JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HIGHWAY ENGINEERING STREAM

DEVELOPING ADVANCED SAFETY EVALUATION MODELS BASED ON UNOBSERVED HETEROGENEITY ACROSS DIFFERENT SIGNALIZED INTERSECTIONS USING BAYESIAN NETWORKS: A CASE OF ADDIS ABABA CITY.

A Final Thesis Submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Highway Engineering).

NAME: - ABDISHAKUR DAIB ADEN

JUNE, 2021

JIMMA, ETHIOPIA

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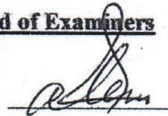
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JIMMA, ETHIOPIA

Jimma University

School of Graduate Studies

Jimma Institute of Technology

Faculty of Civil and Environmental Engineering

Highway Engineering Stream

Developing advanced safety evaluation models based on unobserved heterogeneity across different signalized intersections using Bayesian networks: a case of A.A.

By

Abdishakur Daib

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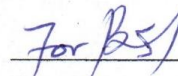
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DECLARATION

I, the undersigned, certify that the following thesis titled "**Developing Advanced Safety Evaluation Models Based on Unobserved Heterogeneity Across Different Signalized Intersections Using Bayesian Networks: A Case of Addis Ababa City**". This thesis is my work and entirely original and has not been presented or submitted for consideration for a degree at this or any other university.

Name: **Mr. Abdishakur Daib Aden**

_____   _____

Signature   Date

CERTICATION

I, the signers, certify that I have read and recommend to Jimma University a paper titled: "**Developing Advanced Safety Evaluation Models Based on Unobserved Heterogeneity Across Different Signalized Intersections Using Bayesian Networks: A Case of Addis Ababa City**" in Partial Fulfilment of the Requirements for the Degree of Masters of Science in Civil Engineering (Highway Engineering).

Engr. Elmer C. Agon, Asso. Prof

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Main Advisor   Signature   Date

Mr. Oluma Gudina, MSc

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Co-Advisor   Signature   Date

ABSTRACT

Traffic accidents which has happened at the signalized intersections are one of the locations that the crashes used to occur compared to the roundabouts and any other roads because it is intersection. Nowadays, it's the raised of epicenter of accidents and has given an alarming rate of increase of crash problems globally and so do here in Ethiopia, especially in Addis Ababa; the capital city. There has potential leaded factors that has contributed to the incremental of the issue such as improper functioning of the traffic light, lack of sign requirements at the intersection, pedestrian misunderstanding about the traffic lights, and so on. It has resulted in fatalities death, injuries, and property damage at least, and all of this has causes loss in the GDP of the nation.

The main objectives of the study are to evaluated, analyzed and characterized the traffic accident parameters at the signalized intersections and draw a solution. Road signs at the intersections, traffic light elements, traffic accident report from the police station such as death, injury, crash and damage of human, animals, and property, AACRA district, document review from driver, consultant, and contractor were the source of data. The samples of the study talked about some of the signalized intersections in Addis Ababa City which has been selected by their influenced about the crashes while used prioritized based on their accident history. The necessary data for the study was collected from daily traffic accident records of the Addis Ababa Traffic Police offices of the Wereda's and the intersection geometric design safety checking and recommendation from the consultant and contractor. Furthermore, the information needed was collected by interviewing traffic police officers.

Majority of the respondents in Immigration, Meskel square and Mexico intersections are educated from diploma level to PhD degree level but in Piassa the majority are from secondary level to master degree level. Out of the all intersections, majority of the respondents are responded that they used to slow down their speed when approaching signalized intersections. So its they are educated people they claimed that the flow the traffic rule. Majority of the respondents in Immigration and Piassa intersections are aged from 15-30 years' age class to 50-60 years' age class but in Meskel square and Mexico respondents were between 30-40 years' age class to 60-more years' age class.

