safety is a critical issue. Reports show that 37% of traffic fatality victims in the country are pedestrians (***WHO et al., 2018***). Most pedestrian crashes occurred in urban environments. The city of Addis Ababa has taken the lion's share of the pedestrian accidents. The majority of pedestrian crashes occurred due to conflicts between pedestrians and vehicles (***Tulu, Washington and King, 2013***). These conflicts occurred when pedestrians tried to cross the road.

At signalized intersections, pedestrian traffic is very high in highly populous cities like Addis Ababa. A great number of problems persist in Addis Ababa traffic networks for its huge population. The high level of conflict between pedestrians and motor vehicles in intersections is one of the most obvious. The primary causes of pedestrian crashes are turning vehicle crashes and pedestrian violations(***Ling, Ni and Li, 2012***). Intersections become disorderly and inefficient when pedestrians violate a red light. Furthermore, the potential threat to pedestrians crossing at signalized intersections may be on the high amount of right turn vehicle volume.

Taking this into account, different researches conducted by different scholars to determine the factors that affects the interaction. Even if plenty of research has dealt with the interaction, none has focused on Ethiopia realities. And that is what initiated the interest of the researcher in conducting a research on the effects of the factors (including mathematical model) on the interaction at signalized intersection; in case of Addis Ababa, Ethiopia .

1.2 Statement of the Problem

In Ethiopia, the majority of pedestrian accidents occur due to conflicts between pedestrians and vehicles (***Tulu, Washington and King, 2013***). The primary causes of pedestrian crashes are turning vehicle crashes and pedestrian violations (***Ling, Ni and Li, 2012***). In pedestrian crossings, pedestrians have priority than the vehicles, and vehicles should yield to the pedestrians. Violating the pedestrian priority rule causes a safety problem along with a mobility problem for pedestrians.

In most signalized intersection right turn vehicles are allowed to perform their maneuver while the pedestrian green light is on. This situation creates conflicts between pedestrians and vehicles that occupy the crosswalk space. Such conflicts bring in delays to pedestrians and turning vehicles, and increase the likelihood for a crash to occur.

On the contrary, the reduction of pedestrian-vehicle conflicts through the application of proper traffic-control measures typically leads to a decrease in the overall operational efficiency of the signalized intersection.

1.3 Research Questions

- What are the key factors that affect number of conflicts between pedestrians and right-turn vehicles?
- What are the key factors that affect pedestrian yielding behavior?
- What mathematical model can model the number of conflicts?
- What mathematical model can model the pedestrian yielding behavior?

1.4 Objective of the Study

1.4.1 General Objective

The general objective of the research is to examine the interactions between right-turn vehicles and pedestrians crossing at signalized intersections.

1.4.2 Specific Objective

The specific objectives of the research are:

- To determine factors that affects the number of potential conflicts between right turning vehicles and pedestrians
- To develop a model of pedestrian-motor vehicle interactions (number of potential conflict)
- To determine factors that affect pedestrian yielding behavior
- To derive a statistical model of pedestrian and right turn vehicle yielding behavior

1.5 Scope and Limitation of the Study

1.5.1 Scope of the Study

The scope of the study covers modeling the conflicts between pedestrians and right turn vehicles (number of potential conflicts and yielding behavior) from a study of a selected signalized intersection in the city of Addis Ababa

1.5.2 Limitations of the Study

The study will not prove to tell adequate about the following issues:

- Effect of considerable pavement distresses
- Effect of seasonal variation
- Effect of pedestrian age and gender
- Due to the shortage of time and budget the selected signalized intersections for this study are only four (this may leads to sample size shortage). This may affect the ststistical result of the study.

1.6 Research Challenge

The following were some of the challenges faced during data collection and data extraction stage.

- Throughout the data collection stage the major challenge was getting permission from authorities to capture a video data on the selected intersection.

- During the data extraction stage due to lack of extraction software the researcher obligated to extract the required data manually and it took more than two months, it was a hard work to do.

1.7 Thesis Organization

This research is basically divided into five main chapters. Chapter one intends to introduce the underlying background science to the topic and the intended purposes in doing the research. The second chapter extends the effort to look on background science in detail by reviewing different literatures in the field. The third one defines the materials and methods that were followed. Fourthly, the data collected from the study area and the results and interpretation of the models are presented summarized in Tables and graphs. Lastly in Chapter five, the General objectives get their directives and it marks the end of the research.

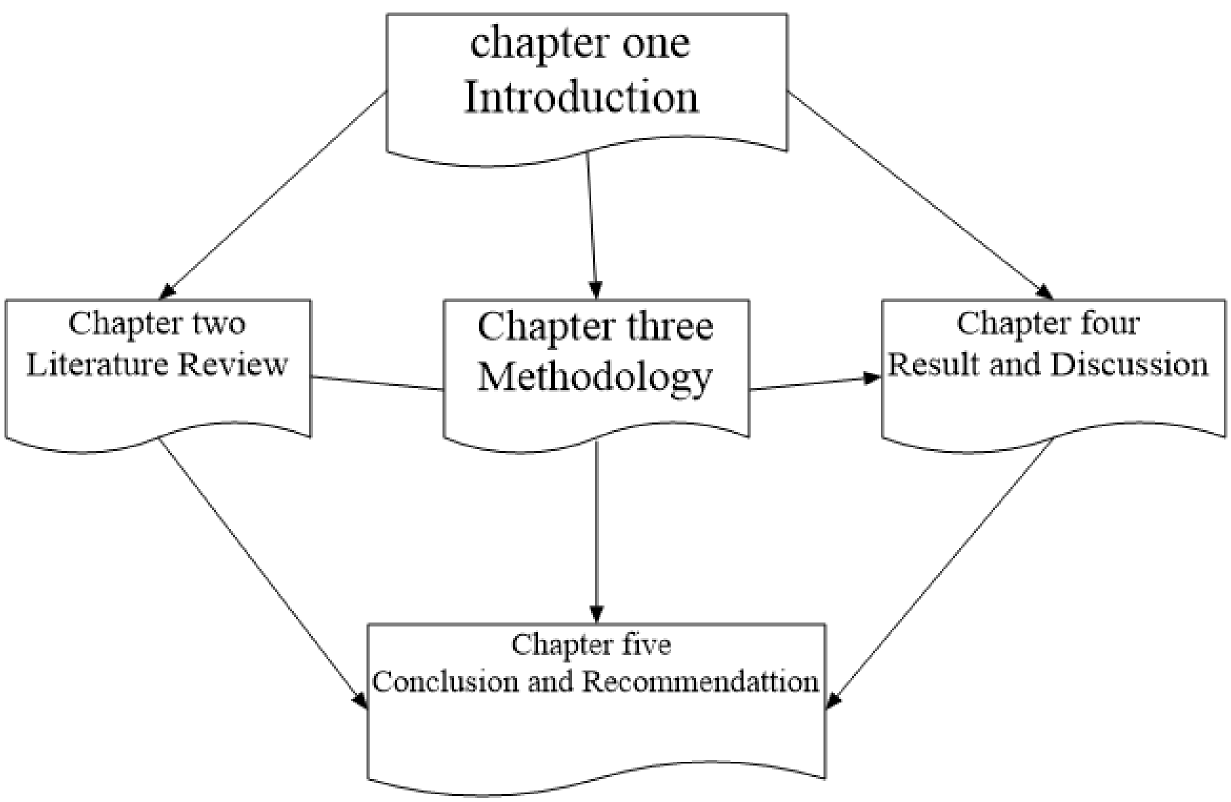


Figure 1 Organization of the Study

CHAPTER TWO - LITERATURE REVIEW

2.1 Introduction

Numerous studies on pedestrian safety have been conducted with different data and methodologies. The main focus has been to explore the factors associated with the severity and frequency of pedestrian crashes; and countermeasures that best address pedestrian fatalities and injuries

Most of the appraisals were based on crash data or conflict data. In these studies, limited research was specifically related to conflicts between pedestrians and turning vehicles at intersections. Crosswalks must provide an acceptable level of service to pedestrians with little or no conflicts with left-or right-turning motor vehicles at intersections. Separation of pedestrians from vehicular traffic and the provision of acceptable level of service in the crosswalks are expected to increase pedestrian crossing compliance with crosswalk settings as well as pedestrian safety (***Akin, 2007***).

2.2 traffic conflict

2.2.1 What is traffic conflict?

Traffic conflict is "an observable situation in which two or more road users approach each other in space and time for such an extent that there is a risk of collision if their movement remain unchanged (***Vuong, 2017***). A traffic conflict occurs when the paths of two movements that are competing for the same space (at the same time) cross each other (***Akin, 2007***). In addition to this (***Liu, 2014***)defines traffic conflict as; "it takes place when two or more road users approach each other in space and time to such an extent that a collision is imminent if their movements remain unchanged". Similarly, (***Lord, 2007)*** pointed out that traffic conflict is an event in which two road users would have collided had their paths, speeds, or both remained unchanged on an element of a transportation system. Traffic conflicts are a measure of the potential for traffic accidents.

Maneuvers taken by traffic participants mainly refer to changes of speeds and/or routes, in order to avoid collisions when they meet or approach each other spatially and/or temporally are defined as interactions. Common interactions between pedestrians and vehicles at signalized intersections such as pedestrians stop, run, withdraw or change routes, vehicles break to slow down, stop or change lanes can be distinguished by five levels depending on whether the participants obey signals, and, intensity of interactions and executor of a maneuvers ***(Ni and Li, 2011***)

The pedestrian-vehicle conflict is defined as the occurrence of collision between pedestrians and vehicles in a multi-lane road segment when they approach to a certain degree in the range of time and space without any trend to change their initial movement state. The affected area of the conflict is the whole lane width where vehicles run ***(Lu, 2009).*** According to (***Lord, 2007)***definition, the conflict between pedestrian and vehicle requires two conditions the first one is there are interactions between the pedestrian and the vehicle, and their trajectories coincide with each other. This definition emphasizes that there is a sudden change of velocity during the conflict process. ***(Davis, 2000***) also indicated right turn- vehicle conflict occurs where the projected paths of a right-turning vehicle and a pedestrian cross and either the pedestrian or the vehicle or both must change direction and/or speed to avoid a collision

2.2.2 Conflict area at intersections

The conflict area can be defined as an area in which collisions may occur if pedestrians and vehicles maintain their respective original state of movement ***(Cheng et al., 2014***).

(***Akin, 2007***) states in order to determine the pedestrian conflicts with right turning vehicles, for the definition of the conflict area, the reason that ¼ of The inner lane width at the median-side is excluded from the conflict area is that pedestrians already in the inner lane of the southbound part of the crosswalk can reach to the conflict-free median at once while they are just one step (0.75 m) away (approximately ¼ of the inner lane width, 3 m/ 4 = 0.75m) from the median.

According to (***Ling, Ni and Li, 2012***), the conflict between pedestrians and vehicles can be broken down into two categories according to the difference of conflict areas. One kind of conflict occurs at vertical pedestrian crossings between pedestrians and vehicles turning right on red. The other kind of conflict occurs at parallel pedestrian crossings between pedestrians and right-turning vehicles on a green signal. Taking safety into consideration, the latter is much more dangerous and frequent than the former(***Hubbard, Bullock and Mannering, 2009***).

2.3 Interaction modeling

2.3.1 Factors affecting the interaction

The interaction between the vehicle and the pedestrian is complex many researchers have paid close attention to the interaction mechanism between the vehicle and the pedestrian.

(***Cynecki, 1980)*** investigated the factors that play a part in the number and severity of pedestrian conflicts. The following list was developed by him to represent pedestrian conflict factors:

- Traffic volumes,
- Right-turn-on-red regulations,
- Vehicle mix (percentage of trucks and buses),
- Pedestrian volumes
- Season
- Visibility
- On-street parking,
- Shoulder widths
- Presence of a left-turn center lane
- Roadway surface conditions(i.e. potholes or drainage),
- The number of vehicle access points
- One-way versus two-way operation
- Pedestrian warning signs or flashers
- Pedestrian phasing at signalized intersections
- Pedestrian barriers
- Crossing location (intersection or midblock)
- Traffic control devices
- School site selection.
- Percentage of vehicles turning
- Traffic speeds
- The relationship between pedestrian and vehicle volumes
- Time of day and day of week,
- Weather conditions
- Sight restriction
- Presence of a left-turn center lane,
- Pavement markings,
- Medians and pedestrian islands,
- Geometrics (grade and horizontal and vertical curvature),
- Roadway lighting
- Location of sidewalks
- Crossing guards
- Enforcement of vehicle and pedestrian traffic regulations
- Grade separations
- Number of legs at intersection and angle of intersection
- Pedestrian age
- Crosswalk

He also stated that the above factors as contributing factors in increasing or reducing the chance of a pedestrian conflict. At a signalized intersection where there are a high percentage of vehicles turning, pedestrian crossing is impeded and conflicts involving turning vehicles with crossing pedestrians will result. If Right turns on red are allowed at that intersection, the number of conflicts and potential pedestrian hazards will be increased.

(***Cheng et al., 2014***), in determining the factors of conflict, his paper focuses on pedestrian volume, density, average travel speed, and the volume and ratio of left-turn vehicles. ***(Davis, 2000***) used different factors that affect number of accidents which are pedestrian and vehicle volumes, conflicts, and number of lanes, type of control, pedestrian violation.

(***Lu, 2009***)developed a probability model of pedestrian-vehicle conflict based on the principle of pedestrian-vehicle traffic conflict and pedestrian's perception of safe gap, which contains the influence factors such as the lane number, vehicle volume, width of lane.

On the other hand**,** (***Marisamynathan and Vedagiri, 2015***) modeled pedestrian vehicular interaction by using binary logit model. The main factors analyzed in his statistical test were pedestrian gender, age, group size, crossing direction, gap size, crossing speed, approaching vehicle direction, approaching vehicle lane, approaching vehicle type, median delay and road marking usage. Similarly, (***Kumar, Paul and Ghosh, 2019***) also developed a binary logistic regression model to identify significant contributing factors to the risk-taking behavior of pedestrians. He selected a total of 17 independent variables for modeling on the basis of the pedestrians' demographic features as well as the existing environmental and traffic characteristics. Pedestrians' demographic features included age, gender, speed, and so on. Waiting time of pedestrians, type of crossing, occurrence of conflicts in different quarters of the green interval, right-turning vehicle volume, and opposing through-vehicle volume are some of the important parameters which may influence the risk-taking behavior of pedestrians.

(***Ling, Ni and Li, 2012***) modeled the interaction between pedestrians and right turn vehicles using existence of pedestrian group, population of pedestrian group, disturbance of non-motorized vehicles, pedestrian crossing direction, volume of right-turn vehicles, distance to the conflict of pedestrians, the time difference between pedestrians and right-turn vehicles arriving at the conflict point as an influencing factor.

(***Tan, 2015***) established a model of conflict probability through theoretical modeling methods. He used various influencing factors on the conflict probability of the right-turn vehicle and pedestrian. The following are the main factors he stated.

- Position of conflict point: the distance of conflict point to walk ways and stop line of right-turn lane can directly determine the time of vehicles and pedestrians reaching conflict point, respectively. Some measurements should be reasonably considered to reduce conflict. Generally speaking: optimize the position of walkways and stop line position, etc.
- Speed of pedestrian & vehicle: they have a significant impact on the time of reaching conflict point. Set the speed limit signs to reduce conflict.
- Signal cycle & green ratio: green time can influence the time of pedestrians reaching the sidewalk endpoints and vehicles arriving the stopping position, and can also affect the queue length of vehicle and pedestrian.

(***He et al., 2019***)used number of people crossing the street, the width of road, the type of day (weekday vs. weekend), the time period of observation (peak hours vs. off-peak hours), and the total number of motor vehicles and pedestrians as potential covariates to examine the relation between transport efficiency and having conflicting traffic lights at intersections (conflicts of pedestrian and left turn vehicle).

2.3.2 Method of modeling

Plenty of research has dealt with the interaction between pedestrian and right-turn vehicles, considering the likelihood of different interaction mechanisms between pedestrians and right-turn vehicles. Most of them focus on number of potential conflicts and pedestrian behavior.

2.3.2.1 Modeling number of potential conflicts

(***Akin, 2007***) proposed a model for the estimation of potential pedestrians conflicts with turning vehicles using only turning vehicle flow and pedestrian flow as a factors.

$$PCRT = 0.4641\ VRT.P\ 10^{-2}$$
$$PCRT = 0.2444\ VRT.P\ 10^{-2}$$

Where,

PCRT = number of potential conflicts between right-turning vehicles and pedestrians (conflicts/hr),
PCLT = number of observed potential conflicts with left-turning vehicles and pedestrians (conflicts/hr),
VRT = right-turning vehicle flow (veh/hr), and
P = pedestrian flow (ped/hr).

Similarly,(***Cheng et al., 2014***) developed a model of pedestrian-vehicle interaction with explanatory variables of left-turn vehicle volume, volume of through vehicle, pedestrian volume, dynamic pedestrian density, pedestrian travel speed and average spot speed of left-turn vehicle. He also designed Pedestrian safety conflict index (SCI) based on conflict analysis of left-turn vehicles and pedestrians at signalized intersections, the range of which is 0 to 1.The purpose of SCI is to provide a system of standards for evaluating signalized intersection safety; the higher the index number is, the safer the pedestrians are, when crossing streets.

$$Cv = -254 + 0.327Qp + 811.596Kp + 15.656D + 0.324Qv + 0.575DG$$

$$SCI = 0.9971^{\frac{933.1\ lnQp\ 2 - 8942.8 lnQp + 20368.2}{-7.72 lnQp + 45.22} + 0.327Qp + 0.324Qv + 0.575DG}$$

Where,

Cv = number of conflict

Qp = pedestrian crossing volume per hour

D = pedestrian coefficient of spatial distribution

Kp = dynamic pedestrian density

Qv = volume of left turn vehicles

DG = disadvantage group percentage

Additionally, (***Davis, 2000)*** proposed an accident prediction model by using discriminate analysis modeling technique, 3- and 2-group models were developed. The three-group models consisted of the following: Group 1, zero-accident intersections; Group 2, one- and two-accident intersections; and Group 3, three- or-more-accidents at three or more intersections. The variables of pedestrian and vehicle volumes, conflicts, type of control, number of lanes, and pedestrian violations best explained the groups that had three accidents or more with a model accuracy of 83 percent.

- 3-group model (DC)

$$G1 = -0.0829C + 0.0041P + 0.0026V + 3.4671S + 0.0222Vp - 3.3074$$
$$G2 = -0.0099C + 0.0006P + 0.0016V - 1.0553S + 0.0127Vp - 1.5951$$
$$G3 = -0.0989C + 0.0045P + 0.0037V + 4.8675S + 0.0254Vp - 6.1205$$

- 3-group model (Seattle)

$$G1 = 0.0943C + 0.0023P - 0.0047V + 1.6625L - 9.4869$$
$$G2 = 0.0533C + 0.0058P - 0.0065V + 2.0950L - 14.048$$
$$G3 = 0.0675C + 0.0155P - 0.0058V + 2.4968L - 27.318$$

where,

G1= 0-accident intersections

G2 = 1-and-2-accident intersections

G3 = 3-or-more-accident intersections

- 2-group model (DC)

$$G1 = 0.0139C - 0.0019P - 0.0029V + 2.0773S + 0.8544L - 4.7114$$
$$G2 = 0.0475C - 0.0045P - 0.0038V + 0.6226S + 1.1048L - 6.9865$$

- 2-group model (Seattle)

$$G1 = 0.0934C - 0.0013P - 0.0052V + 1.5888L - 8.5028$$
$$G2 = 0.0505C + 0.0024P - 0.0070V + 2.0441L - 13.409$$

Where,

Gl = 0-accident intersections

G2 =1-or-more-accident intersections

C = conflicts

P = pedestrian volume

V = vehicle volume

S = type of control

VP = pedestrian violations

L = number of lanes

(***Zhang et al., 2011)***developed conflict prediction models to evaluate the impact of conflicting volumes on opposing left-turn conflicts at signalized intersections. Poisson and NB models were used to relate the number of traffic conflicts to conflicting volumes. He strongly addressed conflict prediction models can be developed as a supplement to traditional crash prediction models to help us better understand the impacts of various contributing factors of safety performance on traffic facilities

(***He et al., 2019***) employed Poisson regression model to examine the relation between transportation safety and having conflicting traffic lights at intersections by controlling for covariates mentioned above. And Generalized linearized random-intercept models examined the association of transportation efficiency of pedestrians (and motor vehicles) with having conflicting traffic lights at intersections by controlling for covariates. The developed model showed use of conflicting vehicle-pedestrian traffic lights at road intersections did not significantly increase transportation efficiency, even after controlling for type of day (weekday vs. Weekend), time period of observation (peak vs. off-peak hours) and traffic flow of motor vehicles or pedestrians.

2.3.2.2 Modeling pedestrian behavior

(***Ling, Ni and Li, 2012***)developed a binary logistic regression model for pedestrians' and right-turn vehicles' yielding decisions.

$$p_{(i=1)}=\frac{1}{1+\exp(-S)}$$

$$S = 0.51 - 0.497\mathrm{Pg} - 0.234\mathrm{Pnum} - 0.698\mathrm{B} - 1.749\mathrm{Pd} + 0.538\mathrm{Cnum} + 0.232\mathrm{Dcon} - 0.424\Delta\mathrm{t}$$

Where,

Pg=existence of pedestrian group; Pd = pedestrian crossing direction

Pnum= population of pedestrian group Cnum= volume of right-turn vehicles

B=disturbance of non-motorized vehicles Dcon= distance to the conflict of pedestrians

Δt= the time difference between pedestrians and right-turn vehicles arriving at the conflict point

(***Ling, Ni and Li, 2013***) publishes another paper; his paper presented a comparative study on the conflicts of right-turn vehicles and pedestrians, especially the behavior of right-turn vehicles in two control schemes (RTOR and PPRT). She concluded that Right-turn vehicles are more likely to yield to pedestrians at PPRT intersections and the time-lags and gaps with RTOR are smaller than those with PPRT, which indicates that the conflicts with RTOR are more serious than those with PPRT.

(***Schroeder and Rouphail, 2010***) his research explores factors associated with driver yielding behavior at un signalized pedestrian crossings and develops predictive models for yielding by using logistic regression. It considers the effect of variables describing driver attributes, pedestrian characteristics, and concurrent conditions at the crosswalk on yield response. The analysis suggests that drivers are more likely to yield to assertive pedestrians who walk briskly in their approach to the crosswalk. In turn, the yield probability is reduced with higher speeds, with deceleration rates, and if vehicles are traveling in platoons.

(***Hubbard, Bullock and Mannering, 2009***) also developed a model for whether a pedestrian is compromised or not using binary logit model. The paper presents a statistical analysis using a binary logit model that provides new insights into the factors that affect the likelihood that a pedestrian is compromised, delayed, altered their travel path, or altered their travel speed in response to traffic turning right on green during concurrent vehicle/pedestrian signal timing. The statistical analysis indicates that a number of factors affect the likelihood of a pedestrian being compromised including pedestrian direction of travel, right-turn traffic volume, number of pedestrians crossing, whether the pedestrian arrived late and began crossing after the end of the walk interval, and the crosswalk characteristics including location, downtown versus suburban and one-way/two-way streets.

(***Perumal, 2014)*** Pearson‟ s correlation coefficient test and ANOVA test were used to examine the significant factors that influencing the pedestrian-vehicular interaction in crosswalk. Tests were performed in SPSS 16.0 software. The main factors analyzed in statistical test were pedestrian gender, age group, group, number of pedestrians and, crossing speed had significant effect on pedestrian-vehicular interaction in crosswalk during pedestrian non-green phases. He also stated the factors, accepting vehicle and suitable gap have significant effects on pedestrian-vehicular interactions at crosswalks.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Description of the Study Area

In order to carry out the study, the researcher selected two road segments located in Addis Ababa city which has continuous signalized intersections.

3.1.1. Location

The selected road segments for the study are located around the center of Addis Ababa in three sub cities; Kirkos sub city, Lideta sub city and Arada sub city.