Out of the all intersections, majority of the respondents are responded that the accidents happened during peak hours. Majority of the accidents happened during peak hours between 8:00 till 9:00 am with regard to immigration. In Meskel square it happened during afternoon peak hour from 5:00 am till 7:00 p, in Mexico it was happened between 12:00 pm till 2:00 pm and in Piassa it happened between during 5:00 pm till 7:00 pm. During these hours the traffic police should supervise and paid attention at signalized intersections traffic movement.

Majority of the respondents have got accident at the intersection from hit in the rear side on the intersection to concert in collision inside the intersection, but in Piassa majority of the respondents had got accident at intersection from hit in the rear side on the intersection to hit us on the intersection. Majority of out of three intersections have respondents that they are pedestrians got incident while in Meskel square responded that the majority got incident are travelers. Out of all the intersections, majority of the respondents have agreed that the geometric design of intersection, traffic congestion, road side elements, pedestrian including non-properly functioning traffic lights are the common factors that affect the safety of signalized intersections. Majority of the respondents are responded that the accident resulted in a fatal injury, injury and property

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damage only at Meskel square and Piassa, but in Immigration and Mexico resulted injury and property damage only. It should be followed the guidelines and maintain accordingly so it could minimize fatality injuries and property damages.

Out of all the intersections, majority of the respondents are responded that the weather condition during accidents was rainy season. Majority of the respondents claimed that the road condition was wet when accident happened at Immigration, Mexico and Piassa but the road condition was dry when the accident happened at Meskel square. Out of all the intersections, majority of the respondents are answered that the accident happened during daytime where the light condition was bright. Out of all the intersections, majority of the respondents are regularly and occasionally crossing at the intersections. Majority of the respondents are responded when vehicles approaching at the intersection, they were approached in speed between 45-55 Kph to 55-65 Kph. Traffic laws should implement to safeguard drivers and pedestrians too.

Based on the result of R software the studied signalized intersections found in the two sub cities of Arada and Kirkos and most of the signalized intersections were somehow in critical conditions according to Highway Manual Capacity and its recommended to increase the number of traffic lanes per direction, provide extra signal light for the approaching roads at intersection to reduce the traffic jam and construct pedestrian bridges passing over the intersections.

ACKNOWLEDGEMENT

I would like to acknowledge and express my heartfelt gratitude to the Almighty ALLAH (SWT). Second, I want to express my heartfelt appreciation to my primary advisor, Engr. Elmer C. Agon, (Asso. Prof.), and co-advisor, Mr. Oluma Gudina(MSc), for their unwavering efforts in guiding me and standing by my side while providing me with a useful reference. Finally, but certainly not least, I would like to express my humble gratitude to my family, friends, and everyone who has, is, or will stand by my side as I reach my height.

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ABBREVIATION

AACRA   Addis Ababa City Road Authorities

AASHTO   American Association of State Highway and Transportation Official

JIT   Jimma Institute of Technology

BNA   Bayesian Networks Analysis

ERA   Ethiopian Road Authorities

AAPC   Addis Ababa Police Commission

ETB   Ethiopian Birr

SITA   Signalized Intersection Traffic Accident

RTA   Road Traffic Accident

RTAs   Road Traffic Accidents

DAG   Directed Acyclic Graph

A1   Education Level

A3   Income Level

A4   Work Experience

A5b   Approximate Age of the Person in The Questionnaire

B11a   Responses on Accidents Happen at The Peak Hour

B11b   Specific Time the Accident Happens

B17   Details of the Impact to the Vehicle upon Accident

B21a   Responses on How the Accident Happen, After Impact

B21b   Responses on How the Accident Happen, Before Impact

B23a   Weather Conditions

B23b   Road conditions

B23c   Light conditions

B24a   Factors Affecting Safety of the Signalized Intersection

CHAPTER ONE

INTRODUCTION

1.1. Background of the Study

Traffic accidents evaluation is one of sub studies under the highway engineering which does studied under civil engineering field and has discussed more about the evaluations, analyses and characteristics of traffic safety and crash reduction, meanwhile held research covered the evaluations safety of signalized intersection as a case study in Addis Ababa, Ethiopia.

Since the raise of the transportation human being have used to have the pros and cons of their usage, while their side effects does increase in terms of taken lives and property damage thus they had paid a lot to overcome the obstacles effected their daily activities by marked core issue to remembered.

Crashes has happened at signalized intersections has rapid incremental number, which directly affected the safety of intersections in cities, particularly citizens used at signalized intersections which are in great numbers; specifically, in Addis Ababa those numbers are gathered for the sake of living in the hub of the most commercial in Ethiopia as well as it is diplomatic relationships center in Africa, but it also peaceful and preferred place of the nation.

Recent years Ethiopia is one of the highest growing nations amongst economic in the Africa; this rapid growth is directly proportional to the number of car householder as well as the urbanization which affects the safety performance of the road in terms of the safety of the pedestrian and drivers with these many incremental numbers of the safety issues. Unfortunately, the country is severing lack of road in the area of capacities, driving behaviors and safety measure.

Addis Ababa city becomes very populated for the last two decades and the number of householders having cars living in the city have increased while this raising graph contributed a lot to the traffic accidents (i.e. fatality deaths, injuries, and property damages). The problem continuously becomes an obstacle to the on-going movements from social interactions (from origin to destinations (i.e. job places and market centers and so on) of the householders and lost to the economy of the city since delay and traffic jam may be in the causal factors of the traffic accidents too.

The history of signalized intersection dates back to the early 1900s which was installed in the city of Paris and it was the followed to London which has the places where has been tested and showed off the used way of signals.[1]

Current observations have shown that the traffic crashes have raised graph of impact among the

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pedestrians and drivers which has covered under this research for their way to find solutions of the accidents does happen at the signalized intersections.

Particularly, this research done to made core importance of the touched problems of traffic accidents has been happened at signalized intersections, especially in Addis Ababa as a case study. Human beings are accustomed to living on the earth planet and by our daily transactions, which we have inherited to go around and sometimes far (as a trip generation) in search of jobs, foods, and shelters, but in connection to that; traffic accidents had become one of the leading causes of fatalities, injuries, and property damages in the world, with more than 1.25 million deaths per year, between twenty to fifty millions injuries, and a global proportion of 18th deaths per 100,000 inhabitants.[2]

The majority of these deaths occur in developing countries (74%) and undeveloped countries (16%), making traffic-related mortality not only a public health issue but also a socioeconomic development issue directly touched towards road construction industry especially road safety(i.e. signalized intersection traffic and pedestrian safety).[3]

Might witness traffic accidents that has been caused by vehicles due to factors that dictated to has happen and the aftermath resulted fatal deaths, injuries, or property damages. Besides, those of us who got jobs like businessmen, daily laborers, government, and private institutional workers are wake up early to arrive the workplaces on time by avoiding traffic jams (those who does cars) they might sometimes did drive faster than the normal and ended up accident who anyone has never planned for, these accident as discussed hereby are major damage to GDP of the entire world countries, which particularly affected cities.[4][5]

The research aims to improve road safety (i.e. Signalized Intersections) for enhancement of the safety of signalized intersection roads. Statistics on traffic accidents confirm the problem's urgency (RA). More than 30% of all traffic accidents occur at street intersections. Cities account for 75% of all traffic accidents, with 50% of them occurring at intersections(Signalized intersections).[6]

Injuries caused road traffics had a high financial cost, estimated to be around 3% of global GDP (Reported of global status on road safety by the WHO in 2015). Despite several government initiatives and actions to improve road safety and reduce this global problem, the results remain unsatisfactory.[7]

Ethiopians living in Addis Ababa city are not just for those people around the world suffering serious causes of traffic accidents with regard to their life and properties. This research has studied lighting, monitoring treatments, reducing and minimizing traffic congestion, optimizing network performance and degraded fuel consumption of Unobserved Signalized intersections.[8]

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According to reports published years ago, the traffic accident data for several years such as 2007, 2008 and till 2017/2018 have been presented that the traffic accidents rate had naturally increased, whereas the WHO report in 2018 says there are 1.35 million deaths each year, as reported globally. [9][10]

The aim of the study is therefore, to evaluate safety of traffic at the signaled intersection by the usages of Bayesian networks which is advanced probability modelling. The research environment has observed that the traffic accident happens on urban intersection roads has raised, and that their congestion of traffic spreading to and impacts on neighboring links and also traffic movements can then stop and block the way and affect for road users (i.e. pedestrians and drivers and property damages).[11]

1.2. Statement of the Problem

Traffic accidents are common problems that occur globally, hereby were working on how to reduce/minimize using scientific methods. The information gap this research has to fill is the compliments and the impact on the crashes occurred at signaled intersections using Bayesian networks.