3.1.2. Description of the road segments

The road segments selected for the research are;

- Road segment one
  - Jomo Kenyata street (Estifanos church – Addis Ababa stadium roadway link)
  - Ras Mekonen street (Addis Ababa stadium- Leghar- Mexico roadway link)
- Road segment two
  - Churchil street (Eliana hotel- Tewodros square- CBE road way link)
  - Ras Abebe Aragay street (CBE-commerce- Shebelle hotel road way link)

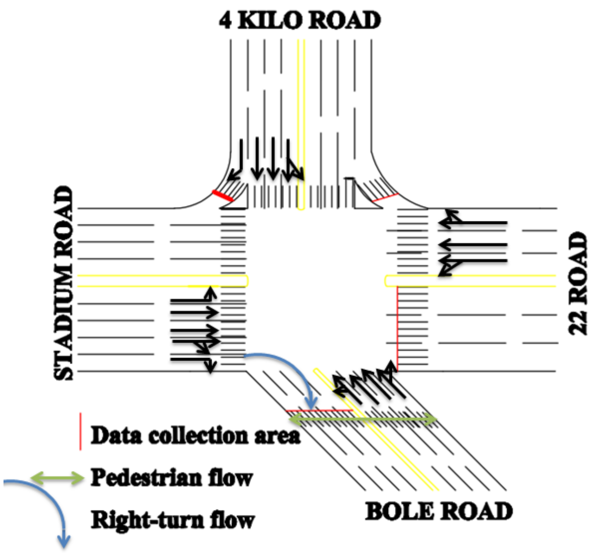
This road segments selected because:

- Central business district
- There is an extreme pedestrian movement on road segment one and moderate pedestrian movement on road segment two. The researcher chooses this road segments in order to include both scenarios on the study. Similarly right turn vehicle movement is higher on road segment one and lower in road segment two.
- Different types of intersections with different types of right turn vehicle controlling mechanisms (RTOG, RTOR, channelized, not channelized)

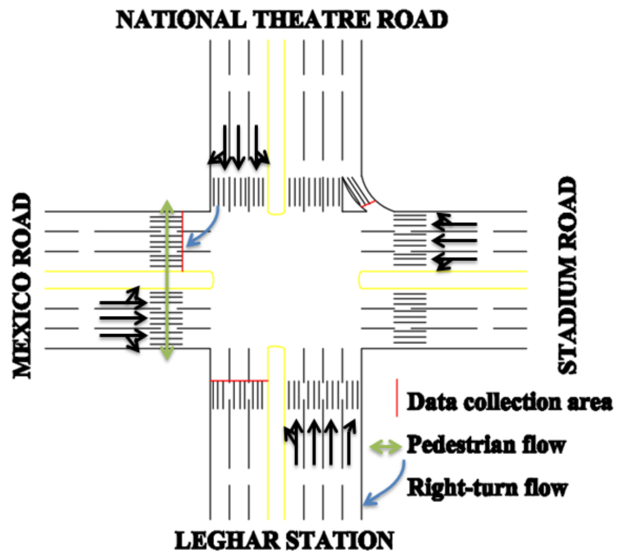
3.1.3. Description of the selected intersections

Both road sections had five signalized intersections. Out of ten intersections, four intersections have been selected based on crossing pedestrian volume, right turn vehicle volume, location of crosswalk and right turn vehicle controlling mechanism.

From the first road segment two intersections selected;

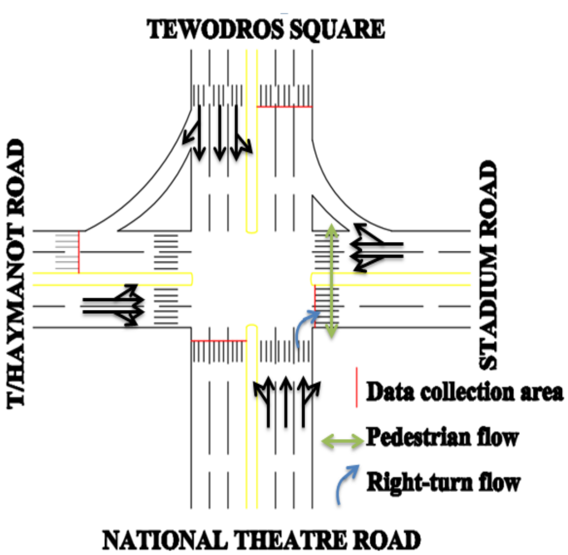


Estifanos intersection

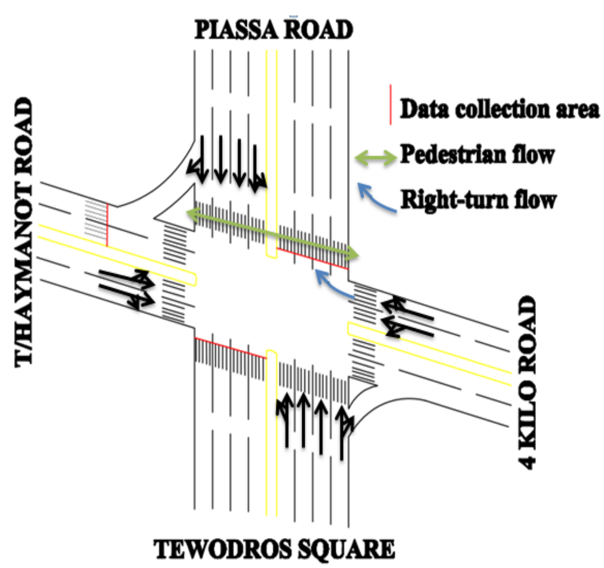


Leghar intersection

Correspondingly from the second road segment; two intersections selected



Tracon intersection



Bankodiroma intersection

Figure 2 Layouts of the Selected Intersections

Table 1 Road and Traffic Characteristics of the Selected Intersections

Estifanos intersection

Item No	Departure name	No of lane	Length of crosswalk (m)	Exclusive right turn lane(Y/N)	Cycle length (Sec)	Channelized (Y/N)	R- turn volume (veh/hr)	Pedestrian volume (ped/hr)
1	Bole	4	14	N	188	N	1358	1689
2	4 Kilo	4	13	Y		Y	100	738
3	22	3	12	N		Y	50	1510
4	Stadium	4	20	Y		N	408	874

Leghar intersection

Item No	Departure name	No of lane	Length of crosswalk (m)	Exclusive right turn lane(Y/N)	Cycle length (Sec)	Channelized (Y/N)	Right turn volume	Pedestrian volume (ped/hr)
1	Leghar	3	9.8	Y	206	N	160	625
2	Mexico	3	13.9	N		N	158	969
3	N. Theatre	3	16	N		Y	171	532

Tracon intersection

Item No	Departure name	No of lane	Length of crosswalk (m)	Exclusive right turn lane(Y/N)	Cycle length (Sec)	Channelized (Y/N)	Right turn volume	Pedestrian volume (ped/hr)
1	Tewodros	3	10.6	N	152	Y	159	539
2	N. Theatre	3	11.5	N		N	118	669
3	Filwuha	2	10.9	N		N	181	426
4	T/Haymanot	2	7.3	N		Y	480	181

Bankodiroma intersection

Item No	Departure name	No of lane	Length of crosswalk (m)	Exclusive right turn lane(Y/N)	Cycle length (Sec)	Channelized (Y/N)	Right turn volume	Pedestrian volume (ped/hr)
1	Piassa	4	11	N	152	N	59	570
2	Tewodros	2	11	N		N	321	273
3	T/Haymanot	2	6.5	N		Y	64	177

3.2. Study Design

In order to perform the study the researcher used (***Lord, 2007***) definition; "A traffic conflict takes place when two or more road users approach each other in space and time to such an extent that a collision is imminent if their movements remain unchanged". According to this definition, the conflict between pedestrian and vehicle requires two conditions there are interactions between the pedestrian and the vehicle, and their trajectories coincide with each other and at least one of the road users takes urgency avoidance measures. As a result, at least one of the road users' movements is suddenly changed. The conflict area covers the entire crosswalk length and the conflict point depends on location of cross walk and radius of the curve.

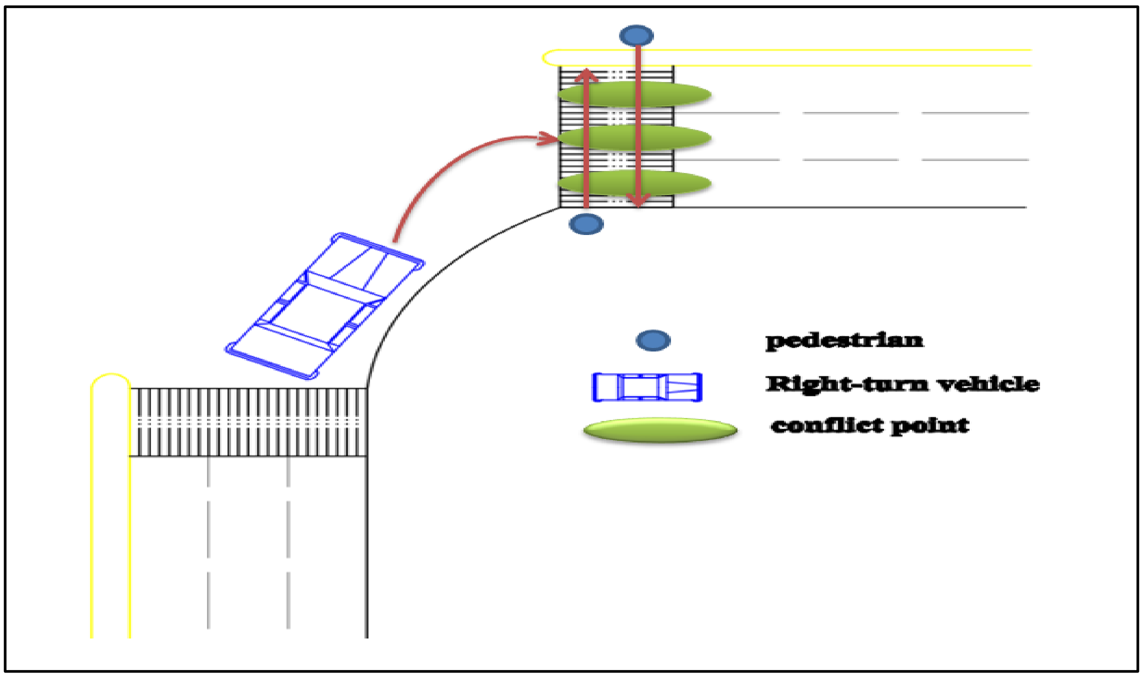


Figure 3 pedestrian and right turn vehicle conflict point

In this study, pedestrian- right turn vehicle interactions mechanism is covered by developing a model for determining number of potential conflicts between pedestrian and right turn vehicles. After conflict occurs, in order to avoid traffic accidents either pedestrian or right turn vehicles must yield. Yielding behavior of pedestrians has been studied by developing a model which describes yielding decision of pedestrians.

3.3. Research Materials

3.3.1. Data

Data required for both models are stated below;

- Number of potential conflict
  - ✓ Number of conflicts
  - ✓ Pedestrian volume
  - ✓ Right-turn traffic volume
  - ✓ Number of lanes

- pedestrian yielding behavior
  - ✓ pedestrian yielding
  - ✓ pedestrian crossing direction
  - ✓ right turn traffic volume
  - ✓ Location of crosswalk
  - ✓ pedestrian volume
  - ✓ Location of conflict
  - ✓ population of pedestrians
  - ✓ Right turn vehicle turning speed

3.3.2. Sample Size

- Number of potential conflicts

(***Green, 1991)***addressed the question of how many subjects does it take to do regression analysis. He considers the two purpose of conducting a multiple regression (testing the multiple R value and beta weights for statistical significance) and statistical power (the probability of rejecting null hypothesis when it is in fact false). For medium effect, he recommended the following;

$n \geq 104 + K$, where K is the number of independent variables

In this study, there are four independent variables; the minimum sample size according to Green is: $n \geq 104 + K = 104 + 4 = 108$

Based on this; a total of **484** five minutes interval conflict data collected.

To justify the collected sample size**;** (***Knofczynski, 2002***) in his study, he extended it in such a way that he took in to consideration the magnitude of the largest correlation between the dependent variable and a predictor variable. The larger those correlations are between the independent variables the smaller the sample size is going to need.

From the collected data, the minimum correlation between the dependent variable and the predictor variable is 0.580 **(**see ***Table 2*****).**

Table 2 Correlation Matrix of Independent Variables

Pearson correlation	Number of potential conflict / 5 min
Right turn vehicle / 5 min	0.580
Pedestrian / 5 min	0.819

From the table given below (using interpolation) the minimum sample size required to do a multiple regression analysis for a correlation coefficient of 0.580 and four predictor variables is **408** which is less than the collected one.

Table 3 Minimum Sample Size Recommended For Values Of Largest Correlation Between The Dependent Variable And Predictor Variable

Excellent prediction level						
	Number of predictor variables					
Max-Pxy	2	3	4	5	7	9
0.2	2400					
0.3	1100	1600	1900	2300	2400	2400
0.4	600	900	950	1200	1200	1700
0.5	320	460	600	750	800	950
0.6	190	300	360	420	460	480
0.7	120	170	220	240	300	340
0.8	60	95	120	140	160	170
0.9	29	45	55	60	65	80

- pedestrian yielding behavior

(***Forsyth, Agrawal and Krizek, 2012***) developed an approach to sampling for pedestrian and bicycle surveys based on population, confident interval and margin of error. He provides sample sizes needed for communities with different population to achieve different margin of errors at 95% confident level (see ***Table 4*)**. According to census carried on 2007 G.C the population of Addis Ababa city was 3,384,569. By 2018 the population size of Addis Ababa city is estimated to be 7.8236 million (https://populationof2019.com/population-of-addis-ababa-2019.html). Depending on the above information, sample size taken is 1068 pedestrians. For a better statistical analysis and result **24,048** pedestrians are taken for this study.

Table 4 Sample Size Needed For Communities with Different Populations

Population	Margin of error			
	±3%	±4%	±5%	±10%
2000	696	462	323	92
5000	880	536	357	95
10000	965	566	370	96
20000	1014	583	377	96
50000	1045	593	382	96
100000	1058	597	383	96
500000	1065	600	384	96
1000000	1066	600	384	96
5000000	1067	600	384	96
8000000	1068	600	384	96

3.4. Research Methods

3.4.1. Primary Data Collection

By directly moving to the study area, the traffic operation of pedestrian crossings and right-turn vehicles were videotaped by Lenovo tablet, which was secured above the observation area. The video field of view included the right-turn lane and the entire crosswalk. In each intersection, there were two camera placing positions to get a clear view of the interaction.

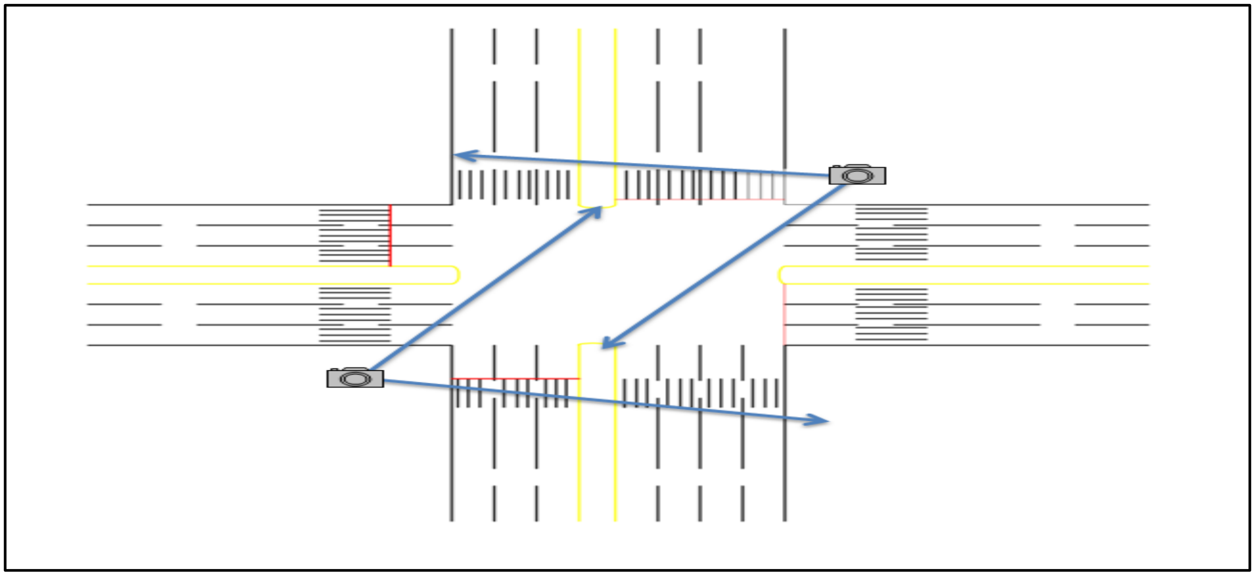


Figure 4 location of cameras located on the sidewalk

Data used in this study were collected along the selected intersections. All video observations were conducted from high buildings around intersections. Potential conflicts, observed as a result of turning vehicle-pedestrian interactions, were counted over 180-min periods. Vehicle and pedestrian movement and conflict data were collected at each camera location during the mid-day (11:00am-2:00pm) periods on working days except on Monday and Friday, to avoid exaggerated traffic and pedestrian movement.

3.4.2. Secondary Data Collection

The researcher has been done considerable number of measures and observations, by directly moving to the study area. Geometric data (number of lane, Lane width) and signal related data (cycle length) were collected at the selected study sites as follows;

- No of lane; counting divided lane on each approach
- Lane width; measuring with roller meter
- Curve length; measuring with roller meter

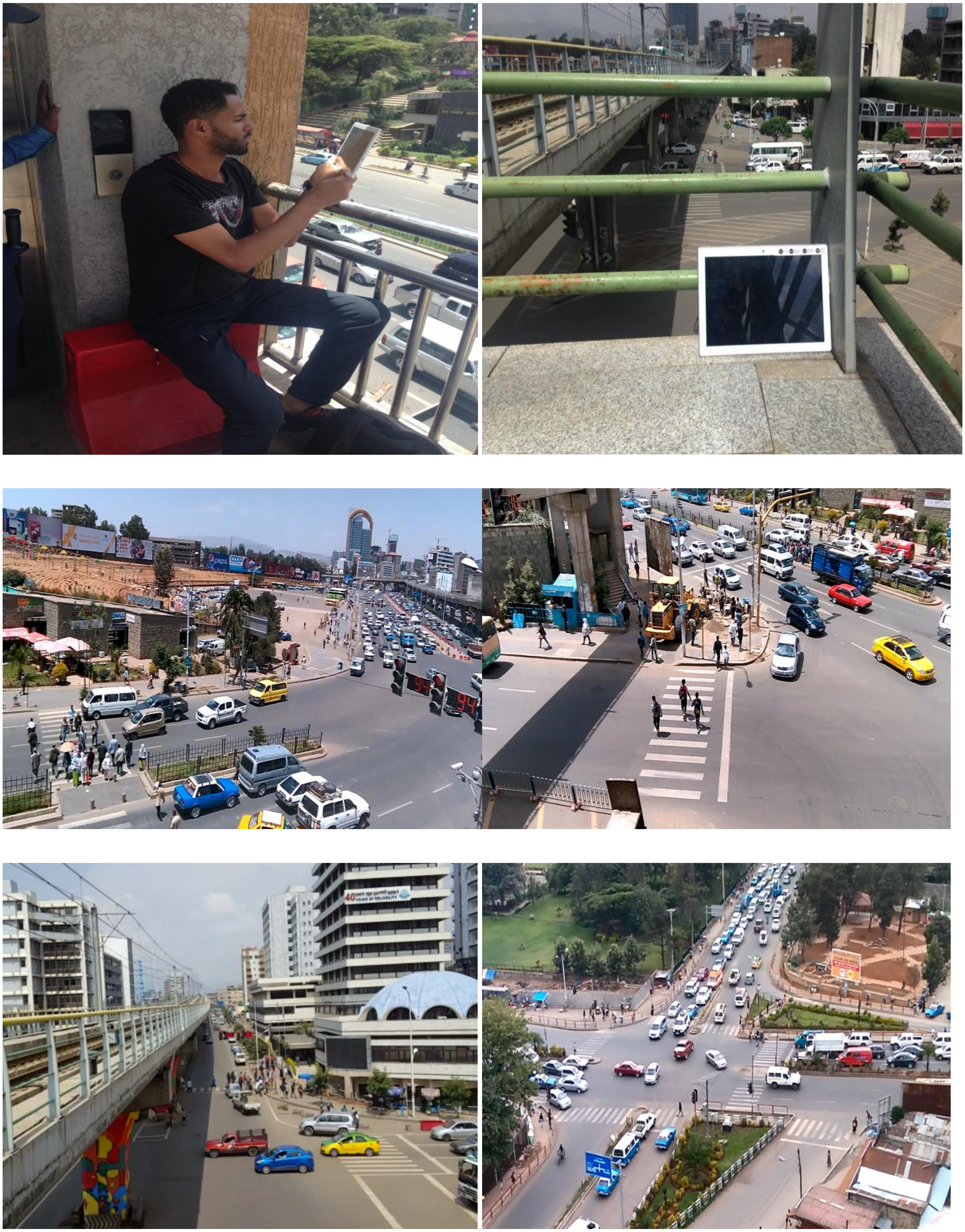


Figure 5 Camera Views of the Selected Intersections

3.4.5. Data extraction

The data stated in ***section 3.3.1*** was extracted from the recorded video manually by using video playback technique.

- Number of potential conflicts

Number of potential conflicts, right turn vehicle volume and pedestrian volume were counted in every five minute interval from the collected video. From each intersection legs 180 minute video data collected so a total of 484 data points extracted.

- pedestrian yielding behavior

For each interaction; Characteristics of yielding behavior between pedestrians and right-turn vehicles were extracted based on the parameters stated in the table below:-

Table 5 List of parameters of yielding behavior

Variable	Parameter definition
Yielding part	0 for right turn vehicle and 1 for pedestrian
Existence of Pedestrian group	0 for single pedestrian and 1 for group pedestrians
Direction of pedestrian crossing	0 for near side to far side and 1 for far side to near side
Location of crosswalk	0 for near to the intersection and 1 for far to the intersection
Location of conflict	0 for on the outer lane and 1 for on the inner lane
Population of pedestrians	Number of people composing the pedestrian group
Volume of right turn vehicle	Number of the RT vehicles being viewed by the pedestrian at one time when crossing
turning speed	Average right turn vehicle turning speed

Turning speed is obtained from spot speed of right turn vehicles. Time mean speed calculated in every 15 minutes using direct observation of the time taken by a vehicle to cover a known distance **(**see ***Figure 8*)**.

$$V = \left(\sum_{i=1}^{n} V_i\right)/n$$

Where, V= time mean speed, Vi= observed spot speed of ith vehicle, n= number of vehicle observed

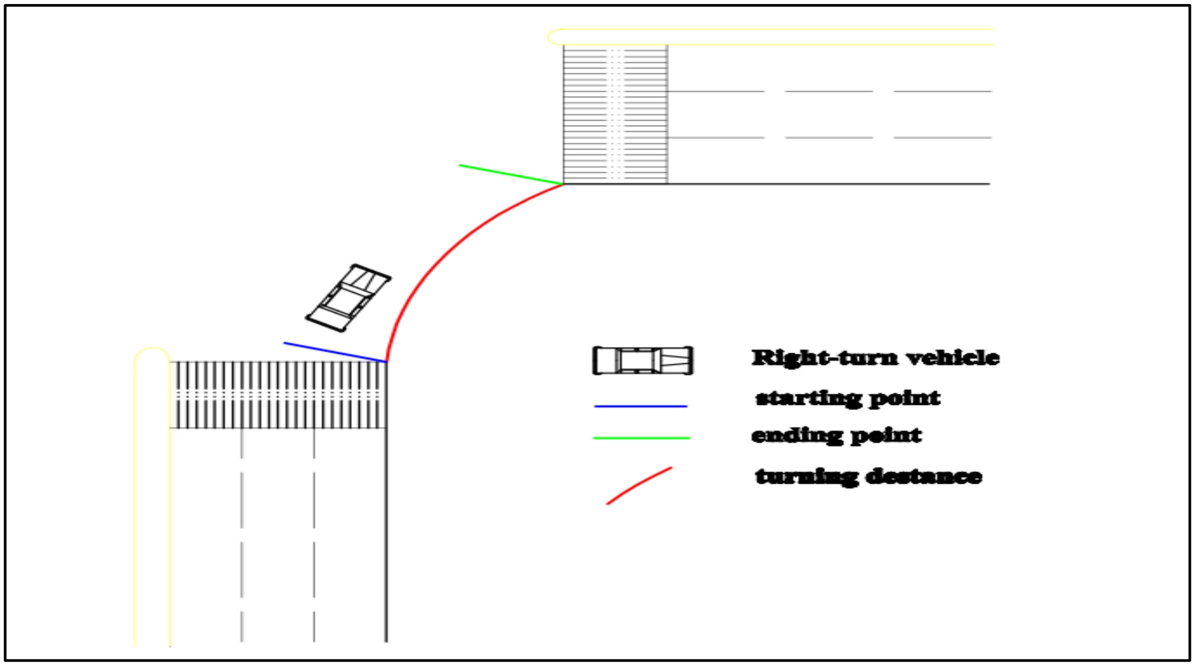


Figure 6 Graphical Expression of Time Mean Speed Calculation

3.4.4 Data analysis

3.4.4.1 Modeling number of potential conflicts

In this study multiple linear regression and Poisson regression analysis techniques employed to model the relationship between the conflicts and the flows of right turning vehicles and pedestrians. Minitab 18 statistical analysis software was used as a major data analysis tool.