To find a way to save lives and reduce property damages caused where happens on signaled crossroads in Addis Ababa city and shown that this method applicable in the worldwide. As shown, the safety of signalized intersections was frequently assessed at the aggregate level for annual traffic volume and geometric characteristics of the intersection.

The collision-based safety assessment can be used for a variety of purposes, including hazard location identification and classification, as well as pre- and post-safety studies regarding safety guidelines. At signaled intersections, however, collisions can occur for a variety of reasons, including driver behavior in dilemma zones, approach queues, and so on. [12]

For intersection access control that targeted these collisions, it's critical to understand how changes in traffic parameters and signal management affect safety at the signal cycle level. Solutions are always dictated by the common problems and this problem focuses on crashes at the four selected signalized intersections in Addis Ababa City (based on traffic volumes, geometry feature, traffic priorities and locations).[13]

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1.3. Research Question

I. What are the parameters that represent the dependencies among related variables(nodes) involving in the traffic safety evaluation?

II. What is/are the conditional probability of variable/s (node/s) in the traffic safety evaluation?

III. What is the reliability of the fitted model for safety evaluation?

1.4. Objectives of the Study

1.4.1 General Objective

The aim of the study is to evaluate, analyze and develop advanced safety models based on unobserved heterogeneity across at various signaled intersections in Addis Ababa city, Ethiopia.

1.4.2 Specific Objectives

The specific objectives of the study are:

- To identify the different factors affecting the safety evaluation performance of the signalized intersections.

- To develop a model equation using Bayesian network analysis for use in safety evaluation.

- To check the reliability and model fitting of the safety evaluation.

1.5. Significance of the Study

The importance of the research studied had the assessment and analysis of the core parameters of the intersections signposted and the obstacles overcome. It also provided a good knowledge of researchers and students conducting research in order to gain knowledge about traffic safety.

The concept of road accidents occurred at marked crossings and their countermeasures to reduce or even minimize, that had tangible when used Bayesian networks analysis; as it shown. The importance of the work has pointed out the performance at signalized intersections. The study given:

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1. Wave universities and students to see and conduct research to help and provide societies with solutions for related issues.

2. Promote the use of advanced statistical methods, such as (i.e. Bayesian networks), usually suitable for the safety and control of traffic at the marked intersections.

3. The results can be referenced as an information source and for input on further research in this field.

1.6. Scope of the study

The scope of the study has focused on four intersections in the sub-cities of Arada and Kirkos. Signalized intersection at Mexico, Piassa and intersection signaled at immigration had under Arada sub-city, where intersection signaled at Meskel Square has under sub-city of Kirkos.

The main point for building and installing signals was the reduction of the number of accidents and traffic jams as well. While a lot of traffic congestion could have been seen at the signaled intersection of Meskel Square and Mexico signaled intersection, had hoped that the problem would remain identical. The problem of the signaled intersections and driving behavior in places had different. Driver behavior is one of the common problems of traffic accidents at the signaled intersections. Therefore, this study has given assessments of safety evaluation for drivers, bicycles and pedestrians (as well as all users) at the signaled intersections which had located in the two sub-cities and factors affecting the safety, which have presented as questions to ask on the questionnaire paper form.

1.7. Limitation of Study

During the research, I have found that the secondary data has not specifically recorded (In terms of the exact place accident had happened and location name has not been recorded but it had kept in a general way). They have been used to recorded in all Addis Ababa traffic accidents data without a specific location and it has confirmed that the researchers face obstacles for considered reliable information to use such data's. The sub-cities bodies have not much information's about the traffic accident data while those who had, have in a way of hardcopy file which it has more than one thousand pages per six months' data's and exact location name is not referred (while data needed the research to be done is five years' data). The usage of the technology like computers has not there in their offices also they might not have skilled labor as well as the enough equipment's (i.e. desktop computers and so on) but it had seemed nowadays there has a raised change as I got information lately. In conclusion, the data has been recorded by the Addis Ababa Police Commission and the concerning bodies in the sub-cities were called hereby that it is not reliable to use.

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The study has done under some important groups from the society of that two sub-cities to fill questionnaire but the people have not interested since it had a coronavirus times so I have decided to collect at least 13th questionnaires with desired confidence level of 95%. I have managed for hired translator which has assisted to the local language and we had responsible to fill it down by gotten the interested society members from the two sub-cities, while we have agreed to let they did the talk and we have about to write it down.

1.8. Structure of the Thesis

The study has consisted of five chapters and it has done as shown below:

The first chapter contents; research background, problem statement, research objectives, research questions, study importance, scope, and limitations. The second chapter; given the literacy review, and discussed definition, history and basic concepts of the intersection, safety assessment factor of the signaled intersection, vital safety assessment materials of the signposted, the effect of traffic lights at the signposted intersection, traffic delay at the signaled intersection, the difference between the signposted intersection and unsignaled intersection literature

The third chapter; has covered up the study methodology, descriptive field of study, period of study, research design, population, sample size and sample technology, research approach, collecting of data and machinery techniques, study variables, software and instruments, methods for analyzing data, ethical consideration and assurance of data quality. Chapter four; has disclosed general safety assessment characteristics at the signaled intersection, questionnaire analysis, general factors decreasing the signaled intersection safety and its possible countermeasures. The conclusion and recommendations had discussed in chapter five.

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CHAPTER TWO

REVIEW OF RELATED LITERATURE

Crash risk reduction is critical for users when it comes to signalized intersection safety. With an increasing number of families owning cars, business owners owning vehicles, and so on, roads are becoming increasingly congested, increasing the likelihood of car accidents resulting in fatal injury, as well as property damage. Road markings and signs are necessary to ensure user's safety when pedestrians and those walking alongside, crossed the intersection roads or approaching zebra crossings on the intersection. Vehicles should have to consider the safety guideline signs and symbols when arriving at the intersections. Additionally, it is beneficial for user's to understand the safety instructions.[14]

2.1. The Definition, History and Concepts of Signalized Intersection

2.1.1. Definition

An intersection is defined as the general area where two or more highways meet or cross, including the roadway and roadside facilities for traffic movement within the area, as quoted by the Green book.[15]

2.1.2. History of a Signalized Intersection

The history of intersections, specifically signalized intersections, dates all the way back to the 17th century, when streets in London, England displayed the first traffic light.
Red, green, and yellow; three-color traffic lights have become an accepted part of daily life for the majority of people. However, this was not always the case. While their presence in city centers is being questioned, they continue to play an important role in regulating competing traffic flows at intersections. Consider 150 years of history.

The First (Failure) Trial in England. The official birth date of the world's first traffic light is December 10, 1868. It was installed in London's Parliament Square. The system consisted of two mobile signs attached to pivoting arms controlled by a lever. To ensure visibility, the post was topped with a gas-lit semaphore. But it was only for a short time. The traffic light exploded less than two months later, killing the officer who worked the signs.[1]

The world had to wait 46 years after electricity became widely available before the first dual-colored traffic light, powered by this new energy, was installed in Cleveland, Ohio. In 1920, Detroit and New

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York added yellow between red and green. The traffic lights we know today were invented and quickly became the norm around the world.

From 1920 to 1930, Europe is illuminated by traffic lights. The first electrically powered mechanical traffic light was installed in Paris in 1923 at the intersection of Boulevard de Strasbourg and Grands Boulevards. Most of Europe's major cities quickly followed suit: Berlin in 1924, Milan in 1925, Rome in 1926, London in 1927, Prague in 1928, Barcelona in 1930 and Tokyo in 1931.