Dependent variable:- number of potential conflicts

Independent variable:- flows of right turn vehicles, flow of pedestrian crossing, number of lanes, channelization

- Multiple linear regression is a technique for studying the linear relationship between a dependent variable, Y, and several numeric independent variables, X_1, X_2, X_3, etc. The dependence of a variable Y on two or more variables X_1, X_2, X_3 … can be modeled using the simple linear equation(***Washington, Karlaftis and Mannering, 2003***)

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots$$

Regression assumptions- before running a regression analysis, the data checked if it meets with the required assumptions using Minitab.

Table 6 Multiple Linear Regression Assumptions

Assumptions	Description
Linear relationships	There needs to be a linear relationship between the dependent and independent variables
Independent errors	Residuals should be uncorrelated
Outliers/influential cases	There should be no significant outlier
Homoscedasticity	The variance of the residuals should be the same at each level of the explanatory variables.
No Multicollinearity	the predictor variables should not be highly correlated with each other
Normally distributed residuals	The residuals should be normally distributed

- The dependent variable is a count of conflicts; it might need to use a different type of regression model. Counts are nonnegative integers (0, 1, 2, etc.). Count data with higher means tend to be normally distributed and you can often use OLS. However, count data with smaller means can be skewed, and linear regression might have a hard time fitting these data. For these cases, Poisson distribution is often used for these types of data.

Table 7 Poisson regression assumptions

Assumptions	Description
Poisson response	The response variable is a count per unit of time or space, described by a Poisson distribution
Independence	The observations must be independent of one another.
Mean = variance	the mean of a Poisson random variable must be equal to its variance
Linearity	The log of the mean rate, log(λλ), must be a linear function of x.

The Poisson regression model assumes that the observed outcome variable follows a Poisson distribution and is characterized by a mean expected value (λ in the above discussion) which is also its variance. The Poisson Regression attempts to 'fit' this parameter (which we will call μ) to a linear model of input or explanatory variables. The simple linear model cannot be used as μ can take on only positive values. A log transformation of μ solves this problem. The Poisson Regression model, therefore, is:

$$\log\ \mu_i \ = \beta_o + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki}$$

$$\mu_i = exp(\beta_o + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki})$$

- Goodness of fit test; the developed model is tested with statistical goodness of fit tests in this case the adjusted R^2 test is conducted. The closer the Adjusted R^2 value to 1 the better the model. (***Montgomery, 2003***)

3.4.4.1 Modeling pedestrian yielding behavior

In this model the output of the data measured in discreet data which is in the form of pedestrian yielding or not yielding. This requires a different regression approach which is called logistic regression. Since only two alternative decisions are made, a binary logistic model was considered to be appropriate;

Binary logistic regression models a relationship between predictor variables and a categorical response variable (Used when the response is binary).

$$P_{yn} = \frac{1}{1 + \exp(-\beta_Y X_{yn})} \qquad P_{yn} = \frac{1}{1 + \exp(-S)}$$

$$S = \beta_0 + \sum_{i=0}^{m} \beta_i X_i$$

Where; Pyn= probability that pedestrian yields,

Dependent variable:- pedestrian yielding or not

Independent variable:- existence of pedestrian group, population of pedestrian, direction of pedestrian, volume of right turn vehicle, location of conflict, location of cross walk, right turn vehicle average turning speed.

- Regression assumption;
  - ✓ The outcome is a binary or dichotomous variable
  - ✓ There is a linear relationship between the logit of the outcome and each predictor variables
  - ✓ There is no influential values (extreme values or outliers) in the continuous predictors
  - ✓ There is no high intercorrelation (multicollinearity) among the predictors.

- Goodness of fit test; overall performance of the fitted model measured by several different goodness-of-fit tests.
  - ✓ Pearson chi-square goodness-of-fit test ; the deviance goodness-of-fit test assesses the discrepancy between the current model and the full model.
  - ✓ Hosmer-Lemeshow goodness-of-fit test; compares the observed and expected frequencies of events and non-events to assess how well the model fits the data.

CHAPTER FOUR - ANALYSIS AND DISCUSSION

4.1 Descriptive Statistics

On this study from the intersections stated in ***section 3.1.3*** around 24,048 pedestrians, 9868 right turn vehicles and 2453 right turn vehicle and pedestrian conflict extracted from the collected video based on the definition indicated in ***section 3.2***. Out of this pedestrian and right turn vehicles only 7426 and 1201 of them involved on the conflict, respectively. This means 30.88 percent of pedestrians, who are crossing the road, are vulnerable to traffic conflicts at signalized intersections.

Table 8 statistical result of the collected data

Collected data	Amount
Total number of conflict	2453
Total number of pedestrians	24048
Total number of right turn vehicle	9868
Pedestrians involved in conflict	7426
Right turn vehicle involved in conflict	1201
% of pedestrian involved in conflict	30.88%
% of right turn vehicle involved in conflict	48.96%

4.1.1 Descriptive Statistics of Data Required for Modeling Number of Potential Conflicts

Number of potential conflicts between pedestrian and right turn vehicle mainly depends on their volume. The volume of right turn vehicle and pedestrian were counted in every five minute interval from the collected video. Each legs of the intersections assessed (see ***section 3.1.3***) and 484 data points extracted from them. As shown in ***Table 9***, the crosswalk at Estifanos intersection (bole approach) has the highest average number of pedestrian and right turn vehicle (119 ped/5min and 111 veh/5min) followed by stadium approach (64 ped/5min and 32 veh/5min) in the same intersection. Also very low average number of pedestrian and right turn vehicle observed at Bankodiroma intersection (13 ped/5min and 5 veh/5min).

Table 9 Average Number of Conflict between RTV and Pedestrian

Item No	Departure name	Number of 5 min interval	Average number of pedestrian (Ped/5mi)	Average number of right turn vehicle (Veh/5 min)	Average number of conflicts (conflict/ 5min)
Estifanos intersection					
1	Bole	33	119	111	20
2	4 Kilo	36	53	6	3
3	22	20	123	3	3
4	Stadium	36	64	32	12
Leghar intersection					
1	Leghar	36	42	12	5
2	Mexico	36	78	11	4
3	N. Theatre	36	47	11	4
Tracon intersection					
1	Tewodros	35	43	12	4
2	N. Theatre	36	49	9	3
3	Filwuha	36	31	13	3
4	T/Haymanot	36	12	32	3
Bankodiroma intersection					
1	Piassa	36	38	4	2
2	Tewodros	36	20	25	4
3	T/Haymanot	36	13	5	2

As we can see from the above table the crosswalk at Estifanos intersection (bole approach) has the highest average number of conflicts (20 conflict/5min) and very low average number of conflicts observed at Bankodiroma intersection (2 conflict/5min). We can clearly see the variation of the data set from ***Figure 7***. Estifanos intersection box plot is condensed which means the collected data sets varies less and more consistent than the others. The other intersections have much larger web of the box plot which means the collected data set have higher variation. The data set collected from Estifanos intersection should make a prediction more dependable than the more variables collected from other intersection. When we look at the box plot of Estifanos intersection (22 approach), Leghar intersection (mexico approach), tracon intersection (N. theatre and T/Haymanot approach) and Bankodiroma intersection (tewodros approach) the data set are skewed to the right which implies the data may not be normally distributed.

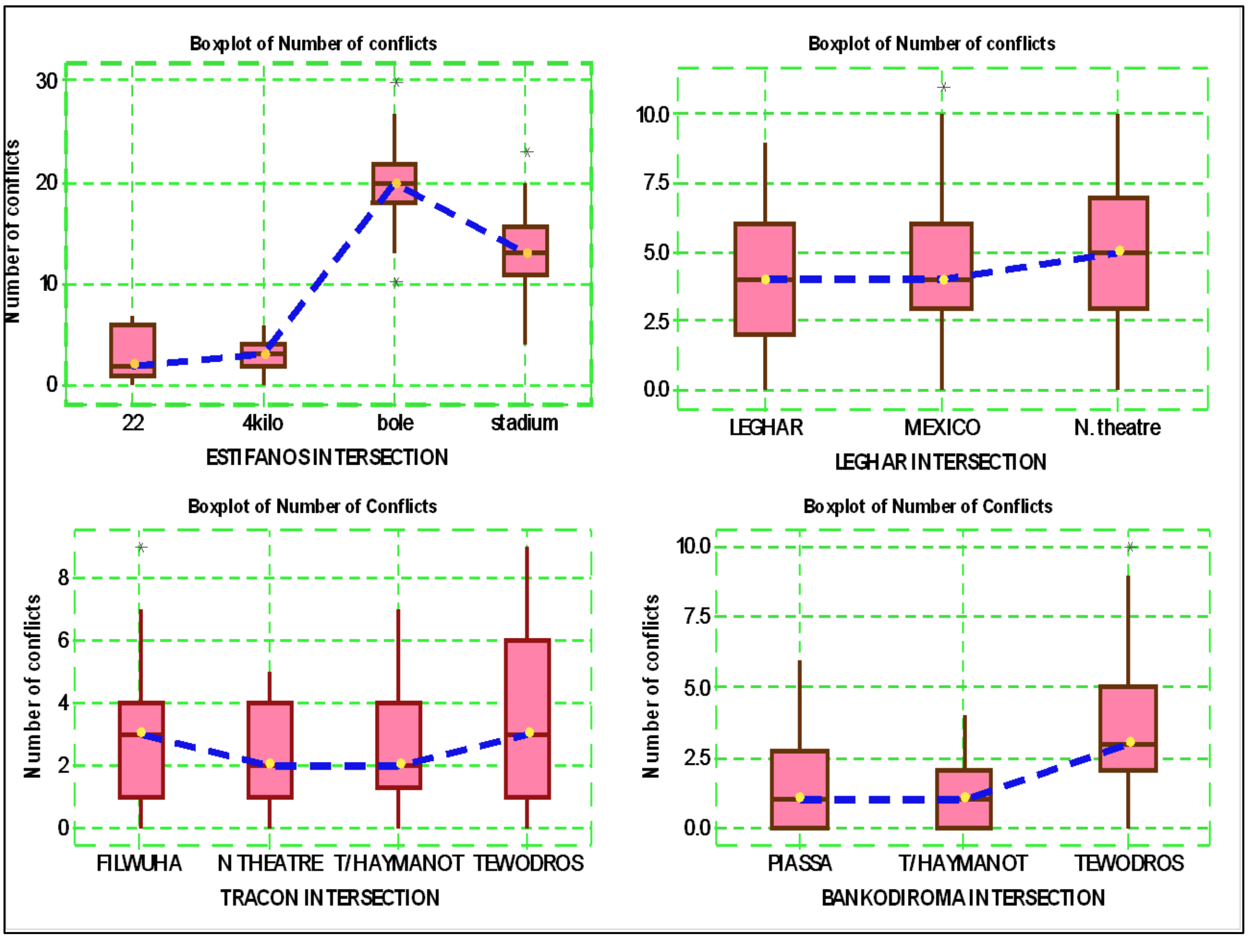


Figure 7 Boxplot of Number of Conflicts

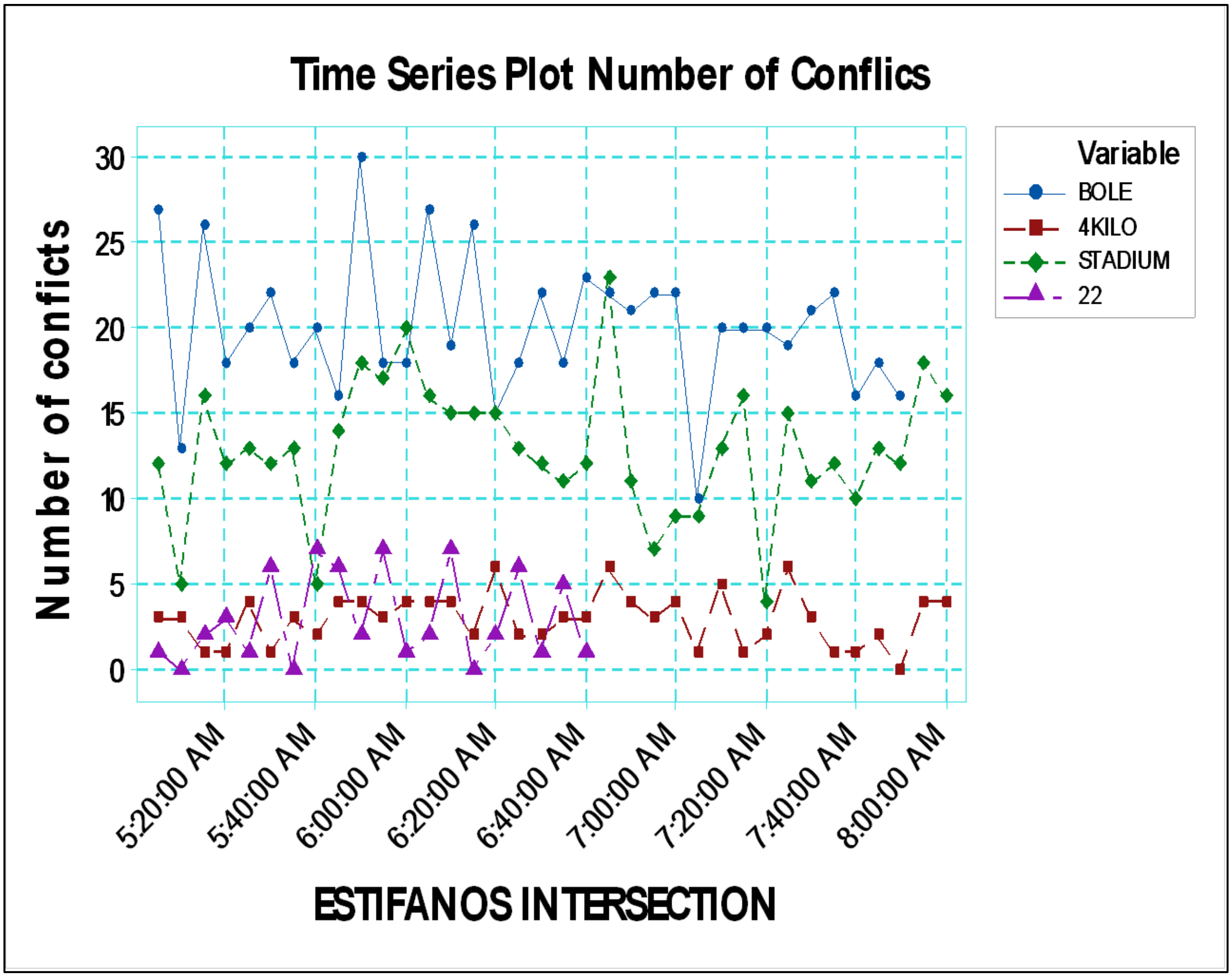


Figure 8 Time Series Plot of Number of Conflicts at Estifanos Intersection

The above time series plot shows the variation within the data collection period along the four approaches at Estifanos intersection. Bole approach has the most number of conflicts in almost throughout the data collection period. We can see as well there was an increase of conflict in 5:40 and decrease after 7:00, this shows the peak hour is within this time interval. When we comparing the data set based on the above time series plots bole and stadium approach covers wider range of number of conflicts than the other approaches. Furthermore, time series plots of 4 kilo approach shows a drastic shift in the number of conflict after 6:40. Time serious plot of 22 approach show slightly upward trend, this shows the increase in the data values seems to accelerate over time. Time serious plots of number of conflicts on the other intersections are stated on the ***Appendix***.

Figure 9 and ***Figure 10*** shows time series plot of pedestrian volume and right turn vehicles volume at Estifanos intersection, respectively. In both plots bole approach has higher value than the other approaches, due to this number of conflicts at this approach is very high (see ***Figure 8***). At 22 approach there is a high amount of pedestrian crossing the road but right turn vehicles is very low comparing to the others, as a result number of conflict at this approach is very low (see ***Figure 8***) . This shows number of potential conflicts between pedestrian and right turn vehicles is going to be very high at crosswalks which have higher amount of both pedestrian and right turn vehicles. When either one of them has a lower volume number of potential conflicts will be lower. Time serious plots of pedestrian volume and right turn vehicles volume on the other intersections are stated on the ***Appendix***.

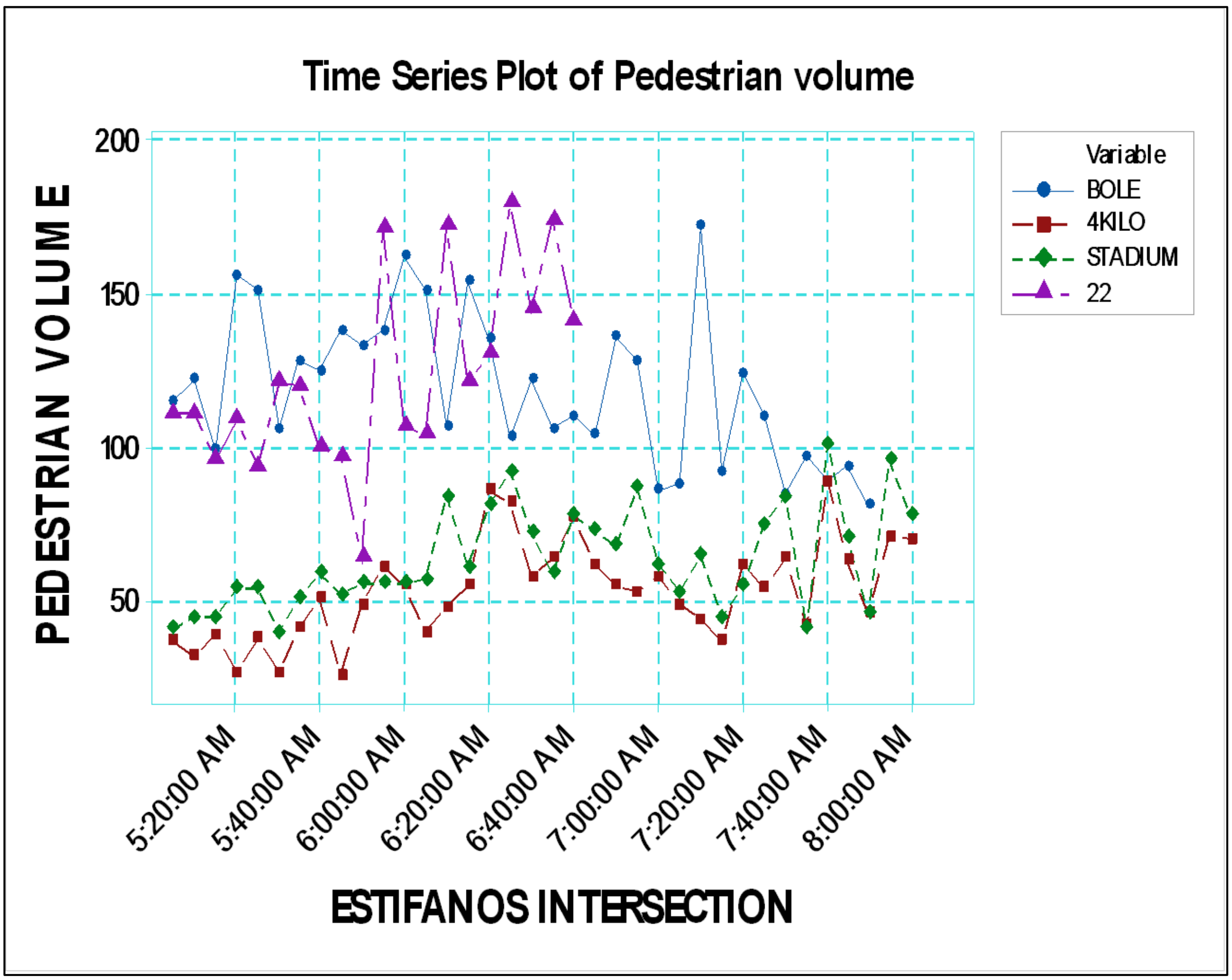


Figure 9 Time Series Plot Of Pedestrian Volume at Estifanos Intersection

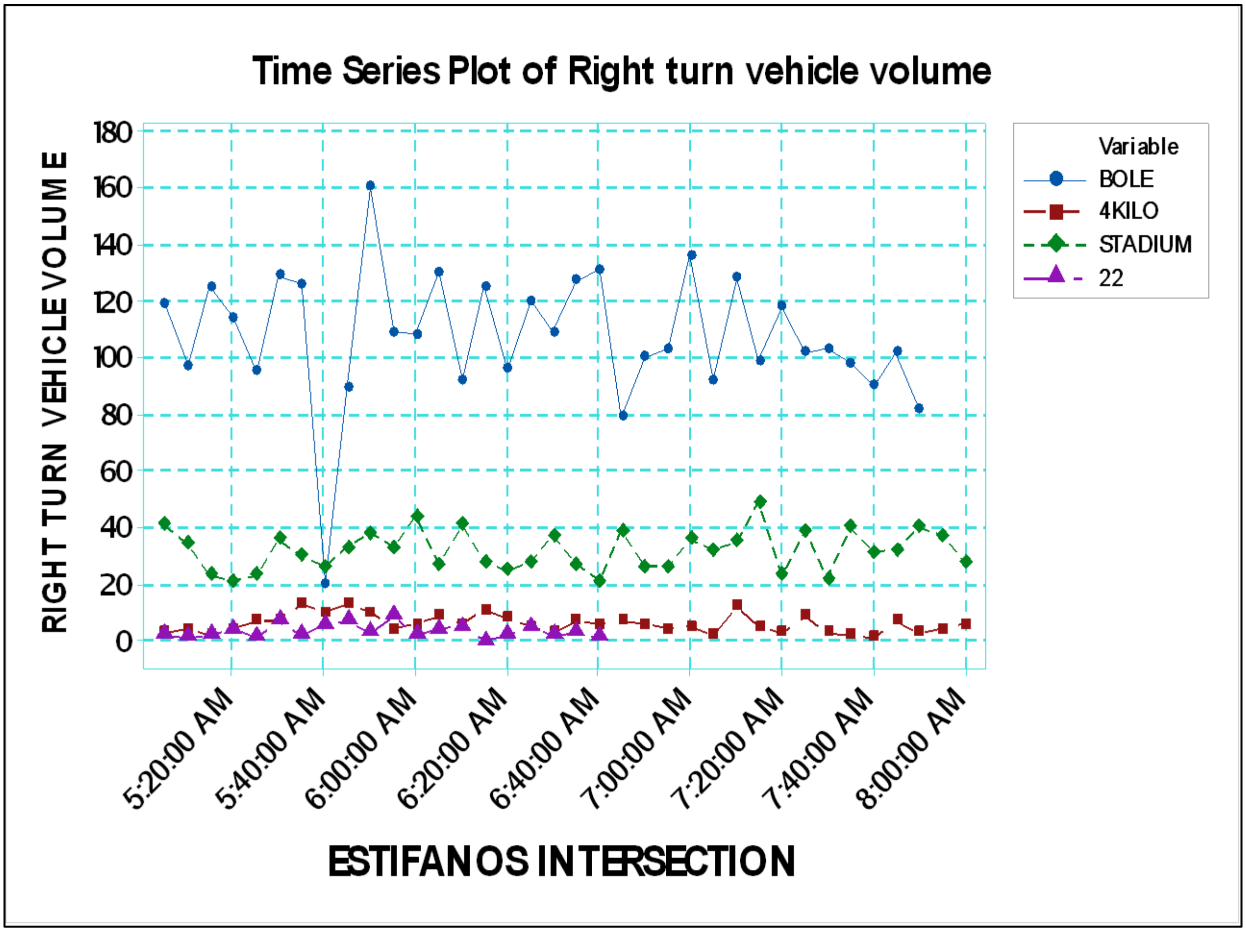


Figure 10 Time Series Plot Of Right-Turn Vehicle Volume at Estifanos Intersection

When we look at the scatter plot of number of conflict versus pedestrian (***Figure 11***), it's shown that there is a leaner relationship between pedestrian and number of conflicts. The direction of the scattered points is positive, as if pedestrian volume increases also the number of conflicts increases. Similarly, the scatter plot of number of conflict versus right turn vehicle (***Figure 12***) is shown there is leaner relationship between them. Scatter plots of number of conflict versus pedestrian and number of conflict versus right turn vehicle on the other intersections are stated on the ***Appendix***.