In the 1930s, there was a lot of standardization and regulation. On March 30, 1931, the first (Convention on the Unification of Road Signals) was signed in Geneva. Its goal was to improve road traffic safety and facilitate international travel by road by implementing a standardized road signaling system. The majority of the signs we recognize today were defined by this treaty. Three-color traffic lights (red, yellow, and green) became the norm.

Pedestrian-Specific Lighting Following the tri-colored traffic lights, pedestrian signals appeared quickly. They began in various forms but matched the colors of vehicles: red and green. They frequently gave the instructions "Wait" in red and "Walk" in green in round, square, or rectangular shapes. Regulations introducing the figures we know today were introduced in 1974 as a result of a concern for foreign speakers and international standardization. However, the installation of pedestrian signals was initially overlooked due to their high cost and dubious utility. Since 1955, at least, they have been systematically installed at the city's intersections in Paris.

Since 1950, when traffic lights were first introduced, road traffic increased dramatically, necessitating increasingly stricter traffic regulations and the near ubiquitous use of traffic lights. In 2011, each 1,000 people in France's largest cities had an average of one traffic light-controlled intersection.

While traffic lights have long been thought to be the best solution for managing competing traffic flows, they are now suspected of encouraging risky behavior. This is why many cities are reconsidering the use of traffic lights on a regular basis in favor of other methods of reducing vehicle speeds. At the same time, they want to improve non-motorized mobility and public transportation circulation conditions. New light signals have emerged as a result of this desire to give these methods priority. Today's challenge is to keep the most vulnerable road users safe and maintain their ability to travel independently in an environment where reference points are constantly shifting.[16]

2.1.3. Concepts of Signalized Intersection

Intersections are critical components of a highway system because their design has a significant impact on the facility's efficiency, safety, speed, operational costs, and capacity.

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Each intersection involves through- or cross-traffic on one or more highways, as well as possible turning movements between them. In traffic, vehicles, pedestrians, and bicyclists may all be present. Various geometric designs and traffic control may be used to facilitate such movements, depending on the type of intersection.

It's a crossroads that allows traffic cars/vehicles to pass through; however, if their analysis, design, construction, maintenance, and performance are not properly(skillfully) managed, accidents can occur quickly(continuously), and it's (signalized intersections) one of the countermeasures to reduce traffic jams, traffic delays, and traffic accidents.

Pedestrian safety is improved by signalized intersections with marked crosswalks, which give pedestrians the designated right of way. However, a large number of pedestrian fatalities occur at signalized intersections, which may be due to pedestrians' violation behaviors, while fatalities are not evenly distributed across the country. Because signalized intersections are common in cities, it's reasonable to assume that violations will vary.[17]

The capacity-determining points on city roads are signalized intersections, and the signal settings are usually based on very primitive algorithms, having caused road users to experience a lot of unnecessary delays.[18]

The volume-to-capacity(v/c) ratio and control delay have become universally important performance measures for assessing the operational condition of a signalized intersection.[19]

2.2. The Factors of Safety Evaluation of Signalized Intersection

The affecting factors and parameters for safety evaluation of signalized intersection are the core pillars of safety evaluation performance guidance which are such:

- o Pedestrians

  Pedestrians are must respect and use the guideline of signalized intersection cross pass

- o Speed of Drivers

  Drivers should have kept in mind that they are approaching the intersection and respect the rule and regulations of traffic by knowing that they have to wait their turn to pass and allow the pedestrians to cross the road.

- o Bicyclists

- o Traffic signal lights

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2.2.1 Vital materials of Safety of Signalized Intersections

Traffic lights, safety markings, on-road users (drivers and vehicles), and pedestrians are core factors that directly make up signalized intersections and are also participants in making the safety of this type of intersection. Pavement marking, pedestrian safety on crosswalks, normal signal light operation, and left-turning vehicles are all important components of signalized intersections. Pedestrians are the most vulnerable road users because they are exposed more than other road users, and their safety at road intersections is the most important but unsolved issue.[20]

2.2.1.1. Traffic Lights at Signalized Intersection

Traffic lights serve as safety instructors, guiding all users (pedestrians and drivers) in a safe manner and reducing traffic accidents that occur when all users (vehicle drivers and pedestrians) mix up (for example, if there are no traffic lights, all users (vehicle drivers and pedestrians) coming from all four roads that meet at the signalized intersection mix up). When traffic lights change, collisions between vehicles and pedestrians are common. However, the impact of traffic lights on transportation safety and efficiency is unknown, and dangerous conflicts in which motor vehicles broke the law and failed to yield to a pedestrian in a crosswalk have been used as a proxy for transportation safety.[21]

As previously stated, traffic lights are widely used, but to a greater extent in urban intersection areas, and a network of traffic lights regulating urban vehicles can be viewed as a complex discrete-event system (DES).[22]

The demonstration of a collision avoidance system that can detect red-light running and warn nearby vehicles and pedestrians in real time to avoid accidents is shown.[23]

2.2.1.2. Safety Markings on Signalized Intersection

They are the markings and signs that instruct, warn, or direct road users (vehicle drivers and pedestrians) in positive safety matters, ensuring that all users are kept safe. The idea behind any type of marking, whether crosswalk markings, edge markings, line separating markings, or even signs, is to warn drivers to watch out and improve safety.[24]

Signalized intersections are one of the most important components of the road network. Intersection efficiency and safety can have an impact on the overall system's operational performance. In general, turning traffic, particularly median-turning traffic, has always been regarded as the most problematic movement in the operation of the intersection; therefore, I hereby declare that safety is paramount.[25]

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While there has been an increase in interest in wet-weather pavement markings due to their improved visibility and potential for improving road safety in wet-night conditions, there is a lack of research evaluating their safety effectiveness based on actual wet-night crash data.[26]

2.2.1.3. Speed of Drivers

On all users, such as drivers and their vehicles (of whatever types they are) and how safely they used as well as instructed, but behaviors of all drivers matter the safety, as behavioral observation studies have shown that in road safety research collected naturalistic data of road users who were not informed (beforehand) of their participation in research and it allows the observation of behaving.[27]

There is a lot of uncertainty about the future use of automated vehicles, including how they will interact with vulnerable road users. So far, only a small amount of research has been done on this interaction. As a first step in investigating this interaction, relevant conflict points involving both types of road users (automated vehicles and vulnerable road users) must be identified. A conflict point is a location where several infrastructure-related elements, as well as surrounding-related elements, increase the likelihood of an accident. These points of contention should include both safety concerns for vulnerable road users and operational concerns for automated vehicles. [28]

Pedestrians, cyclists, and motorcyclists are collectively referred to as "vulnerable road users" (VRU) because they have insufficient physical protection in the event of collisions on urban road networks. To make the road transportation system safer and more sustainable, adequate protective countermeasures must be implemented.[29]

2.2.1.4. Pedestrians

They are indeed road users who used to walk around and cross to get to the other side of the road for their travel needs. It's one of the most common pillars among road users' families, and it's simply to ensure that road designers take their safety into account. One of the most important pedestrian road-crossing behaviors is pedestrian road-crossing strategy, and pedestrian safety is often dependent on it. The most dangerous is rolling gap crossing at intersections.[30]

The findings revealed that speed limits have a significant positive impact on fatal pedestrian crashes, and that both incapacitating and non-incapacitating injury crashes increase as motorized traffic volume increases, but that pedestrian volume at intersections has a positive impact on non-incapacitating injury crashes. The difference in influence between intersection designs for reducing

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all types of pedestrian crashes.[31]

According to WHO, pedestrians are the most vulnerable road users, accounting for 23% of global traffic deaths in 2018. (World Health Organization, 2018). Naturally, China has the most pedestrians in the world due to its largest population and traffic developing state, and pedestrian safety has always been a problem in China, with pedestrians accounting for 26.1 percent of traffic deaths in 2013, compared to 16.1 percent in America (World Health Organization, 2016), and close to 5% in Ethiopia.[32]