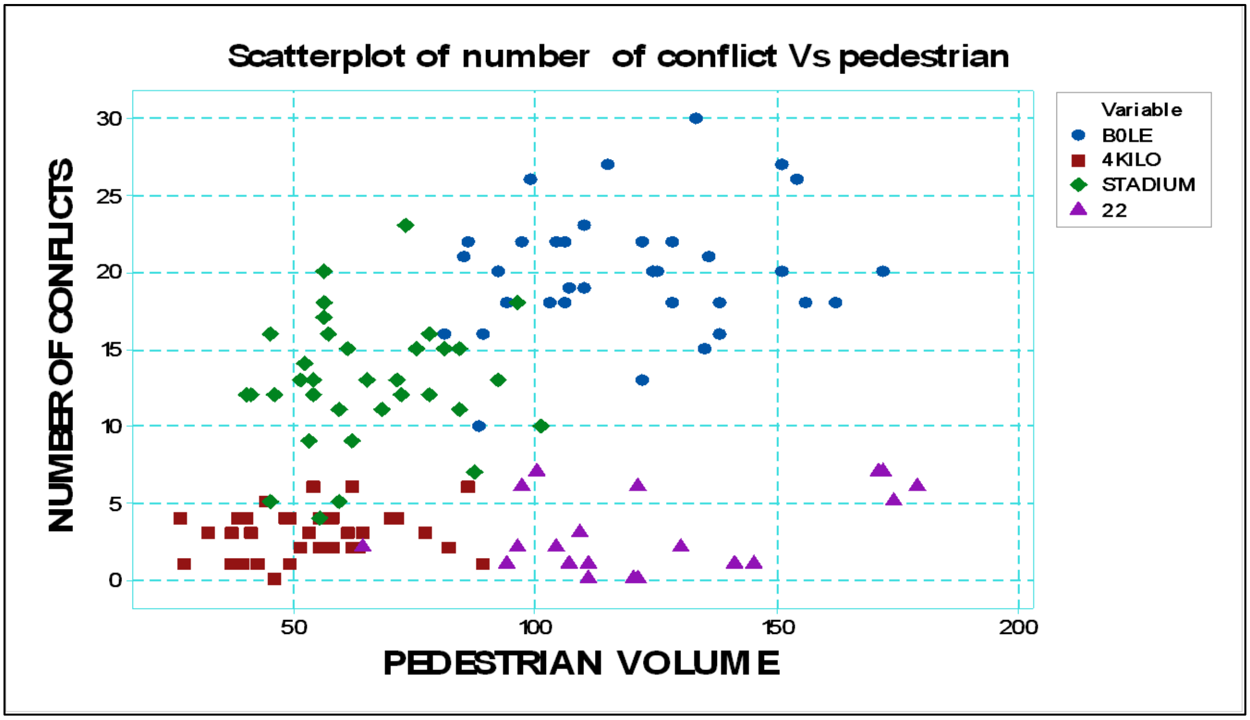


Figure 11 Scatter Plot of Number of Conflict versus Pedestrian at Estifanos Intersection

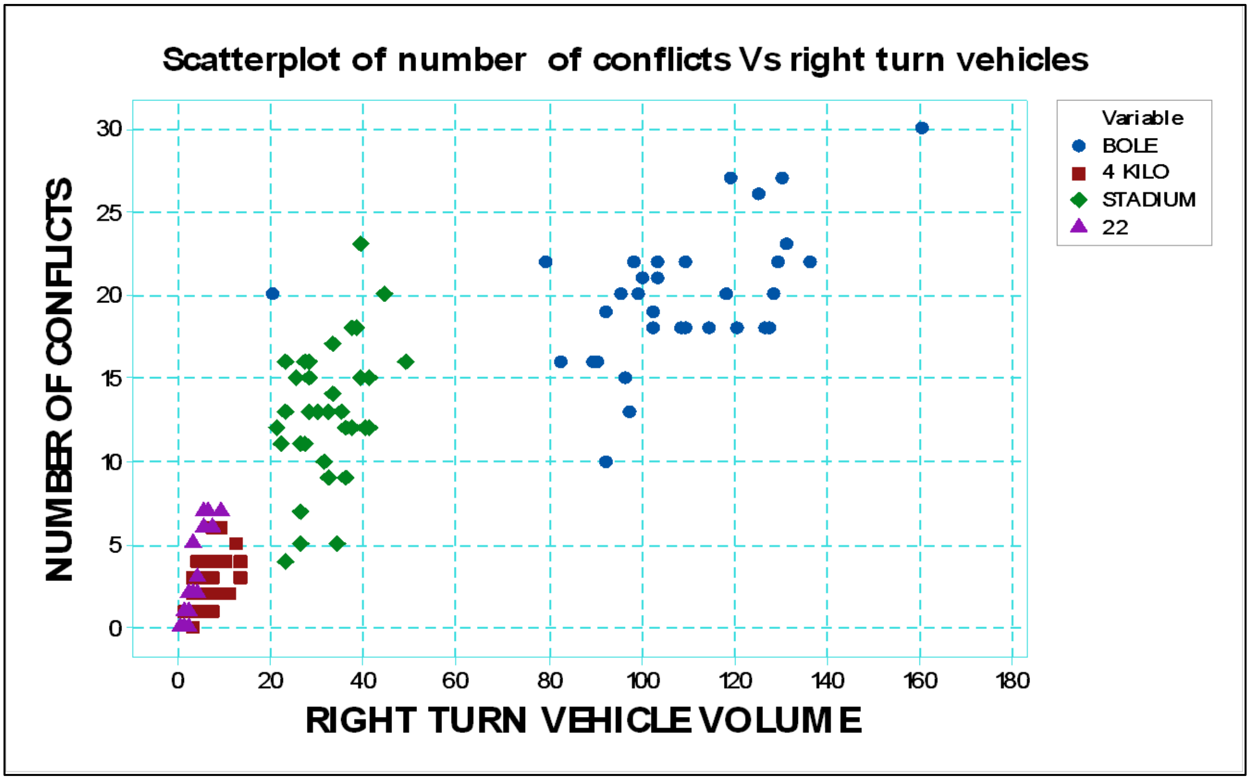


Figure 12 Scatter Plot of Number of Conflict versus Right-Turn Vehicle at Estifanos Intersection

In order to see the effect of number of lanes on the conflicts between pedestrian and right turn vehicles, number of lanes categorized in two three groups as stated in ***Table 10***. When we look at the individual value plot of number of conflicts versus number of lane (***Figure 13***) it's clearly shown us, even if the means of number of conflict on the graph is very close, high amount of number of conflicts occurs on the number of lanes greater than or equal to four and lower amount of number of conflicts occurs on the number of lanes is three.

Table 10 List of Parameter of Number of Lanes

Number of lanes	Parameter
Less than or equal to two (≤2)	0
Three (3)	1
Greater than or equal to four (≥ 4)	2

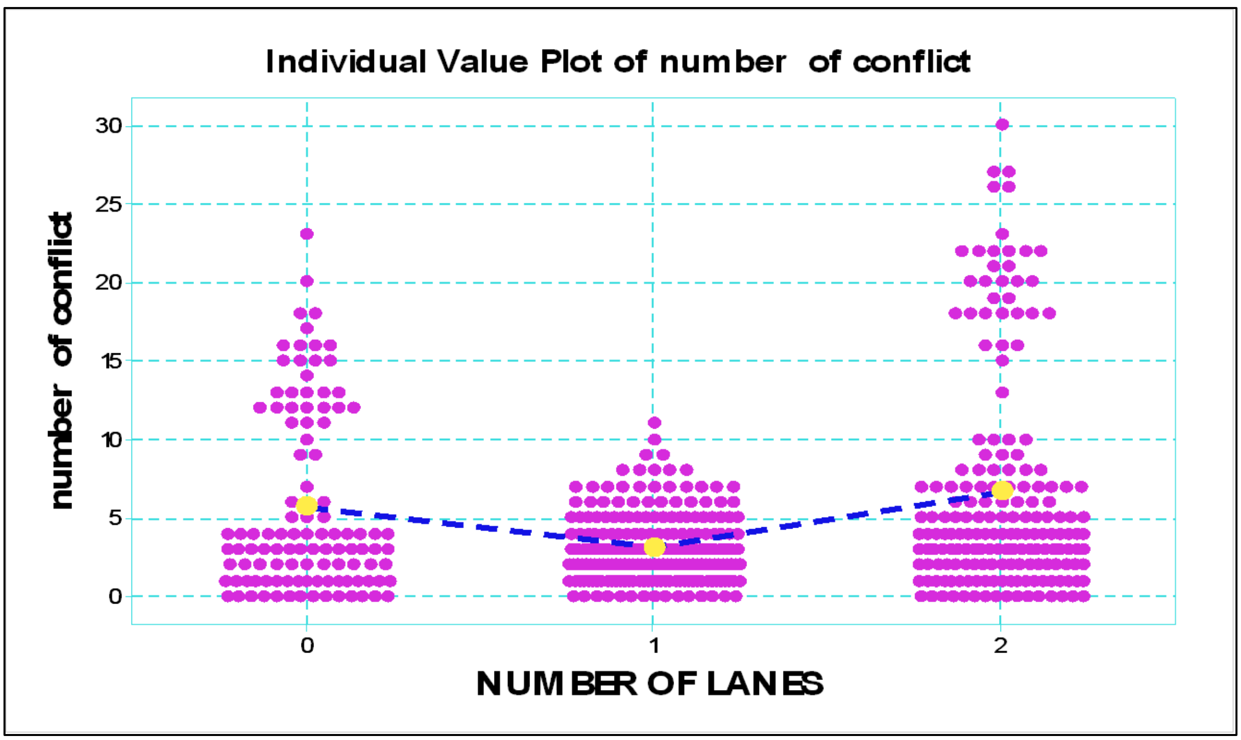


Figure 13 List of Parameters of Channelized Legs

In order to see the effect of right turn vehicle controlling mechanism, the approaching lane categorized in to two parts (as shown in the ***Table 11***). When we see the individual value plot of number of conflict versus channelization (***Figure 14***), there is no significant different in number of conflicts. This implies number of conflict doesn't depend on what kind of right turn vehicle control mechanism used.

Table 11 List of Parameters of Channelized Legs

Channelization	Parameter
Channelized lane	0
Not channelized lane	1

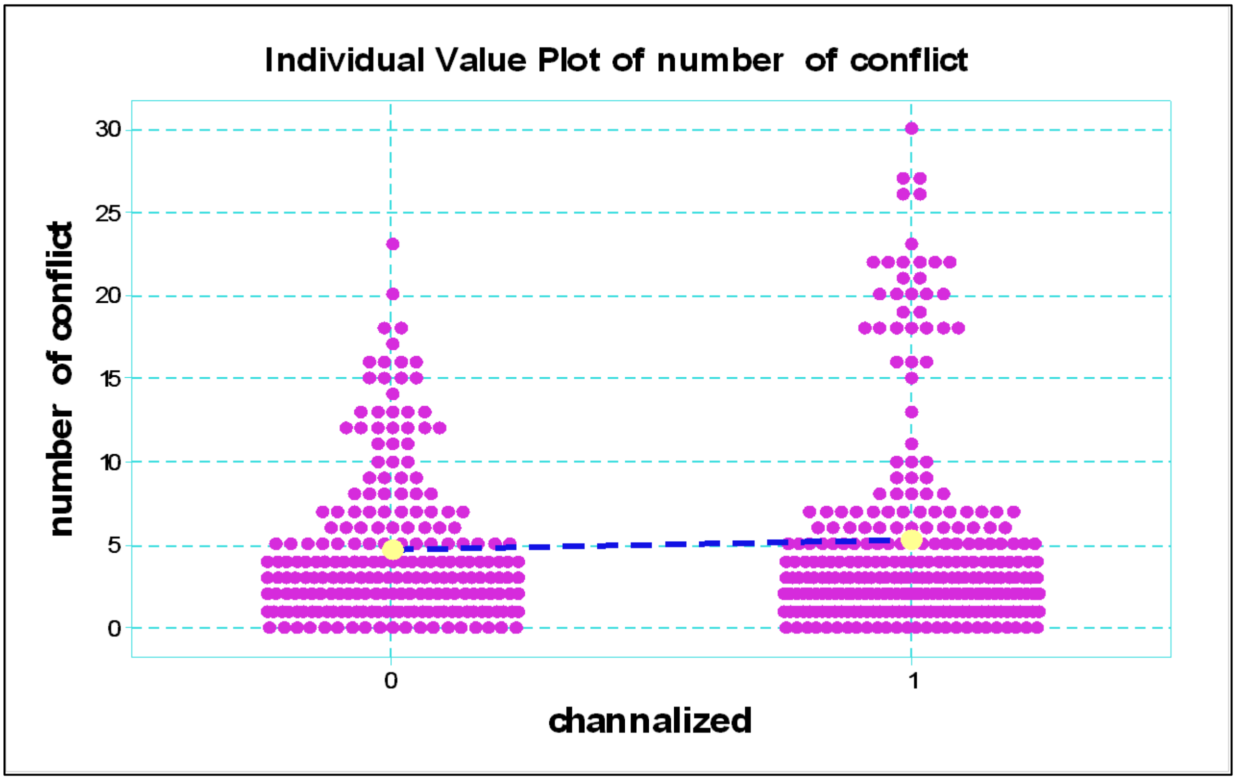


Figure 14 Individual Value Plot of Number of Conflict versus Channelization

4.1.2 Descriptive Statistics of Data Required For Modeling Pedestrian Yielding Behavior

Each individual conflicts between pedestrian and right turn vehicles assessed Based on the parameters defined on ***section 3.4.5***. The statistical result of yielding behavior between pedestrian and right turn vehicle tabulated in ***Table 12***. The table shows that 2452 conflicts observed from the selected intersections and the percentage of pedestrian yielding to the right turn vehicle is 61.66%, which is almost twice that of right vehicle yielding (38.34%). The number of times existence of single pedestrian in a single conflict is 1024 (41.76% of the observation), it is very close to the number of times existence of multiple pedestrian in a single conflict which is 1428 (58.24% of the observation). 68.65% of single pedestrian who are involved in a conflict yield to right turn vehicles, on the contrary 56.65% of multiple pedestrian who are involved in a conflict yield to right turn vehicles. Only 31.35% of right-turn vehicles yield to a single pedestrian involved in a conflict. This indicates that the more people in pedestrian group, the higher probability of vehicle yielding when a pedestrian crosses with the pedestrian group. This statement strengthens by the scatter plot of population of pedestrian group versus yielding part (***Figure 15***). This figure shown us the number of times of vehicle yielding is increased as the number of pedestrian increased with in the pedestrian group.

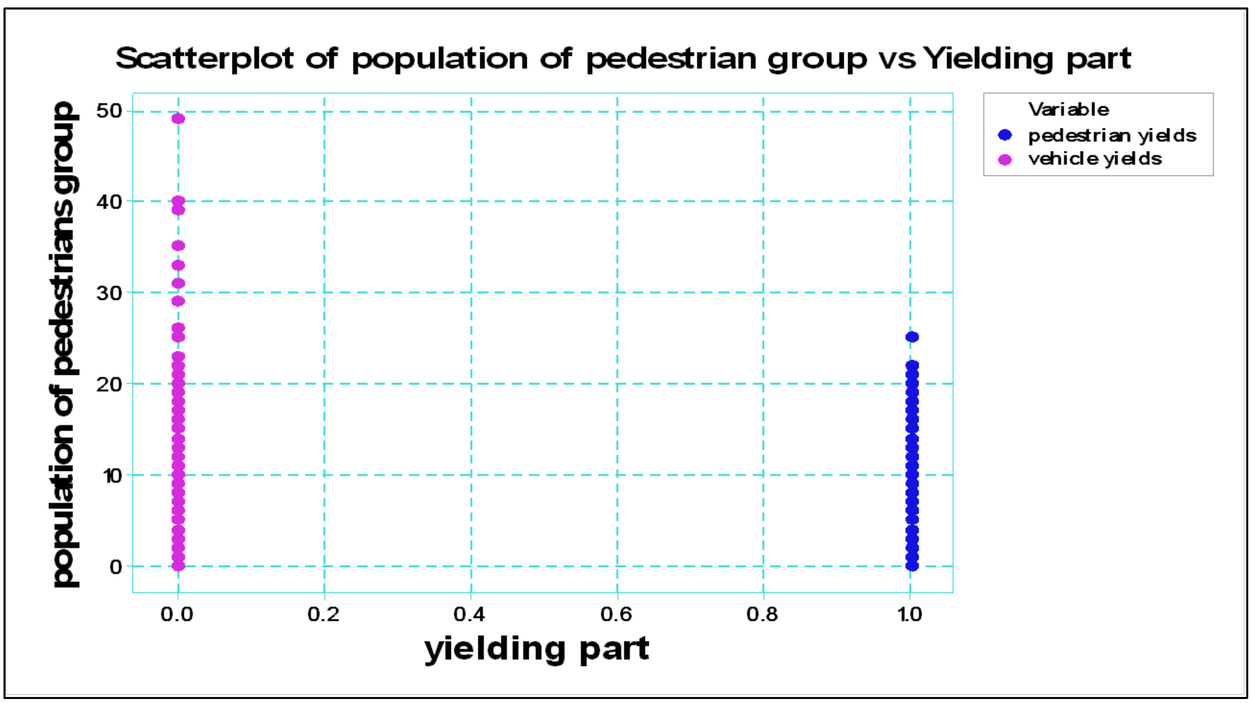


Figure 15 Scatter Plot of Population of Pedestrian Group versus Yielding Part

There were more near-side pedestrian crossings (51.02% of the Observations) than far side crossings (48.98% of the observations) in the data set. This may indicates pedestrian movement allied with the times of day that the data were collected. When a pedestrian crosses from the near-side to the far-side, the pedestrian yielding is higher than the vehicle yielding (which is 64.99% of the observation). 70.39% of the conflicts between pedestrian and right turn vehicle observed at the outer lane of the cross walk, which is three times that of the conflict observed at the inner lane (29.61% of the observation). 63.33% of Pedestrians who are involved in a conflict at the outer lane of the cross walk end up yielding to right turn vehicles.

43.68 % of the pedestrian crosswalks were located near to the intersections; the remaining 56.32 % of the pedestrian crosswalks were located far from the intersections. On the crosswalks which are placed near to the intersection 57.61% of pedestrians yields to right turn vehicles. On the other hand, Crosswalks located far from the intersection 64.81% of pedestrian yields to right turn vehicles.

Table 12 Statistical Result of Yielding Behavior between Pedestrians and Right Turn Vehicles

Collected data				Pedestrians yields		Right turn vehicles yields	
		Qty	Percentile	Qty	Percentile	Qty	Percentile
Total number of conflict		2452		1512	61.66%	940	38.34%
Existence of pedestrian group	Single pedestrian	1024	41.76%	703	68.65%	321	31.35%
	Multi pedestrian	1428	58.24%	809	56.65%	619	43.35%
Direction of pedestrian	Near side	1251	51.02%	813	64.99%	438	35.01%
	Far side	1201	48.98%	699	58.2%	502	41.8%
Location of conflict	Outer lane	1726	70.39%	1093	63.33%	633	36.67%
	Inner lane	726	29.61%	419	57.71%	307	42.29%
Location of cross walk	Near	1071	43.68%	617	57.61%	454	42.39%
	Far	1381	56.32%	895	64.81%	486	35.19%

Speed of a turning vehicle can tell as geometric characteristics of intersection layout. The higher vehicle speeds are strongly associated with both a greater likelihood of pedestrian crash occurrence and more serious resulting pedestrian injury. Therefore, average turning speed used as one of the factors that affects pedestrian yielding decision. The scatter plot of average turning speed versus number of vehicles shows that there is an inverse relationship between them. As number of right turn vehicles increase their turning speed decreases.

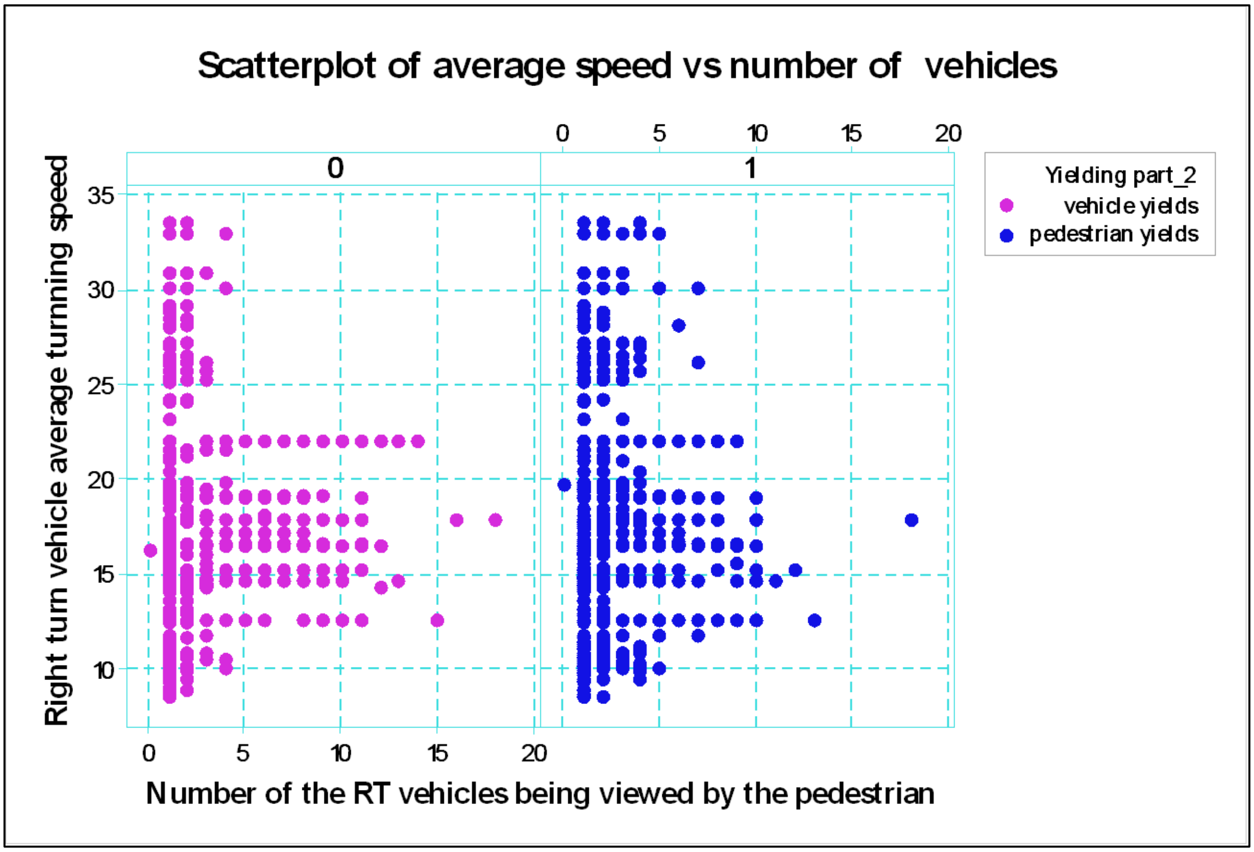


Figure 16 Scatterplot of Average Turning Speed versus Number of Right Turn Vehicle

4.2 Modeling Number of Potential Conflicts

In this study multiple linear and Poisson regression analysis techniques employed to model the number of potential conflicts between right turning vehicles and pedestrians. Dependent and independent variables are stated in ***section 3.4.4.1***. Minitab 18 statistical analysis software was used as a major data analysis tool. Before conducting any regression analysis, regression assumptions have been checked.

4.2.1 Multiple Linear Regression

4.2.1.1 Testing Multiple Linear Regression Assumptions

- **Linear Relationship**

There needs to be a **linear relationship** between the dependent and independent variables. Scatter plot of the each independent variable versus the dependent variable shows that there is no significant evidence for the existence of nonlinear relationship. Refer ***Appendix.***

- **No Multicollinearity**

The predictor variables should not be highly correlated with each other. If they are highly correlated with each other, the standard error from the regression analysis tends to increase and give us a misleading result. If there exists a correlation coefficient greater than 0.8 then we will have Multicollinearity. As we can see in the ***Table 13*** the correlation coefficients for all the variables are much lesser than 0.8, so the independent variables are not strongly correlated with each other**.** This assumption also can be tested by looking at the Coefficients table. This allows us to more formally check that our predictors are not too highly correlated. We can use Variance inflation factor (VIF) to assess this assumption. For the assumption to be met we want VIF scores to be below 10. As ***Table 15*** shows All VIF scores were well below 10, therefore the independent variables are not strongly correlated with each other.

Table 13 Correlation Matrixes of Independent Variables

	Pedestrian volume	Right turn vehicles	Number of lanes
Right turn vehicles	-0.185		
	0.000		
Number of lanes	-0.045	0.031	
	0.375	0.535	
Channelization	0.219	-0.167	0.537
	0.000	0.001	0.000

Table content; Person correlation, p - value

- **Homoscedasticity**

A homoscedasticity is a graphical data analysis technique for assessing the assumption of constant variance across subsets of the data. The scatter plot of residuals versus fitted value is generated and interpreted as the greater the spread on the vertical axis, the less valid is the assumption of constant variance. ***Figure 17*** shows the scatter plot of residuals versus fitted value and it looks great the variance of the residuals is constant across the full range of fitted values. So, our data set shows Homoscedasticity.

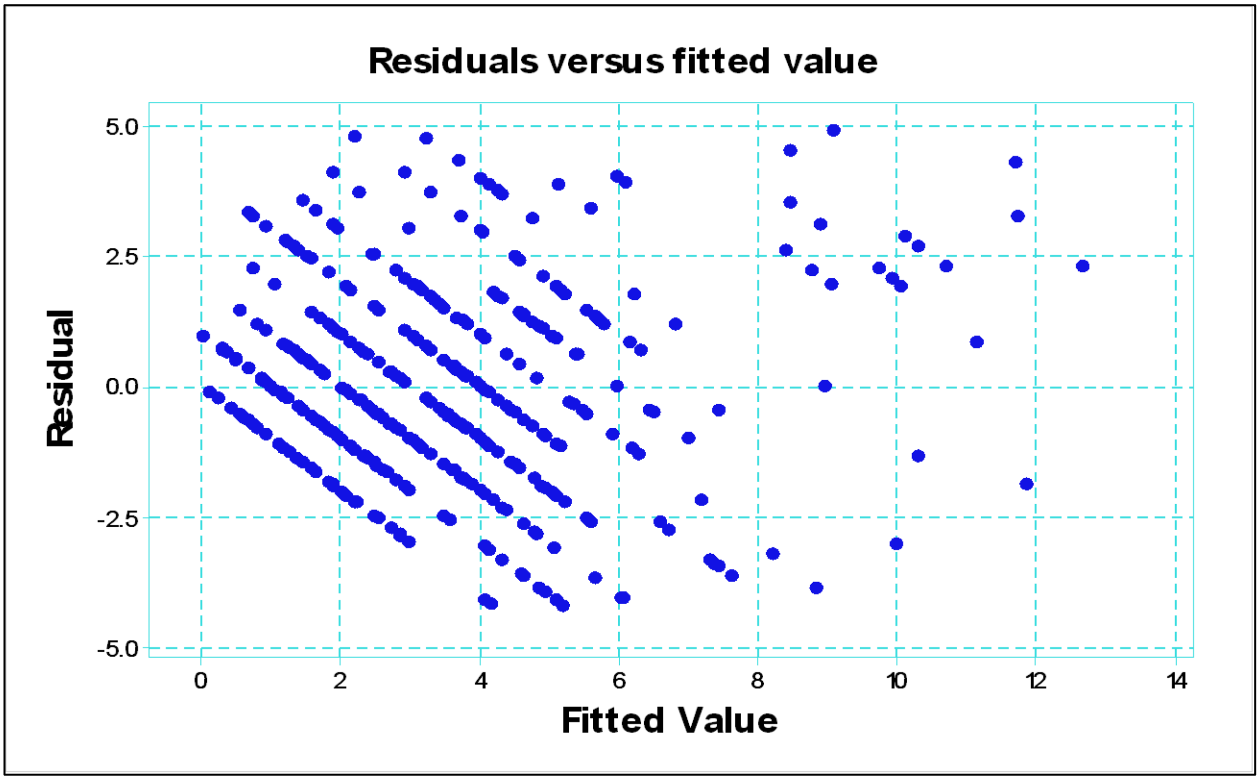


Figure 17 Residuals versus Fitted Value

- **Independent Error**

The residuals versus order plot used to verify the assumption that the residuals are independent from one another. Independent residuals show no trends or patterns when displayed in time order. Patterns in the points may indicate that residuals near each other may be correlated, and thus, not independent. Ideally, the residuals on the plot should fall randomly around the center line. As we can see from ***Figure 18*** there is a nonrandom pattern which implies the residuals are uncorrelated to one another.

- **Normally distributed residuals**

The histogram of the residuals shows the distribution of the residuals for all observations. In ***Figure 19*** shows Histogram plot of the residuals which indicates that the residuals are normally distributed.

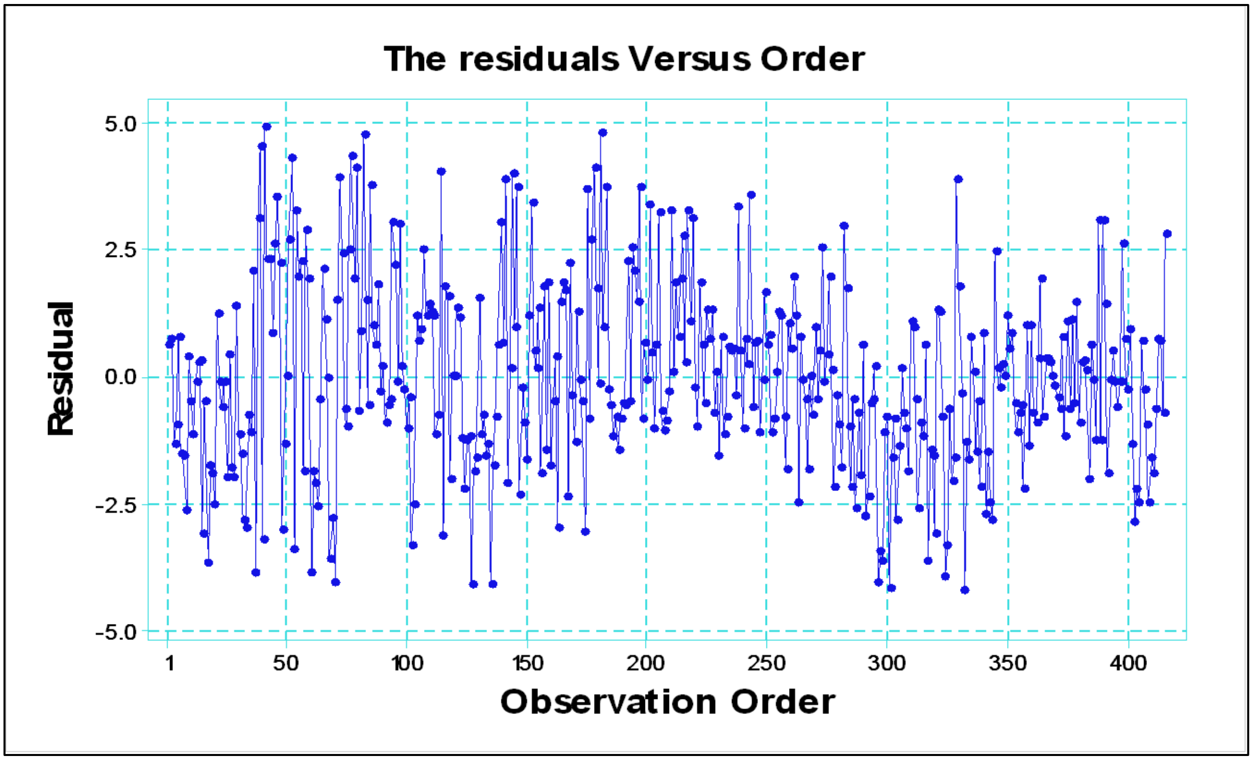


Figure 18 Residual versus Order Plot

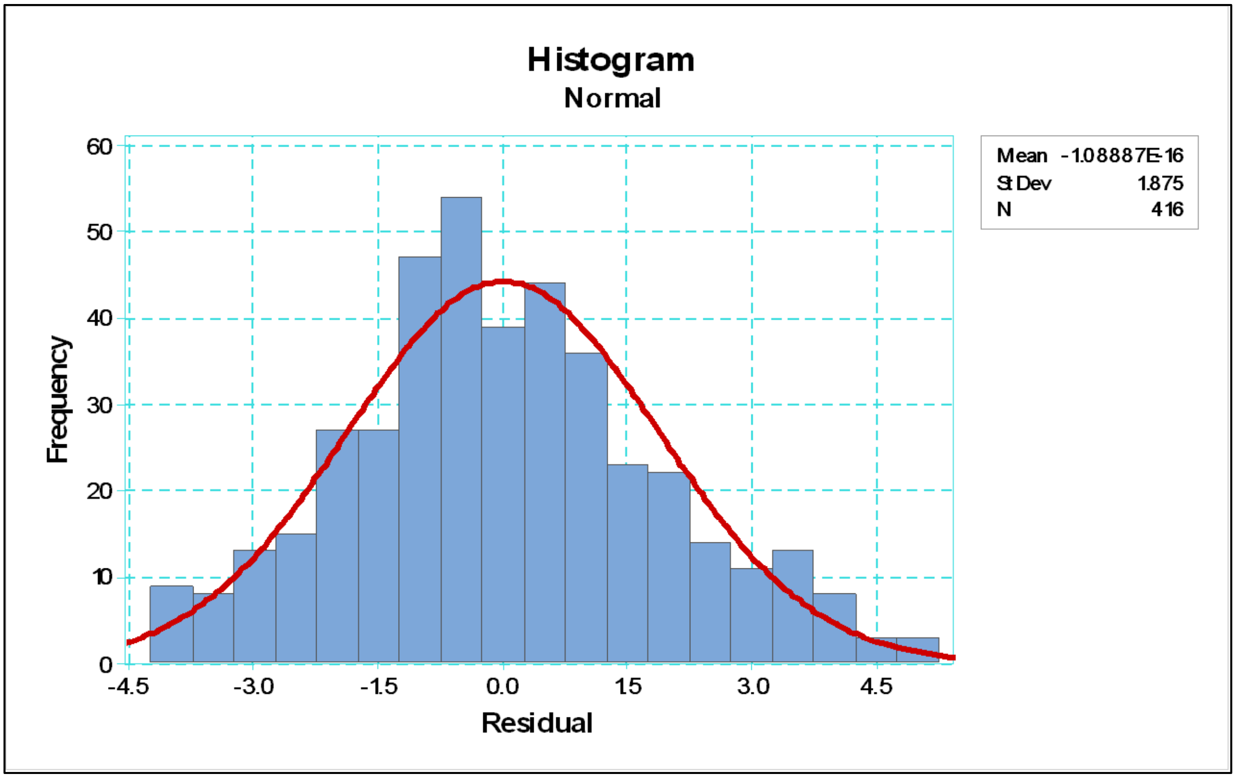


Figure 19 Histogram of Residuals

4.2.1.2 Running the Regression Analysis

The researcher used stepwise model-selection techniques to screen out predictors not associated with the responses. Stepwise regression is an automated tool used in the exploratory stages of model building to identify a useful subset of predictors. The process systematically adds the most significant variable or removes the least significant variable during each step.

Minitab 18 statistical analysis software was used as a major data analysis tool. The predictor variables consists both continuous and categorical values.

$$conflict = \beta_o + \beta_1 PED + \beta_2 RTV + \beta_3 NL + \beta_4 C$$

Dependent variable : number of potential conflicts (conflicts/ 5 min)

Predictor variables; pedestrian volume (ped/5 min) , Righ turn vehicle volume (RTV/5 min) and

Number of lanes (NL) and channelization (C) (both are categorical variables stated in table 9 and 10)

Stepwise regression both adds and removes predictors as needed for each step. Minitab stops when all variables not in the model have p-values that are greater than the specified alpha-to-enter value and when all variables in the model have p-values that are less than or equal to the specified alpha-to-remove value. On this study for 95 % level of confidence the alpha value is 0.05. Only three predictor variables are selected which are significantly affects the response variable **(**see ***Table 14*****)**. These predictor variables are pedestrian volume, right turn volume and number of lanes. They have p value that is less than to the specified alpha-to-remove value which is 0.05.

On the contrary, channelization has p-values that are greater than the specified alpha-to-enter value. This implies channelization of the intersection lane doesn't affect the number of conflicts between right turn vehicle and pedestrian. Therefore, channelization is removed from the model.

Table 14 Stepwise Selection of Terms

	Step 1		Step 2		Step 3	
	Coefficient	p-value	Coefficient	p-value	coefficient	p-value
Constant	1.400		-1.355		-0.630	
RTV/ 5min	0.1488	0.000	0.17460	0.000	0.18709	0.000
PED/ 5min			0.05888	0.000	0.06451	0.000
Number of lanes					-1.912	0.000
R-sq	29.62		54.38		72.43	
R-sq(adj)	28.48		53.63		72.04	

Table 15 Coefficient Table

Term		Coefficient	SE coefficient	T- value	p -value	VIF
Constant		-0.630	0.259	-2.43	0.015	
PED/ 5min		0.06451	0.00374	17.25	0.000	1.08
RTV/ 5min		0.18709	0.00878	21.3	0.000	1.06
Number of lanes	1	-1.912	0.219	-8.72	0.000	1.71
	2	-0.843	0.226	-3.72	0.000	1.65

Table 16 Regression Equation

Number of lanes	Equation
Less than or equal to two (≤2)	Conflict= -0.630+0.06451PED+0.18709RTV
Three (3)	Conflict= -2.541+0.06451PED+0.18709RTV
Greater than or equal to four (≥ 4)	Conflict= -1.473+0.06451PED+0.18709RTV

The final regression equation is;

$$conf. = -0.630 + 0.0645PED + 0.18709RTV - 1.912NL(3) - 0.843NL(\geq 4)$$

Number of lanes takes dummy variables 1 and 0.

4.2.1.3 Interpretation of the regression result

The final result of the regression analysis is tabulated in the above table (***Table 15***). The results have shown that three predictors are significant because of their low p-values. Together, the predictors explain 72.04 % of the variance of number of conflicts.

Coefficients represent the mean change in the response for one unit of change in the predictor while holding other predictors in the model constant. The sign of the coefficient indicates the direction of the relationship between the term and the response. The size of the coefficient is usually a good way to assess the practical significance of the effect that a term has on the response variable. ***Table 15*** shows that;

- For Both pedestrian and right turn vehicle volume the coefficient is positive which indicates as they increase the mean value of the number of conflict also increases. But there size of the coefficients is different, For 1 unit increase in right turn volume, the percentage of number of conflicts expected to increase is 0.18709%. In contrast for 1 unit increase in pedestrian volume, the percentage of number of conflict expected to increase is 0.06451%. An increase in right turn vehicle volume significantly affects the number of conflicts more than pedestrian volume.
- Number of lanes is a categorical variable stated on table 4.3. Number of lanes has an inverse relationship with number of conflicts. The coefficient for the categorical variable

of number of lanes indicates that number of lanes with three lanes have conflicts that are an average of 1.912 points less than number of lanes with less or equal to two lanes. Similarly, number of lanes with greater than or equal to four lanes have conflicts that are an average of 0.842 points less than number of lanes with less or equal to two lanes.

4.2.2 Poisson regression

A stepwise Poisson regression analysis was performed to model number of conflicts between right turn vehicles and pedestrians at signalized intersections with the following explanatory variables. The explanatory variables consists both continuous and categorical variables. Pedestrian volume and right turn vehicle volume are continuous variables. Number of lanes and channelization are categorical variables. Number of lanes consists three categories which are presented in Table 10, and channelization possesses two categories stated in table 11. The categorical predictor variables are encoded in the regression model as dummy variables which take a value of 1 or 0.

$$\log\ \mu_i\ = \beta_o + \beta_1 PED + \beta_2 RTV + \beta_3 NL + \beta_4 C$$

$$\mu_i = exp(\beta_o + \beta_1 PED + \beta_2 RTV + \beta_3 NL + \beta_4 C)$$

Dependent variable : number of potential conflicts (conflicts/ 5 min)

Predictor variables; pedestrian volume (ped/5 min) , Righ turn vehicle volume (RTV/5 min) and

Number of lanes (NL) and channelization (C) (both are categorical variables stated in table 9 and 10)

Stepwise selection of terms is used for all candidate predictor variables. Only one variable is added at each step of the regression. As shown in the table below p-values for each added variables is less than the significance level which confirms that all predictor variables significantly predict departure headway of vehicles and there is an increment in the adjusted r squared value at each step of the regression

Table 17 Stepwise Selection of Terms

	Step 1		Step 2		Step 3		Step 4	
	Coef.	p-value	Coef.	p-value	Coef.	p-value	Coef.	p-value
Constant	0.6675		-0.1603		-0.124		-0.139	
RTV/ 5min	0.0358	0.000	0.04382	0.000	0.04385	0.000	0.04275	0.000
PED/ 5min			0.01585	0.000	0.01658	0.000	0.01726	0.000
No of lanes					-0.2238	0.000	0.204	0.000
channelization							-0.1604	0.031
R-sq		25.79		49.98		72.43		53.36
R-sq(adj)		25.67		49.73		72.04		52.75

The final regression analysis was run to predict number of lanes from pedestrian volume, right turn vehicle volume, number of lanes and channelization. The predictor variables were found to statistically significantly predict number of conflict, ***p<0.05***, and R^2***Adj = 0.53.36***. All predictor variables added statistically significantly to the prediction, ***p<0.05***.

Table 18 Coefficient Table

Term		Coefficient	SE coefficient	Z- value	p -value	VIF
Constant		-0.139	0.109	-1.28	0.202	
PED/ 5min		0.01726	0.00120	14.35	0.000	1.26
RTV/ 5min		0.04275	0.00254	16.86	0.000	1.17
Number of lanes	1	-0.1260	0.0836	-1.51	0.000	2.19
	2	0.2040	0.0964	-2.12	0.034	2.67
Channelization		-0.1604	0.0742	-2.16	0.031	1.79

The final regression equation is

Number of conflict = exp(-0.139+0.01726PED+0.04275RTV-0.126NL(3)+0.204(≥4)-0.1604C)

- Goodness of fit test

The goodness-of-fit tests are all greater than the significance level of 0.05, which indicates that there is not enough evidence to conclude that the model does not fit the data.

Table 19 Goodness of fit

Test	DF	Chi-Square	P-Value
Deviance	386	385.36	0.5
Pearson	386	334.5	0.972

4.2.2.1 Interpretation of the regression result

A regression coefficient describes the size and direction of the relationship between a predictor and the response variable. Coefficients are the numbers by which the values of the term are multiplied in a regression equation. The estimated coefficient for a predictor represents the change in the link function for each unit change in the predictor, while the other predictors in the model are held constant. The relationship between the coefficient and the number of events depends on several aspects of the analysis, including the link function and the reference levels for categorical predictors that are in the model. Generally, positive coefficients make the event more likely and negative coefficients make the event less likely. The interpretation of the estimated coefficients for categorical predictors is relative to the reference level of the predictor. Positive coefficients indicate that the event is more likely at that level of the predictor than at the reference level of the factor. Negative coefficients indicate that the event is less likely at that level of the predictor than at the reference level.

- The coefficient of pedestrian volume and right turn vehicle is positive, this indicates that number of conflicts is more likely occurs when they increases.

- The coefficient of number of lane is positive, this indicates that number of conflict is more likely to occur when number of lanes is greater than four than when number of lane is less than two.

- The coefficient of channelization is negative; this indicates that number of conflict is less likely when there is channelization at the intersection legs.

4.3 Modeling Pedestrian Yielding Behavior

In this study logistic regression analysis techniques employed to model the pedestrian yielding behavior. Dependent and independent variables are stated in ***section 3.4.4.2***. Minitab 18 statistical analysis software was used as a major data analysis tool. Before conducting any regression analysis logistic regression assumptions have been checked.

4.3.1 Testing binary logistic Regression Assumptions

- **Binary outcome**

Binary logistic regression requires the dependent variable to be binary. Yielding behavior of pedestrians has two outcomes pedestrian yielding or not yielding. Hence, binary variable is suitable to indicate the decision. If pedestrian yields using one as variable or zero if not.

- **No Influential Values (extreme values or outliers)**

There should be no influential values (extreme values or outliers) in the continuous predictors. The continuous predictors (Population of pedestrians, Volume of right turn vehicle and Turning speed) are tested for outliers using Grubbs' test and the outliers are removed from the analysis. As we can see from the below table in all continuous predictors p-value is greater than alpha value (0.05) which indicates there is no outlier at 5% of level of significance.

Table 20 Grubbs' Test Result

Variable	N	Mean	StDev	Min	Max	G	P
Population of pedestrians	2304	2.284	1.6838	1.0000	9.0000	23.99	0.149
Volume of right turn vehicle	2304	2.0925	1.9415	0.0000	10.0000	1.07	0.104
Turning speed	2304	2.2840	6.403	8.4000	33.460	2.42	1.000

*** NOTE * No outlier at the 5% level of significance**

- **No Multicollinearity**

As we can see in the ***Table 21*** the correlation coefficients for all the variables are much lesser than 0.8, so the independent variables are not strongly correlated with each other.

Table 21 Correlation Matrix of Independent Variables

	Existence of pedestrian group	Direction of pedestrian	Location of conflict	Location of cross walk	Volume of right turn vehicle	Turning speed
Direction of pedestrian	0.004					
	0.846					
Location of conflict	0.035	0.419				
	0.089	0.000				
Location of cross walk	-0.081	0.056	-0.267			
	0.000	0.007	0.000			
Population of pedestrians	0.677	0.008	0.062	-0.135		
	0.000	0.713	0.003	0.000		
Volume of right turn vehicle	0.115	-0.106	0.064	-0.232	0.252	
	0.000	0.000	0.002	0.000	0.000	
Turning speed	0.005	0.022	0.307	-0.508	-0.023	-0.040
	0.810	0.287	0.000	0.000	0.272	0.053

Table content; Person correlation, p – value

- **Linear Relationship Between The Logit Of The Outcome And Each Continuous Predictor Variables**

The linear relationship between continuous predictor variables and the logit of the outcome is checked by visually inspecting the scatter plot between each predictor and the logit values. The smoothed scatter plots show that variables Population of pedestrians, Volume of right turn vehicle and Turning speed are all quite linearly associated with the pedestrian yielding outcome in logit scale (see ***Figure 20*** and ***Appendix***)

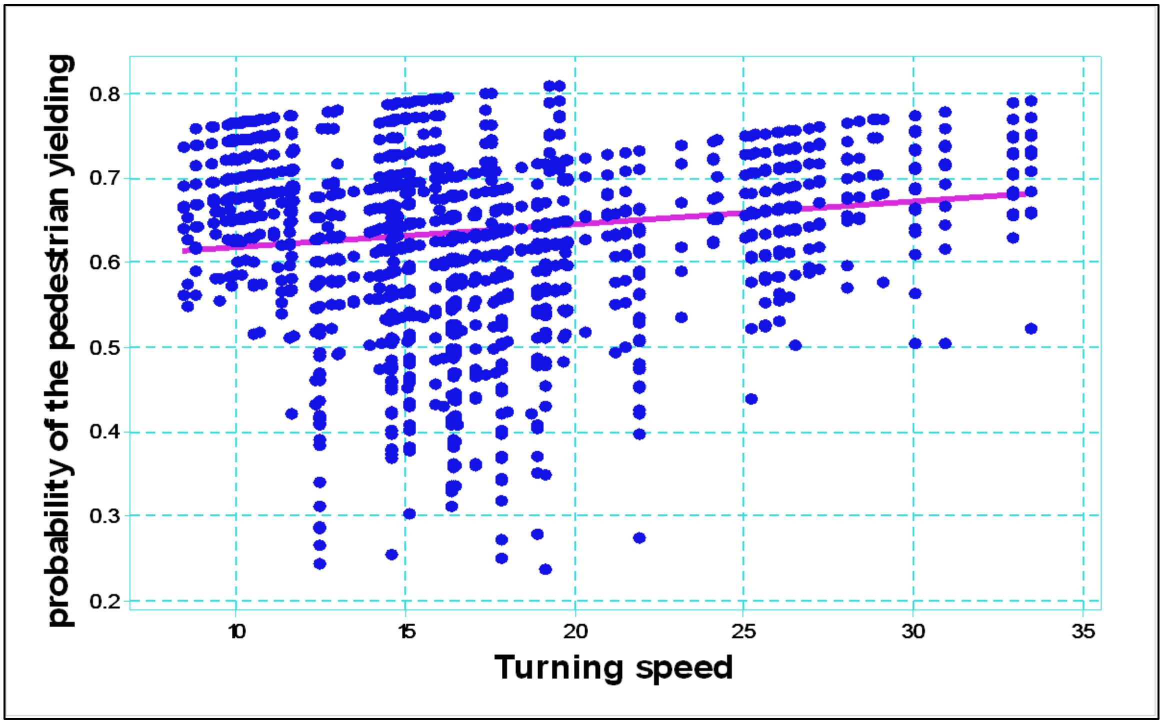


Figure 20 the Scatter Plot of the Probability of the Pedestrian Yielding Versus Turning Speed

4.3.2 Running the Regression Analysis

Stepwise model-selection techniques used to screen out predictors not associated with the responses. Minitab 18 statistical analysis software was used as a major data analysis tool. The predictor variables consists both continuous and categorical values.

$$P_{(pedestrian\ yeilding\ )} = \frac{\exp(Y\prime)}{1+\exp(Y\prime)}$$

$$Y' = \beta_o + \beta_1 P_n + \beta_2 R_n + \beta_3 T_t + \beta_4 EPG + \beta_5 DP + \beta_6 LCW + \beta_7 LC$$

Dependent variable; yielding part (0 for right turn vehicle and 1 for pedestrian)

Independent variables;

- ✓ Population of pedestrian group, Pn(number)
- ✓ Volume of right turn vehicle, Rn(number)
- ✓ Turning speed, Tt(km/hr)

- ✓ Existence of pedestrian group, EPG (0 for single pedestrian and 1 for group pedestrians)
- ✓ Direction of pedestrian, DP (0 for near side to far side and 1 for far side to near side)
- ✓ Location of cross walk, LCW (0 for near to the intersection and 1 for far to the intersection)
- ✓ Location of conflict, LC (0 for near the outer lane and 1 for near the inner lane)

The stepwise regression step by step process tabulated below (***Table 22***). The predictors Location of conflict and Existence of pedestrian group are not eligible for entry into the stepwise model because its P-value is greater than αE = 0.05. The other predictors are candidates because each P-value is less than αE = 0.05.

Table 22 Stepwise Selection of Terms

	Step 1		Step 2		Step 3		Step 4		Step 4	
	Coef.	P	Coef.	P	Coef.	P	Coef.	P	Coef.	P
Constant	0.8940		1.1340		1.299		1.199		0.618	
Vol. RTV	0.1484	0.00	0.1222	0.000	0.1319	0.000	0.1197	0.000	0.1068	0.000
Pop. ped			-0.1273	0.000	-0.1248	0.000	-0.1192	0.000	-0.1134	0.000
Dir. ped					-0.3078	0.001	-0.3165	0.000	-0.3332	0.000
Loc. CW							0.277	0.012	0.502	0.000
Tur.speed									0.02770	0.001

The coefficient table (***Table 23***) shown as all P-values are less than the significance level (α=0.05), this indicates there is a statistically significant association between the response variable and the predictors. And all Variance inflation factor (VIF) scores were well below 10, therefore the predictor variables are not strongly correlated with each other.

Table 23 Coefficient Table

Term	Coefficient	SE coef	Z-value	P-value	VIF
Constant	0.618	0.201	3.07	0.002	
Population of pedestrian group	-0.1134	0.0266	-4.26	0.000	1.06
Volume of right turn vehicle	0.1068	0.0238	-4.50	0.000	1.14
Turning speed	0.02770	0.00832	3.33	0.001	1.37
Direction of pedestrian (far side)	-0.3332	0.0898	-3.71	0.000	1.02
Location of cross walk (far)	0.502	0.129	3.91	0.000	1.46

- Odds ratio for continuous predictors

Odds ratios that are greater than 1 indicate that the event is more likely to occur as the predictor increases. Odds ratios that are less than 1 indicate that the event is less likely to occur as the predictor increases.

Table 24 Odds Ratio for Continuous Predictors

	Odds ratio	95% confident interval
Population of pedestrian group	0.8928	(0.8474,0.9406)
Volume of right turn vehicle	1.2789	(0.8578,0.9415)
Turning speed	1.0281	(1.0115,1.0450)

- Odds ratio for categorical predictors

The odds ratio compares the odds of the event occurring at 2 different levels of the predictor. Minitab sets up the comparison by listing the levels in 2 columns, Level A and Level B. Level B is the reference level for the factor (as shown in ***Table 21***). Odds ratios that are greater than 1 indicate that the event is less likely at level B. Odds ratios that are less than 1 indicate that the event is more likely at level B.

Table 25 Odds Ratio for Categorical Predictors

	Level A	Level B	Odds ratio	95% CI
Direction of pedestrian	far side to near side	near side to far side	0.7166	(0.6010,0.8546)
Location of cross walk	far from the intersection	near to the intersection	1.6527	(1.2846,2.1262)

Odds ratio for level A relative to level B

- Binary logistic regression equation

The probability of pedestrian yielding to right turn vehicle and the final result of the regression analysis is stated below.

Table 26 Regression Equation

Direction of PED.	Location of cross walk	Equation (Y')
near side to far side	near to the intersection	Y=0.6177-0.1134Pn+0.1068Rn+0.0277Vt
near side to far side	far from the intersection	Y=0.120-0.1134Pn+0.1068Rn+0.0277Vt
far side to near side	near to the intersection	Y=0.2845-0.1134Pn+0.1068Rn+0.0277Vt
far side to near side	far from the intersection	Y=0.7869-0.1134Pn+0.1068Rn+0.0277Vt

Where, Pn=Population of pedestrian group, Rn=Volume of right turn vehicle, Vt =Turning speed

The final regression equation is;

$$P_{(pedestrian\ yielding\ )} = \frac{\exp(Y\prime)}{1+\exp(Y\prime)}$$

$$Y' = 0.6177 - 0.1134P_n - 0.1068R_n + 0.0277T_t - 0.3332DP - 0.502LCW$$

Direction of pedestrian and location of conflicts takes a dummy variable (0 and 1) which is stated on ***section 3.4.5***.

- Goodness of fit test

The goodness-of-fit tests are all greater than the significance level of 0.05, which indicates that there is not enough evidence to conclude that the model does not fit the data.

Table 27 Goodness of Fit Test

Test	DF	Chi-Square	P-Value
Pearson	2297	2305.44	0.447
Hosmer- lemeshow	8	9.84	0.303

4.3.3 Interpretation of the result

The selected interaction between pedestrians and right turn vehicle, which is pedestrian yielding behavior, is modeled by binary logistic regression. The key predictor variables according to the stepwise regression result are population of pedestrian group, volume of right turn vehicle, turning speed, Direction of pedestrian and Location of cross walk.

The relationship between the coefficient and the probability depends on several aspects of the analysis, including the link function. Generally, positive coefficients indicate that the event becomes more likely as the predictor increases. Negative coefficients indicate that the event becomes less likely as the predictor increases.

- The coefficient of population of pedestrian group is negative; the more people in pedestrian group the lower probability of pedestrian yielding when a pedestrian crosses with the pedestrian group. In other world the higher the probability of vehicle yielding.
- The coefficient of volume of right turn vehicle is positive; the higher right turn vehicle volume increases the probability of pedestrian yielding.
- The coefficient of turning speed is positive; the higher turning speed of right turn vehicle increases the probability of pedestrian yielding.
- The coefficient of the direction of pedestrian crossing from far side to near side is negative: when pedestrian crossing from far side to near side the probability of pedestrian yielding is lower than the opposite direction.

- When the location of crosswalk far from the intersection the coefficient is positive; the probability of pedestrian yielding is higher than when the location of crosswalk is near to the intersection.

We can use the odds ratio to understand the effect of a predictor. The interpretation of the odds ratio depends on whether the predictor is continuous or categorical.

- Odds ratio of population of pedestrian group is less than 1 (as shown in the ***table 24***). This indicates that pedestrian yielding is less likely to occur as the more people in pedestrian group increases.
- Odds ratio of volume of right turn vehicle is greater than 1(as shown in the ***table 24***). This indicates that pedestrian yielding is more likely to occur as right turn vehicle volume increases.
- Odds ratio of turning speed of right turn vehicle is greater than 1(as shown in the ***table 24***). This indicates that pedestrian yielding is more likely to occur as right turn vehicle turning speed increases.
- An odds ratio of pedestrian crosses from far side to near side is less than 1 (as shown in the ***table 25***). This indicates that pedestrian yielding is more likely when pedestrian crosses from near side to far side.
- An odds ratio of location of cross walk far from the intersection is greater than 1 (as shown in the ***table 25***). This indicates that pedestrian yielding is less likely when the location of cross walk is near to the intersection.

CHAPTER FIVE- CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The main objective of this paper is to study the interaction between pedestrians and right-turn vehicles at signalized intersections. The following conclusions were reached from the analysis of the interaction between pedestrians and right turn vehicle:

- 30.89% of pedestrians, who are crossing the road, are vulnerable to traffic conflicts and 48.96% of right turn vehicle are involved in conflict with the pedestrians at signalized intersections.
- High amount of number of conflicts occurs on the number of lanes greater than or equal to four and lower amount of number of conflicts occurs on when number of lanes is three
- Number of conflict doesn't depend on what kind of right turn vehicle control mechanism used.
- The percentage of pedestrian yielding to the right turn vehicle is almost twice that of right vehicle yielding at signalized intersections.
- The number of times of vehicle yielding is increased as the number of pedestrian increased with in the pedestrian group.
- When a pedestrian crosses from the near-side to the far-side, the pedestrian yielding is higher than the vehicle yielding.
- The conflicts between pedestrian and right turn vehicle observed at the outer lane of the cross walk is three times that of the conflict observed at the inner lane.
- On the crosswalks which are placed near to the intersection half of pedestrians yield to right turn vehicles. On the other hand, Crosswalks located far from the intersection two third of pedestrian yields to right turn vehicles.
- Multiple linear regression analysis techniques employed to model the number of potential conflicts between right turning vehicles and pedestrians. The predictor variables significantly affect the number of potential conflicts are pedestrian volume, right turn volume and number of lanes.

- Both pedestrian and right turn vehicle volume have positive relationship with number of potential conflict which indicates as they increase the mean value of the number of conflicts also increases.
- An increase in right turn vehicle volume significantly affects the number of conflicts more than pedestrian volume.
- Number of lanes has an inverse relationship with number of conflicts.
- Logistic regression analysis techniques employed to model the pedestrian yielding behavior. The key predictor variables significantly affect pedestrian yielding behavior are population of pedestrian group, volume of right turn vehicle, turning speed, Direction of pedestrian and Location of cross walk
- The more people in pedestrian group the lower probability of pedestrian yielding when a pedestrian crosses with the pedestrian group. In other world the higher the probability of vehicle yielding. This indicates that pedestrian yielding is less likely to occur as the more people in pedestrian group increases
- The higher right turn vehicle volume increases the probability of pedestrian yielding. This indicates that pedestrian yielding is more likely to occur as right turn vehicle volume increases
- The higher turning speed of right turn vehicle increases the probability of pedestrian yielding. This indicates that pedestrian yielding is more likely to occur as right turn vehicle turning speed increases
- When pedestrian crossing from far side to near side the probability of pedestrian yielding is lower than the opposite direction. This indicates that pedestrian yielding is more likely when pedestrian crosses from near side to far side
- The probability of pedestrian yielding is higher when the location of crosswalk is far from the intersection. This indicates that pedestrian yielding is less likely when the location of cross walk is near to the intersection

5.2 Recommendations

- The researcher of this study recommends the derived models should evaluate signalized intersections located in Addis Ababa.
- A future study should investigate the relationship between pedestrian crashes and pedestrian-right turn vehicle conflicts. This helps to define the effect of potential conflicts on the occurrence of pedestrian crashes at signalized crosswalks.
- For future research , it is recommend to study conflict on other areas;
    - Conflict b/n left turn vehicles and pedestrians at intersections
    - Conflict b/n vehicles and pedestrians at a road segment
    - Conflicts b/n vehicles at non signalized intersections

REFERENCE

Akin, D. and virginia p. sisiopiku (2007) 'Modeling interactions between pedestrians and turning-vehicles at signalized crosswalks operating under combined pedestrian-vehicle interval', *Transportation Research*, 5000(101), pp. 1–25.

Cheng, W. *et al.* (2014) 'Modeling and Application of Pedestrian Safety Conflict Index at Signalized Intersections', *Discrete Dynamics in Nature and Society*, 2014, pp. 1–6. doi: 10.1155/2014/314207.

Cynecki, M. J. (1980) 'Development of conflicts analysis technique for pedestrian crossings', *Transportation Research Record, Vol. 743.*, p. 43. Available at: http://onlinepubs.trb.org/Onlinepubs/trr/1980/743/743-003.pdf.

Davis, S. E. (2000) 'pedestrian_vehicle conflicts an accident prediction model', *transportation research record, vol. 1216*, (5).

Forsyth, A., Agrawal, A. W. and Krizek, K. J. (2012) 'Simple, Inexpensive Approach to Sampling for Pedestrian and Bicycle Surveys', *Transportation Research Record: Journal of the Transportation Research Board*, 2299(1), pp. 22–30. doi: 10.3141/2299-03.

Green, S. B. (1991) 'How Many Subjects Does It Take To Do A Regression Analysis, Multivariate Behavioural Research', *Multivariate Behavioral Research*, 26(3), pp. 499–510. doi: 10.1207/s15327906mbr2603.

He, Y. L. *et al.* (2019) 'Left-turning vehicle-pedestrian conflicts at signalized intersections with traffic lights: Benefit or harm? A two-stage study', *Chinese Journal of Traumatology - English Edition*, 22(2), pp. 63–68. doi: 10.1016/j.cjtee.2018.07.007.

Hubbard, S. M., Bullock, D. M. and Mannering, F. L. (2009) 'Right Turns on Green and Pedestrian Level of Service: Statistical Assessment', *Journal of Transportation Engineering*, 135(4), pp. 153–159. doi: 10.1061/(asce)0733-947x(2009)135:4(153).

Knofczynski, G. T. (2002) *Sample Sizes for Predictive Regression Models and Their Relationship to Correlation Coefficients*, *Journal of Mathematical Sciences & Mathematics Education*. Available at: https://sci-hub.tw/https://doi.org/10.1207/s15327906mbr2603_7.

Kumar, A., Paul, M. and Ghosh, I. (2019) 'Analysis of Pedestrian Conflict with Right-Turning Vehicles at Signalized Intersections in India', *Journal of Transportation Engineering, Part A: Systems*, 145(6), p. 04019018. doi: 10.1061/JTEPBS.0000239.

Ling, Z., Ni, Y. and Li, K. (2012) 'Modeling Interaction between Pedestrians and Right-turn Vehicles at Signalized Intersection', *American Society Civil Engineers*, pp. 2615–2626.

Ling, Z., Ni, Y. and Li, K. (2013) 'Analysis of Conflicts between Right-Turn Vehicles and Pedestrians under Different Right-Turn Control Schemes: A Comparative Study', *American Society Civil Engineers*, pp. 206–214. doi: 10.1061/9780784413036.029.

LIU, T. Z. yingying Z. and D. Ya. shuai (2014) 'Real time Pedestrian-Vehicle Conflict Detection Algorithm Using Video Data', *American Society Civil Engineers*, (1967), pp. 3743–3751.

Lord, D. (2007) 'Analysis of Pedestrian Conflicts with Left-Turning Traffic', *Transportation Research Record: Journal of the Transportation Research Board*, 1538, pp. 61–67. doi: 10.3141/1538-08.

Lu, Z. S. F. and (2009) 'Probabilistic Pedestrian-Vehicle Conflict Micro-Model in Non-Signal Controlled Multi-Lane Segments', *Management*.

Marisamynathan, S. and Vedagiri, P. (2015) 'A Stati istical Analysis s of Ped destrian n Behav viour at Signalize ed Inter rsection ns', *European Tra sport \ TrasportiEurop n pei (2015) Issue 57, Pa aper n° 7, ISSN 1825-3 997 A*, (May), pp. 1–18.

Montgomery, D. C. (2003) *Applied Statistics and Probability for Engineers Third Edition*, *Phoenix Usa*. doi: 10.2307/1269738.

Ni, Y. and Li, K. (2011) 'Modelling Pedestrian Behavior at Signalized Intersections: A Case Study in Shanghai', *American Society Civil Engineers*, (1), pp. 1745–1754. doi: 10.1061/41177(415)221.

PERUMAL, V. and M. and (2014) 'Study on Pedestrian Crossing Behavior at Signalized Intersections', *American Society Civil Engineers*, pp. 3743–3751.

Schroeder, B. J. and Rouphail, N. M. (2010) 'Event-Based Modeling of Driver Yielding

Behavior at Unsignalized Crosswalks', *Journal of Transportation Engineering*, 137(7), pp. 455–465. doi: 10.1061/(asce)te.1943-5436.0000225.

Tan, G. ; Z. W. G. L. and H. L. (2015) 'A calculation of traffic conflict probability of right- turn vehicles and Pedestrians at No Right Turn phase Intersections', pp. 2815–2826. Available at: http://ascelibrary.org/doi/abs/10.1061/9780784479292.fm.

Tulu, G., Washington, S. and King, M. (2013) 'Characteristics of police-reported road traffic crashes in Ethiopia over a six year period', pp. 1–13. Available at: https://www.researchgate.net/publication/257927241.

Vuong, T. Q. (2017) 'Traffic Conflict Technique Development for Traffic Safety Evaluation under Mixed Traffic Conditions of Developing Countries', *Journal of Traffic and Transportation Engineering*, 5(4), pp. 228–235. doi: 10.17265/2328-2142/2017.04.004.

Washington, S. P., Karlaftis, M. G. and Mannering, F. L. (2003) *Statistical and Econometric Methods for Transportation Data Analysis Library of Congress Cataloging-in-Publication Data*.

WHO *et al.* (2018) *GLOBAL STATUS REPORT ON ROAD SAFETY*. doi: 10.1590/s1809-98232013000400007.

Zhang, Y. *et al.* (2011) 'Vehicle-Pedestrian Interaction Analysis in Mixed Traffic Condition', *American Society Civil Engineers*, pp. 552–559. doi: 10.1061/41177(415)70.

APPENDIX

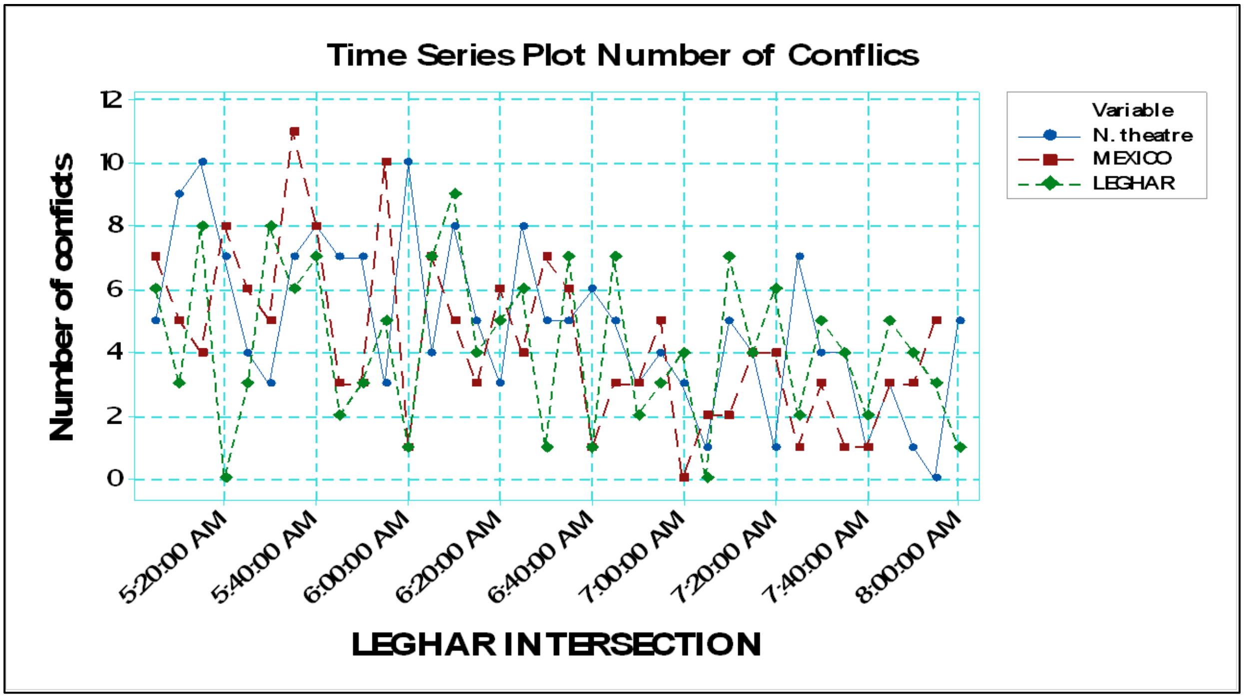
Descriptive Statistics of the Collected Data

Table; Data Statistics Used In Modeling Number of Conflicts

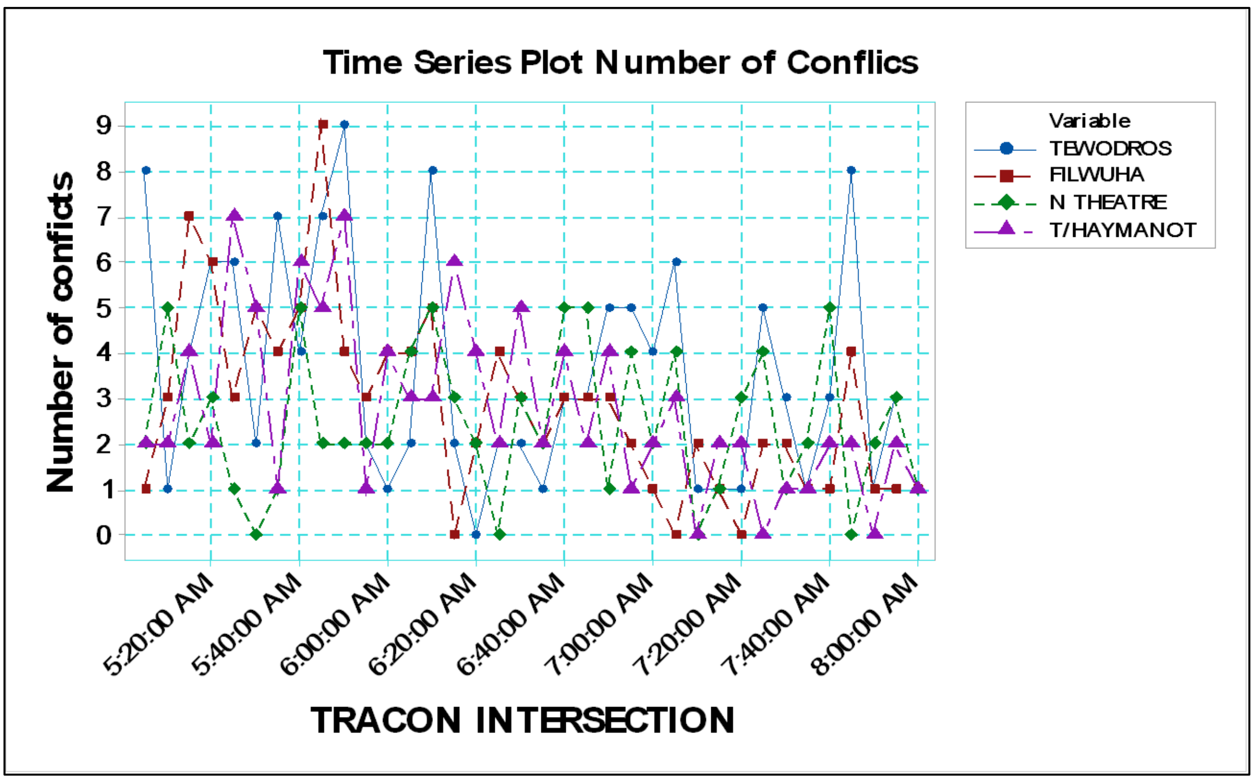
Variables	Total count	Mean	SE mean	STDev	Min	Q1	Median	Q3	Max	Range
Number of conflicts	484	5.04	0.252	5.544	0.00	1.25	3	6	30	30
Pedestrian volume	484	49.7	1.54	33.78	2	27	42.5	63	179	177
Right turn vehicles volume	484	20.4	1.22	26.79	0.00	6.25	11	23	160	160

Table; Data Statistics Used In Modeling Pedestrian Yielding Pedestrian

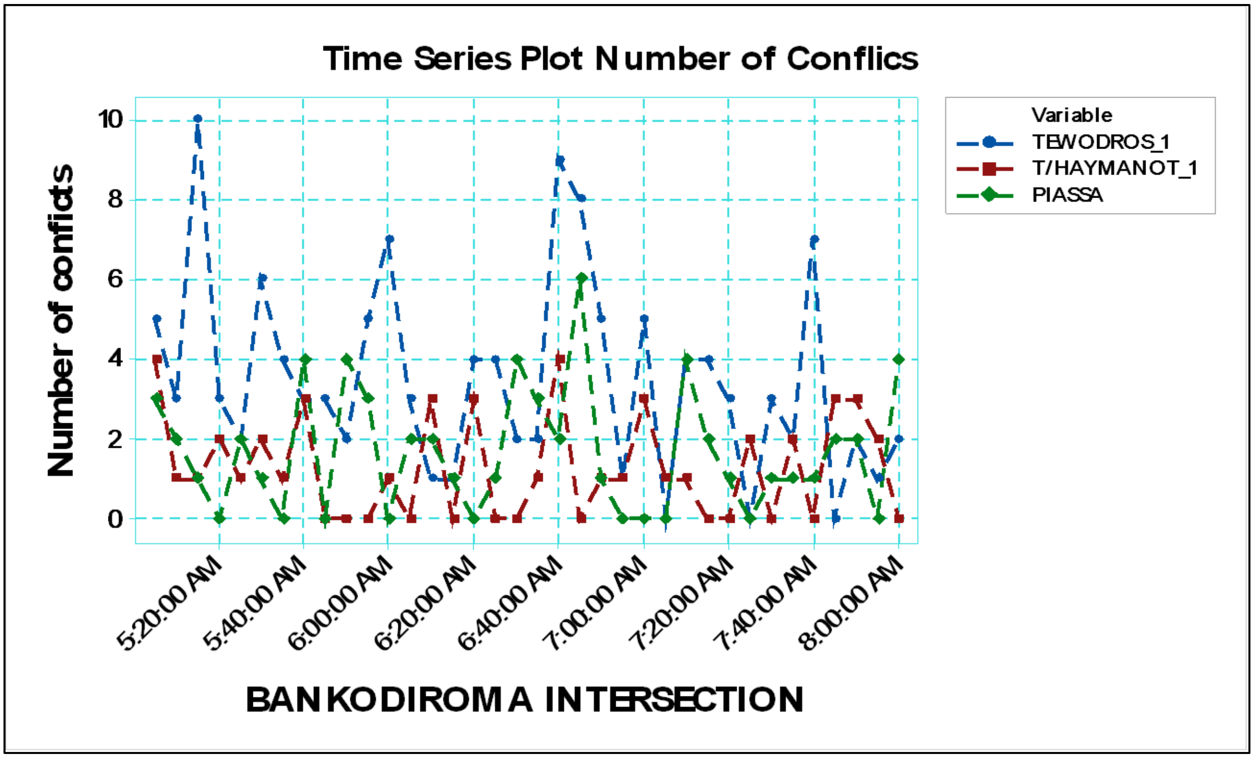
Variables	Total count	Mean	SE mean	STDev	Min	Q1	Median	Q3	Max	Range
Population of pedestrian	2453	3.03	0.078	3.87	0.00	1	2	3	49	49
Volume of right turn vehicle	2453	2.33	0.048	2.37	0.00	1	1	3	18	18
Turning speed	2453	20.4	0.127	6.27	8.40	13	16.38	21.	33.4	25.1



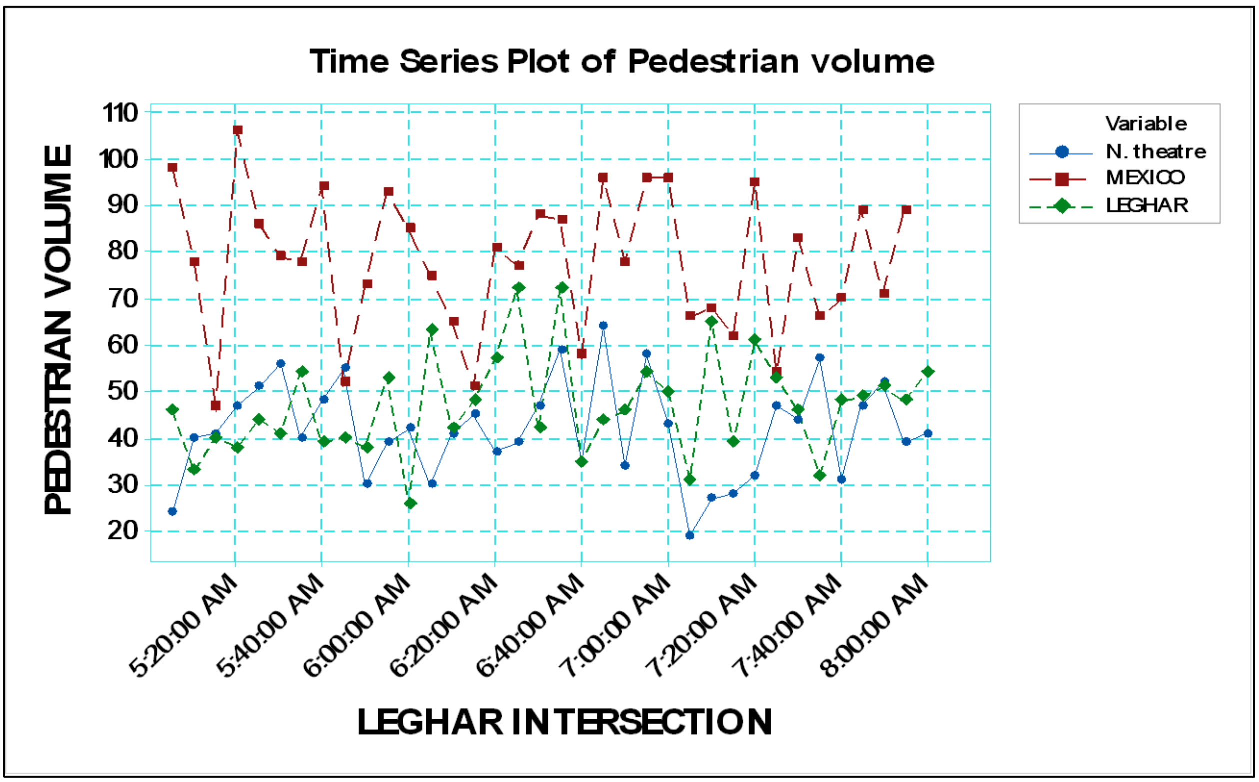
Time Series Plot of Number of Conflicts at Leghar Intersection



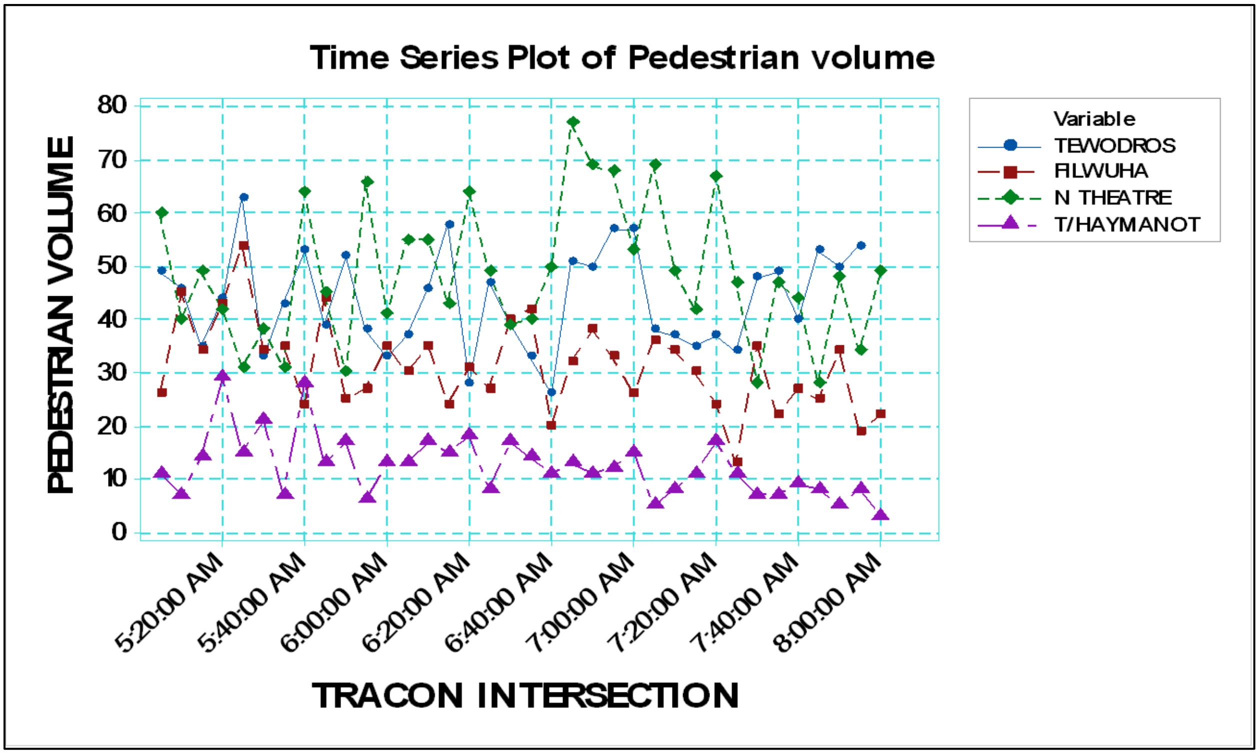
Time Series Plot of Number of Conflicts at tracon Intersection



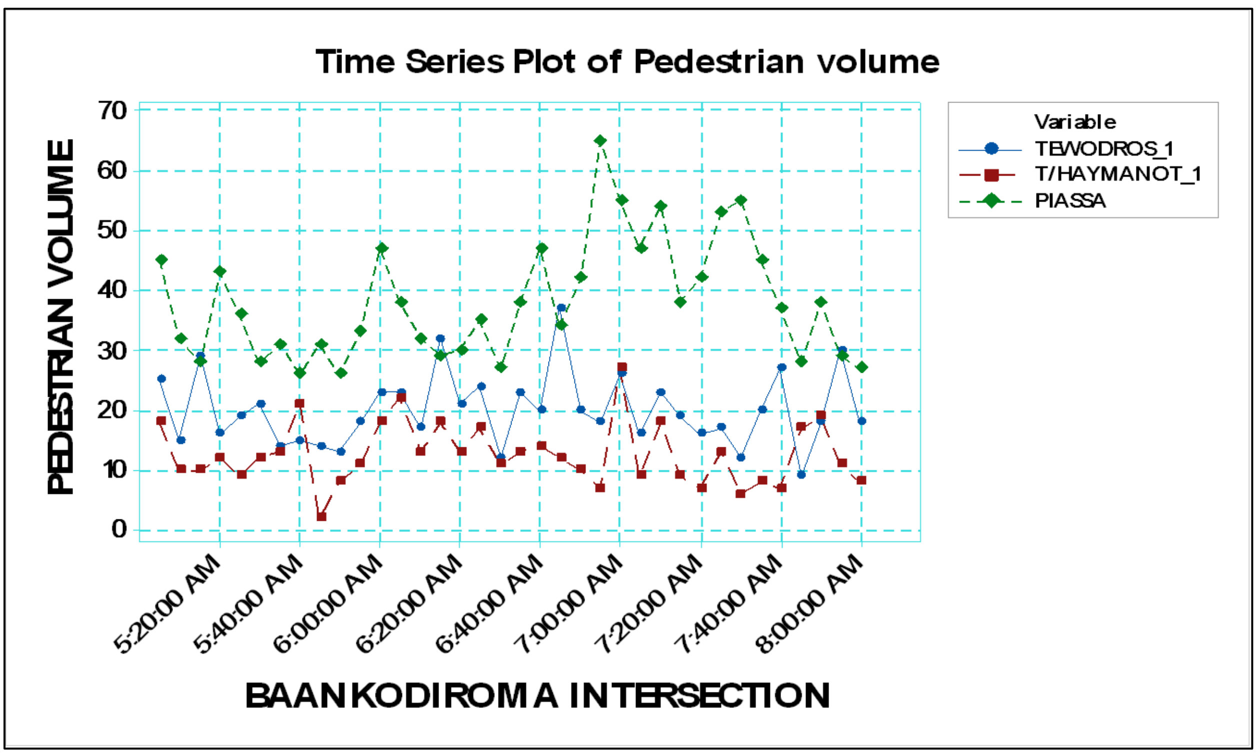
Time Series Plot of Number of Conflicts at bankodiroma Intersection



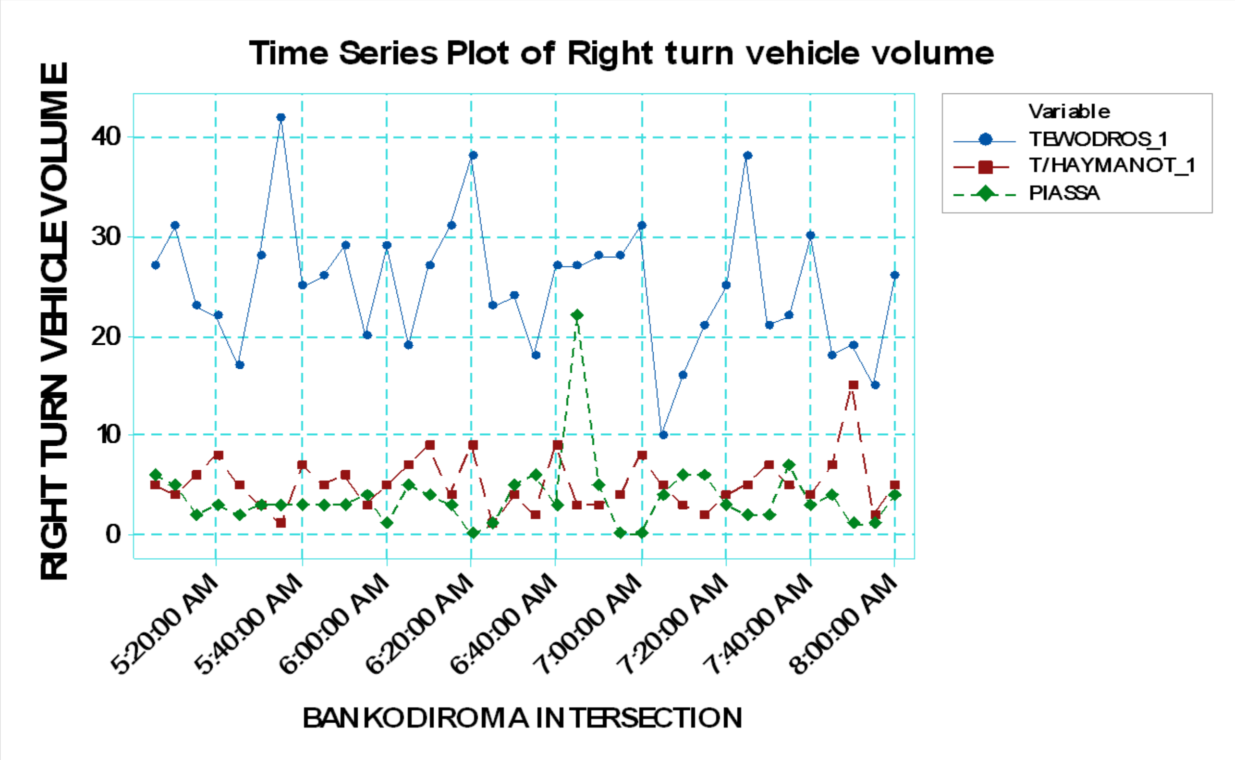
Time Series Plot of Pedestrian Volume at leghar Intersection



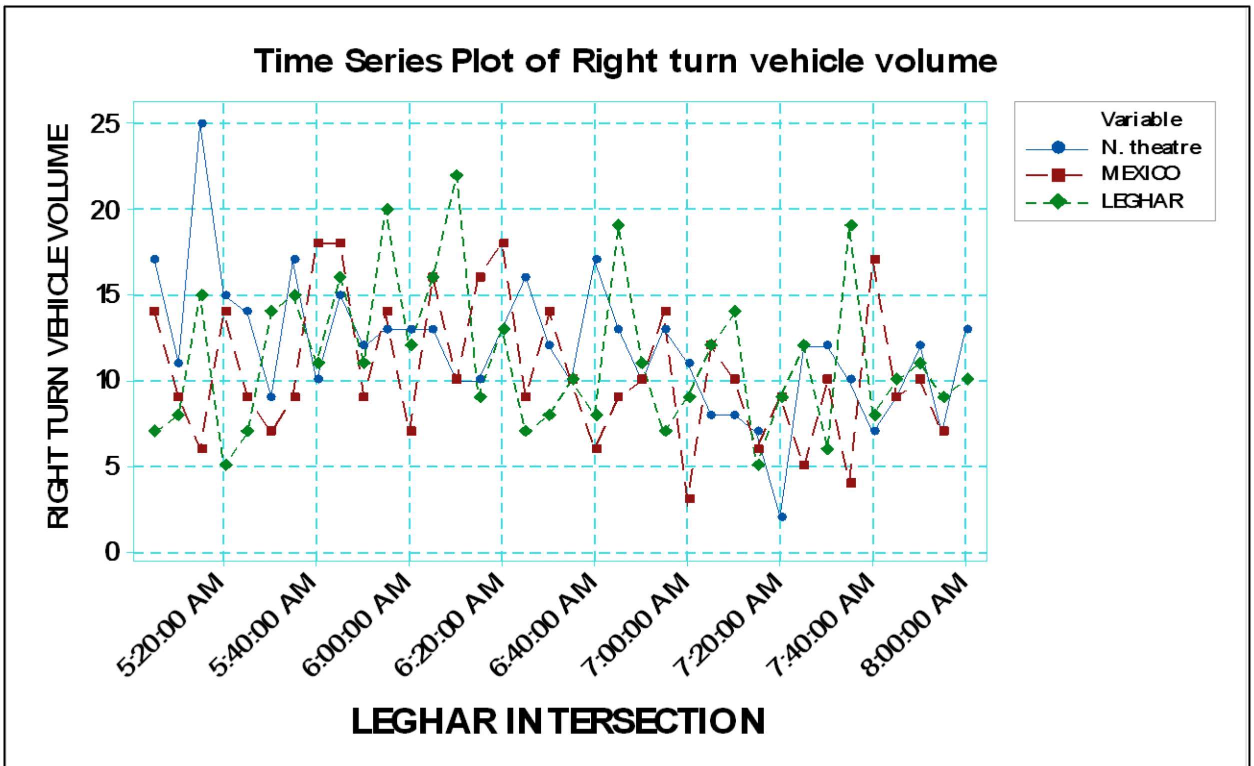
Time Series Plot of Pedestrian Volume at Tracon Intersection



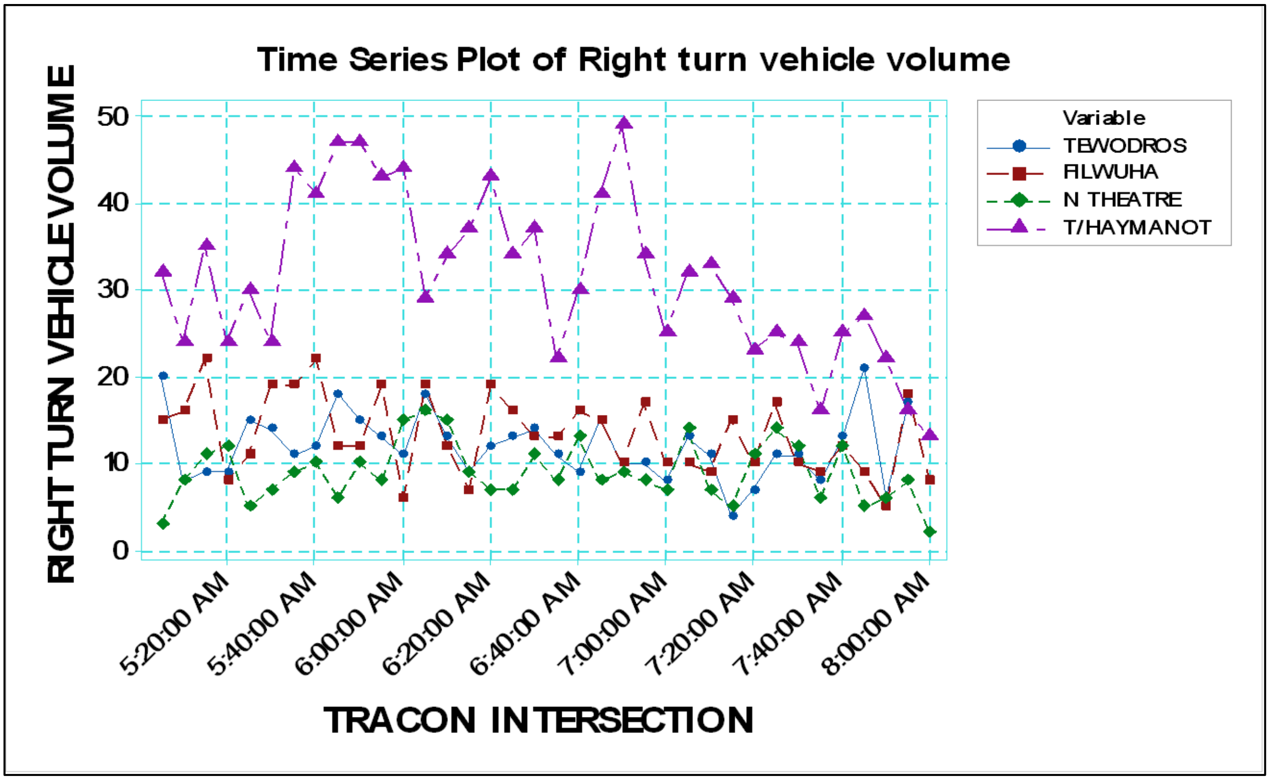
Time Series Plot of Pedestrian Volume at Bankodiroma Intersection



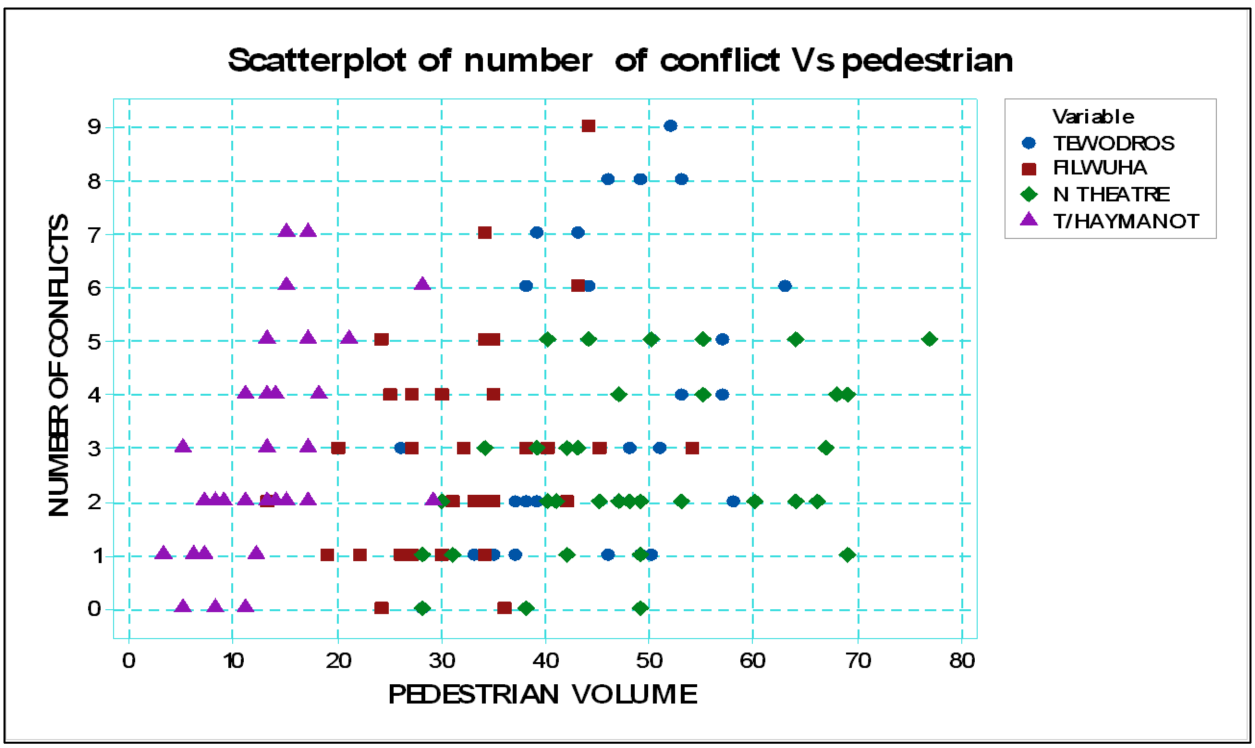
Time Series Plot Of Right-Turn Vehicle Volume at bankodiroma Intersection



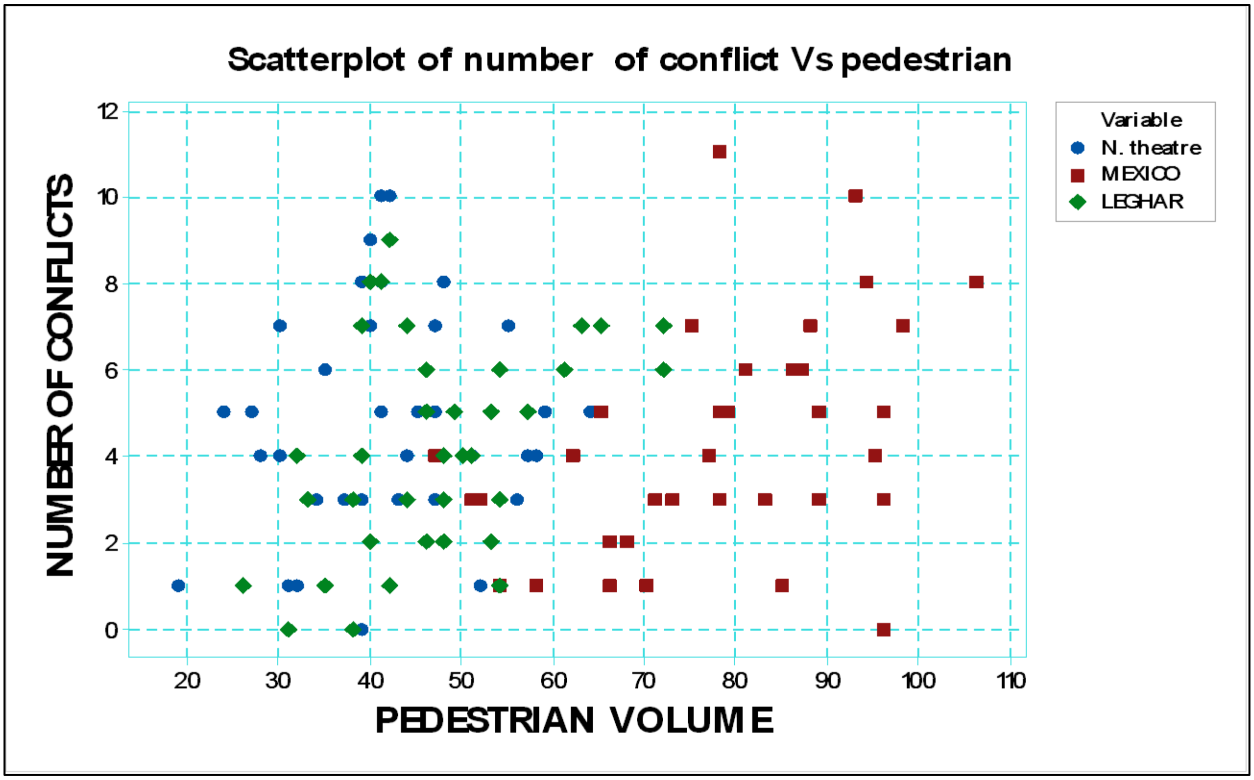
Time Series Plot of Right-Turn Vehicle Volume at Leghar Intersection



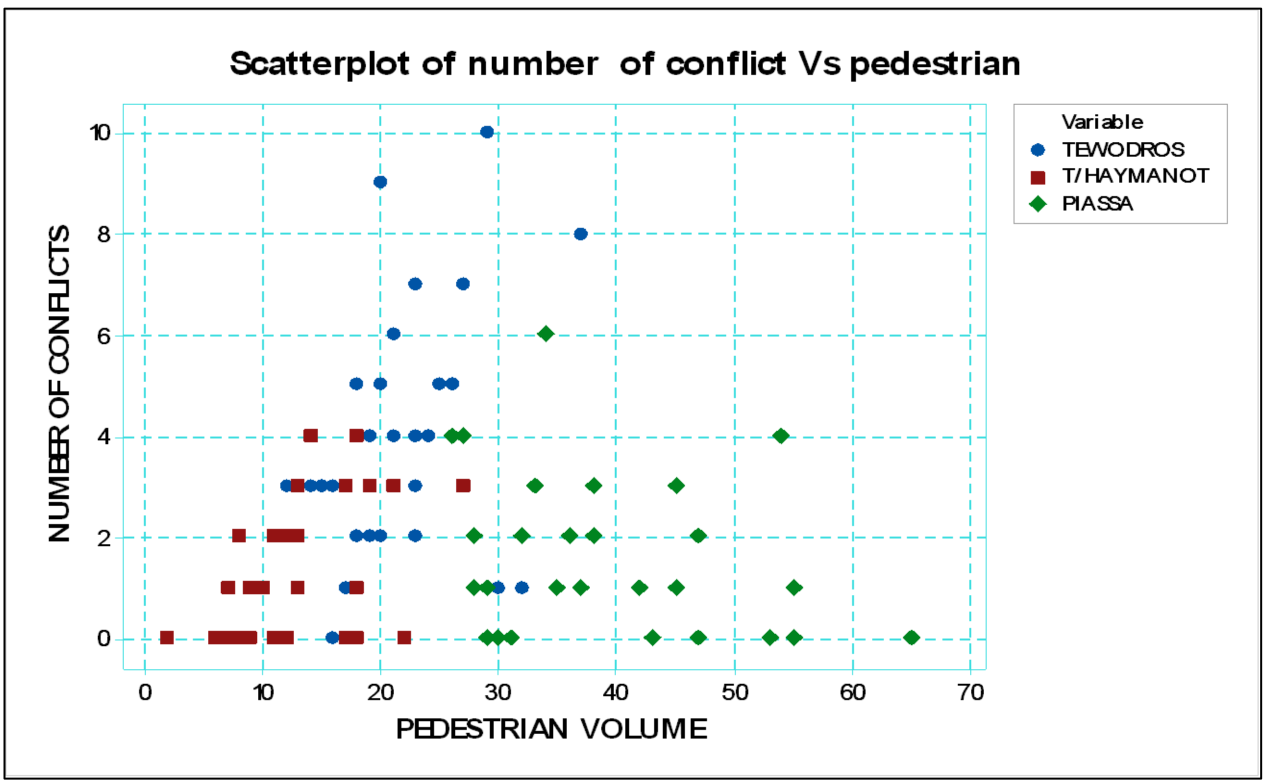
Time Series Plot of Right-Turn Vehicle Volume at Tracon Intersection



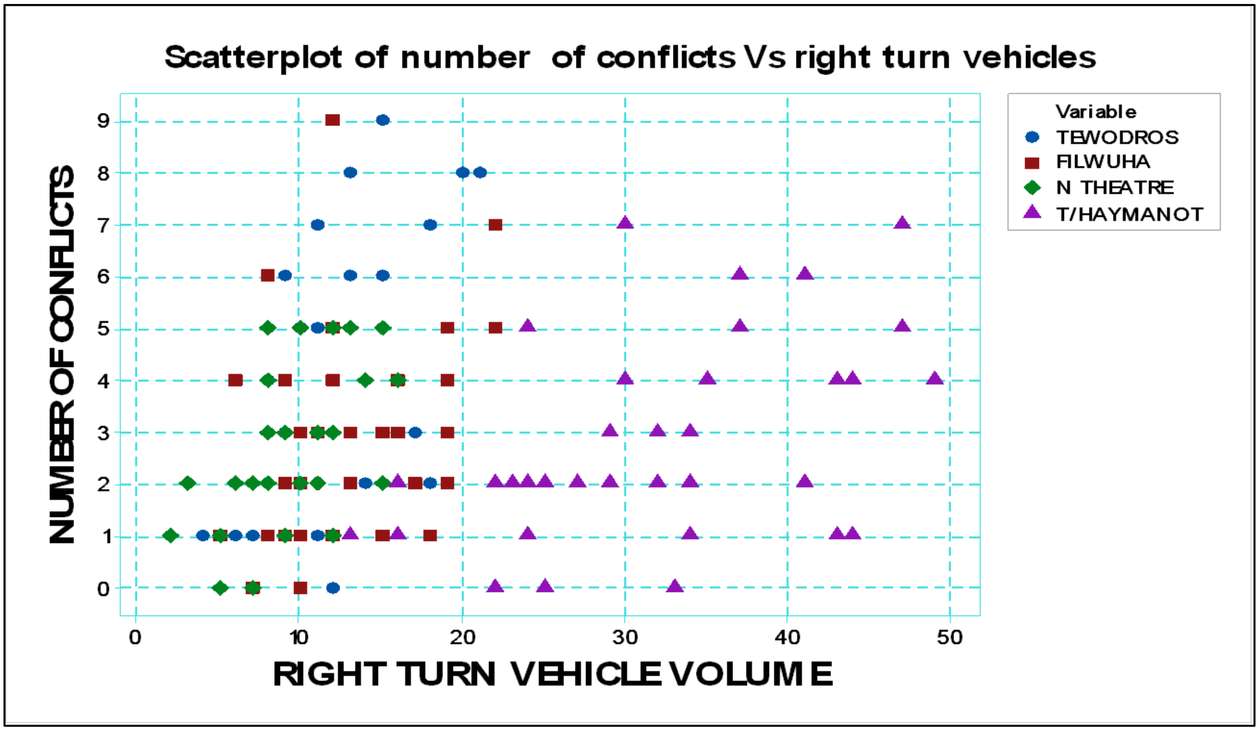
Scatter Plot of Number of Conflict versus Pedestrian at Tracon Intersection



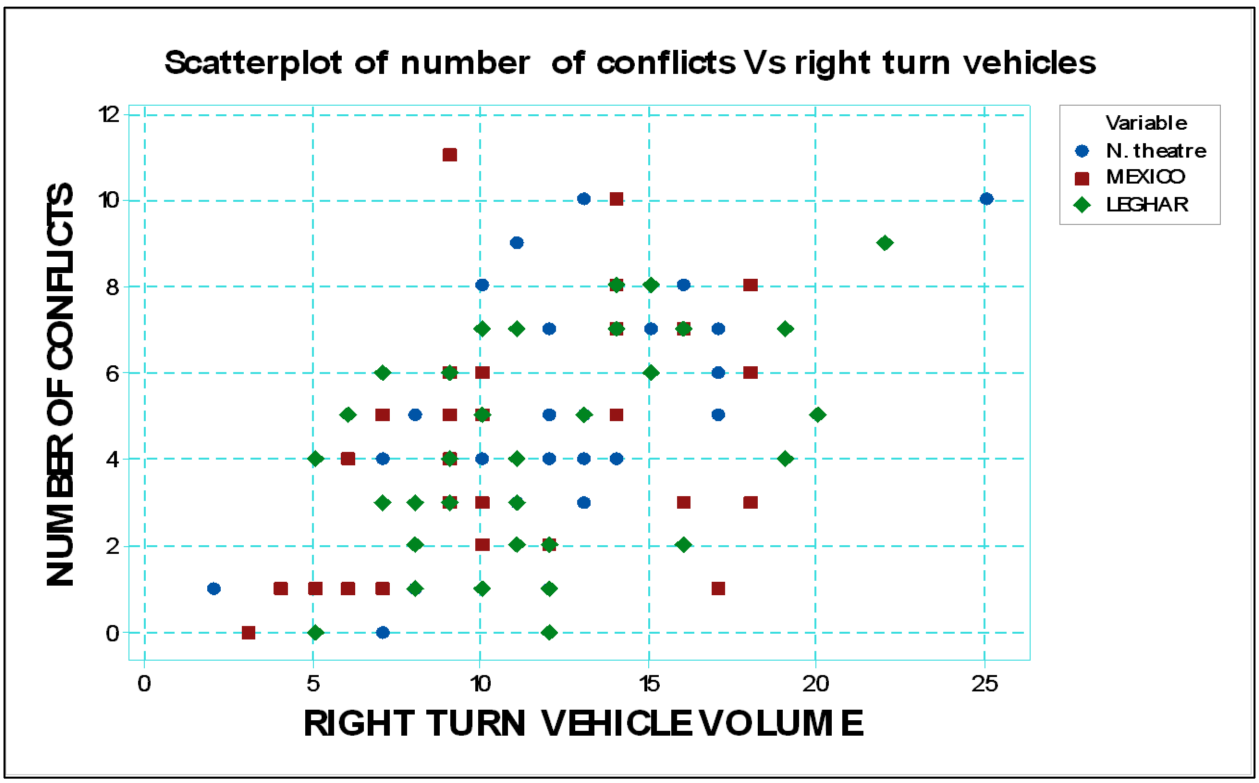
Scatter Plot of Number of Conflict versus Pedestrian at Leghar Intersection



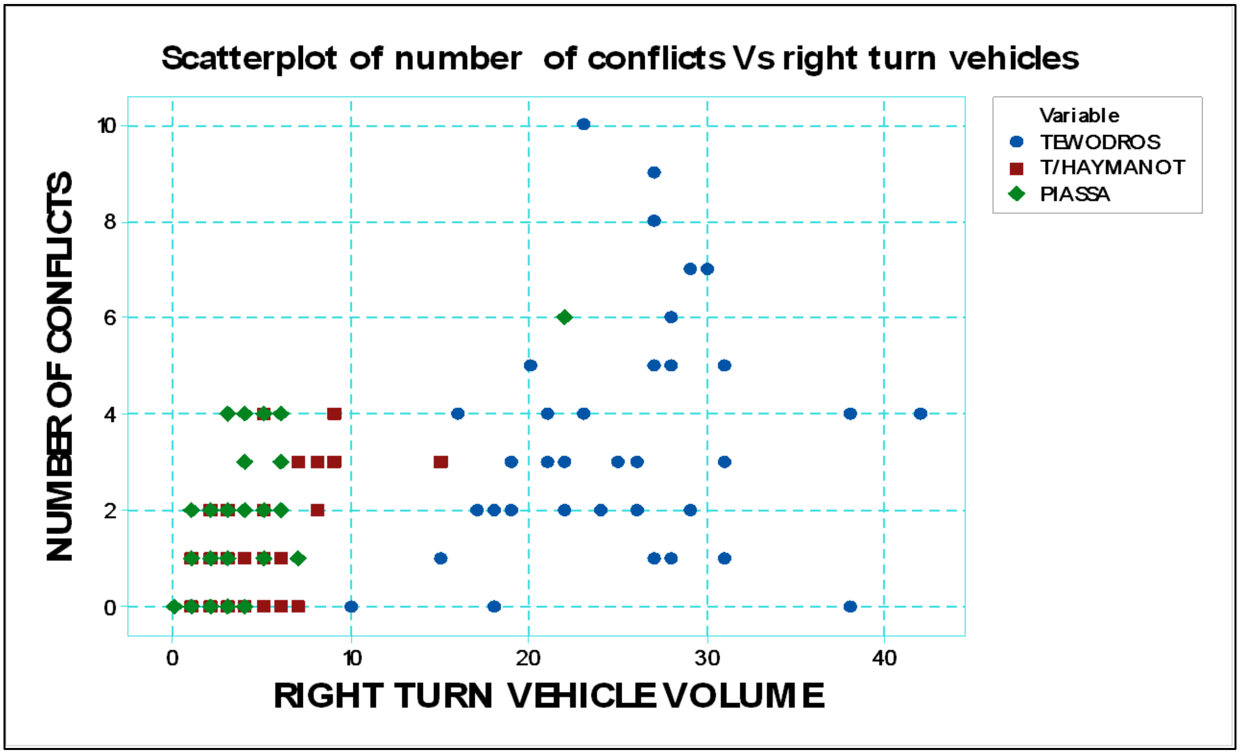
Scatter Plot of Number of Conflict versus Pedestrian at Bankodiroma Intersection



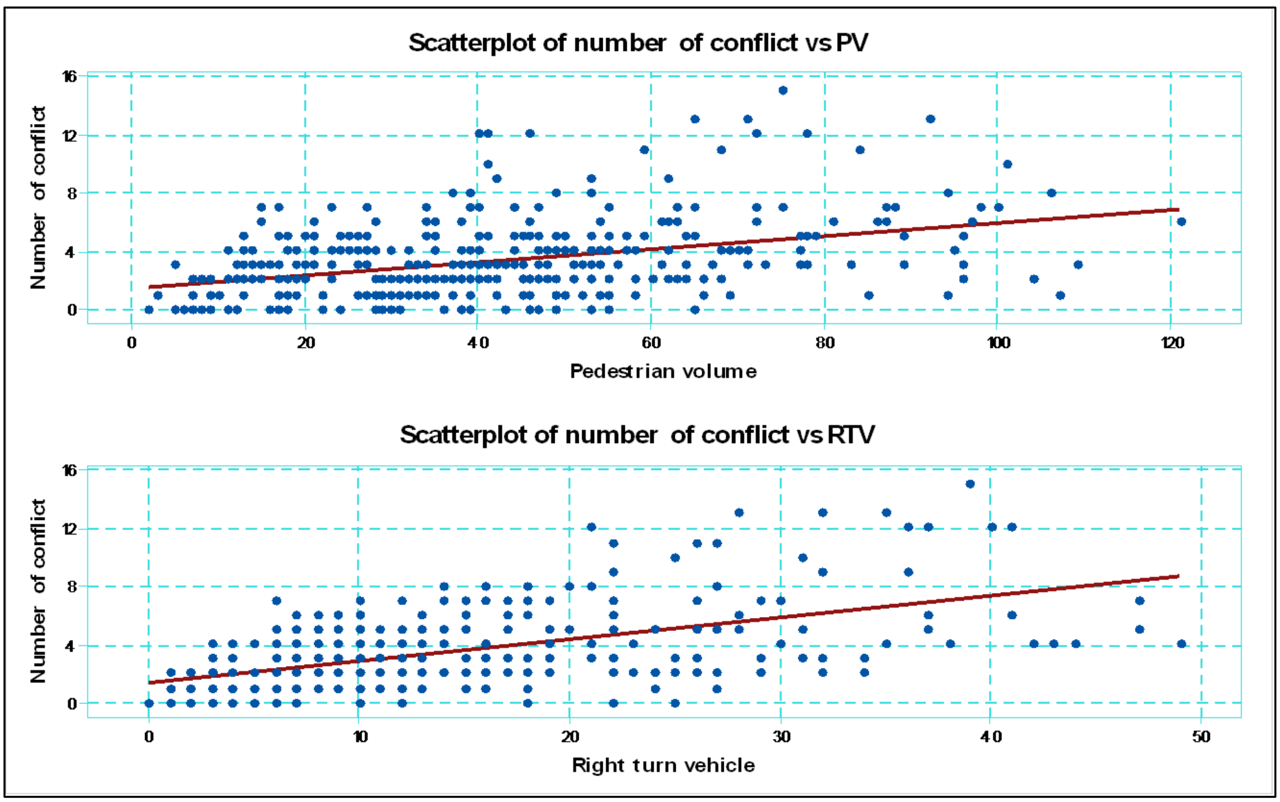
Scatter Plot of Number of Conflict versus Right-Turn Vehicle at Tracon Intersection



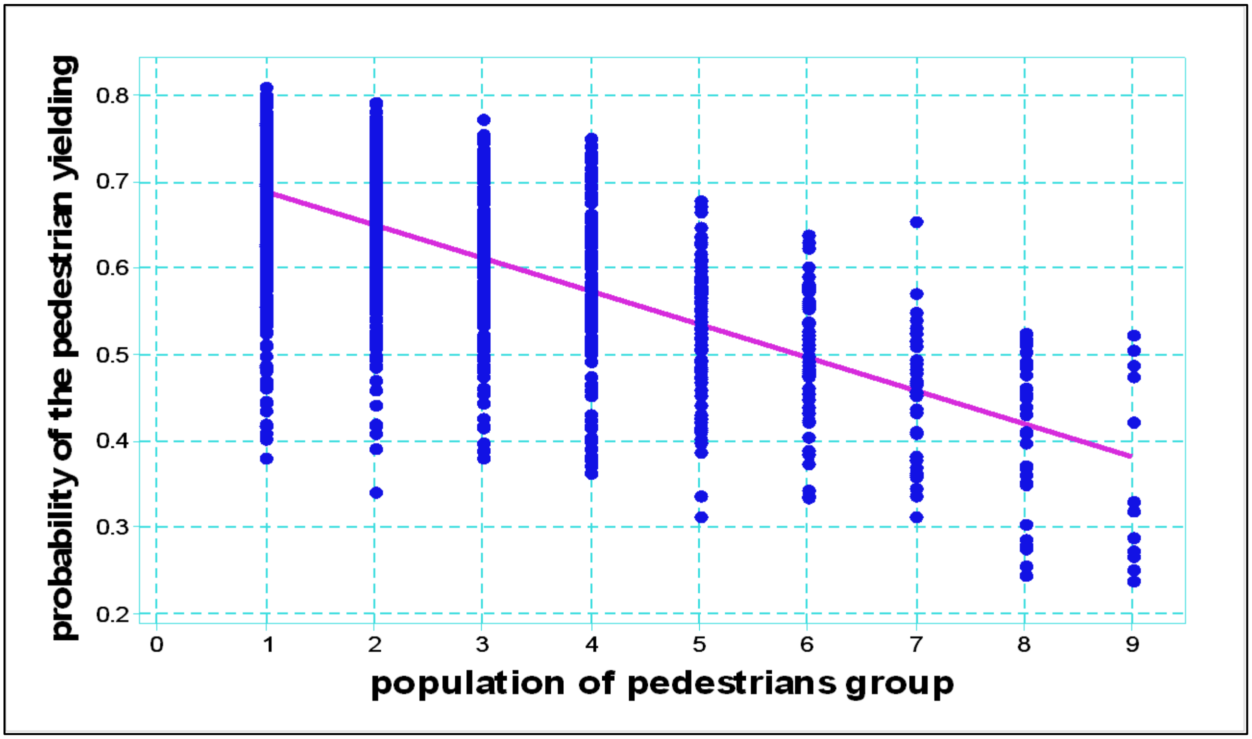
Scatter Plot of Number of Conflict versus Right-Turn Vehicle at Leghar Intersection



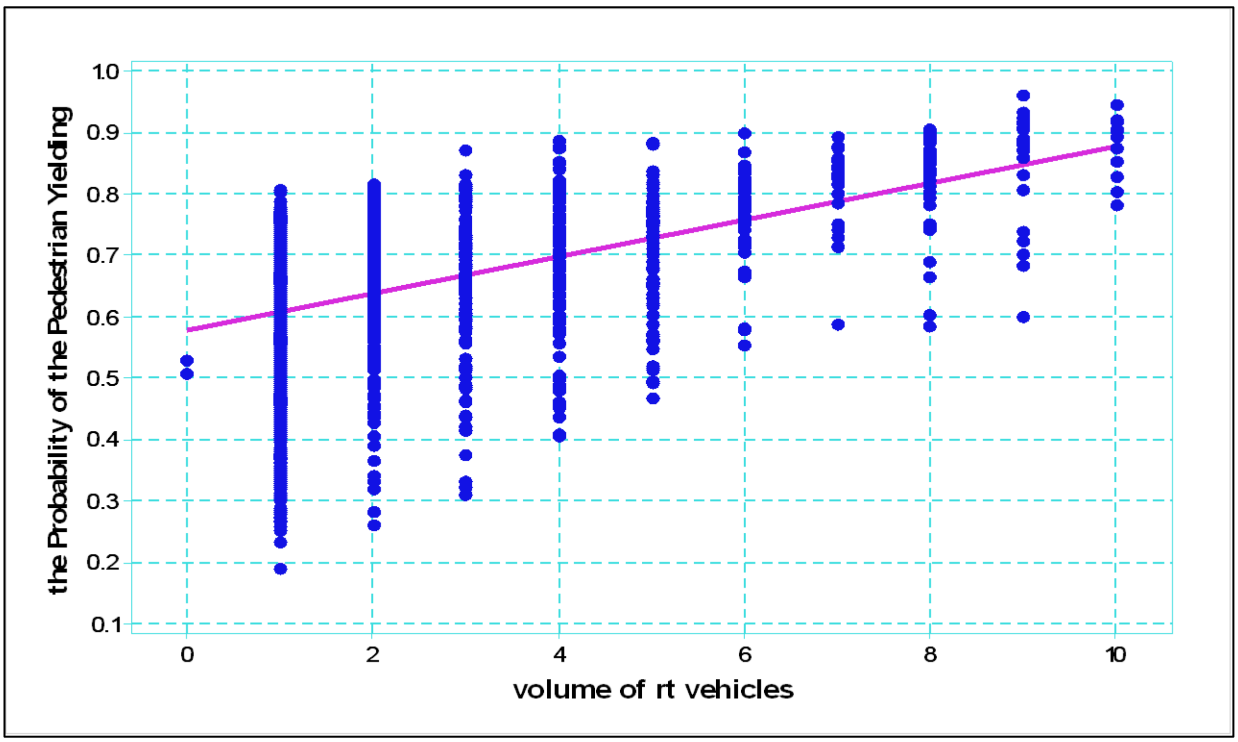
Scatter Plot of Number of Conflict versus Right-Turn Vehicle at Bankodiroma Intersection



The scatter plot of dependent variable versus independent variable at all intersections



The Scatter Plot of the Probability of the Pedestrian Yielding Versus Population of pedestrian group



The Scatter Plot of the Probability of the Pedestrian Yielding Versus Population of Volume of Right Vehicles