Pedestrian movement is still a significant part of today's urban transportation networks, and walking is an important mode of transportation. Because pedestrians interact with the environment and other people in a dynamic process while walking, pedestrian behavior is complex and multidimensional. Walking as a mode of transportation necessitates pedestrian-friendly environments that make people feel safe, empowered, and welcome. It is critical to have a thorough understanding of pedestrian behavior in order to ensure pedestrian safety and to determine the implications for crowd management, building design, urban development, and evacuation planning, among other things.[33]

Pedestrians who arrive at the clearance phase (Flashing Don't Walk) face varying degrees of risk depending on their subsequent behavior. Few studies, however, have focused on pedestrian decisions during this phase. This field study looked at pedestrian choices after they arrived, assessed their safety, and developed a model to predict pedestrian choices. Pedestrians arriving during the clearance phase were found to make dynamic decisions based on changing contexts. The majority chose to "cross" rather than "wait" (85.2 percent vs. 14.8 percent, respectively), despite the fact that only the latter option is legal. Seventy-nine percent of pedestrians did not complete their crossing before the traffic light turned red, and they walked 41 percent of the road width while waiting for the light to turn red. Approximately half of those who waited until the light turned green or crossed at an intersection. Others began on a red light at an intersecting crosswalk, while others finally began on a green light.[34]

2.3. Effect of Traffic Lights at Signalized Intersections

The contribution of traffic lights to guiding, controlling, and leading road users to when they're allowed to pass and stay in position if it's not, as well as pedestrians using to safely pass, is one of the most important aspects of signalized intersections. Its effects on signalized intersections serve the aforementioned purposes, as well as solutions for reducing traffic jams, minimizing poor service, and traffic control in general.

Traffic light systems are designed to control traffic flow at intersections and ensure that traffic flows smoothly throughout the network. The lengthening of queues at the intersection is caused by

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increasing traffic flows that are not supported by current traffic light systems. Through simulations, the effect of queue length, green time, cycle time, and amber time in the traffic system is observed and studied. Longer green times will allow more vehicles to pass through, but it will also lengthen the cycle time, causing more vehicles to congregate at the intersection during the waiting period.[35]

Modern traffic intersections' sensing and computing capabilities have greatly improved in recent years, but current control policies do not fully utilize these capabilities.[36]

Understanding the performance of older and younger drivers in terms of sight and driving when traffic lights changed from green to yellow at the last second of signalized intersections, as well as their contributions to safety and crash, is something which is more important to consider here.[37]

2.4. Traffic Delay at the Signalized Intersections

The presence of traffic lights can cause a variety of issues, including delays. While the reasons for such a problem are numerous, this study focuses on two types of delays: recurrent and non-recurrent delays. Recurrent delays are caused by day-to-day congestion (i.e. rush hours), while non-recurrent delays are caused by irregular traffic patterns. Overall, crashes account for 45.9% of all delays, followed by roadwork (24.3%), breakdowns (12%), weather (9%), signal timing (8.1%), toll facilities (0.6%), rail road crossings (0.1%), and commercial pick-up delivery operations (0.035).[38]

The variable speed limit application in a connected vehicle environment (CV-VSL) can estimate and deliver recommended travel speeds to individual drivers in response to developing and/or diminishing foggy conditions, which can help to reduce crashes when visibility conditions change. The goal of this study is to determine the effectiveness of the CV-VSL application by looking at how drivers react to warnings (e.g., recommended travel speeds). To assess the effectiveness of the CV-VSL application, a connected vehicle testing platform based on a driving simulator was established, and the characteristics of drivers' speed adjustments after receiving warnings were analyzed for different levels of visibility (no fog, slight fog, and heavy fog).[39]

In order to achieve a smooth, safe, and reliable traffic operation, highway and traffic engineers have focused on weather conditions and their effects. Changes in the weather have been known to wreak havoc on traffic flow. Delays, accidents, safety implications, speed reductions, congestion, and other hazardous driving conditions could all result from the disruptions (FHWA, 2008 and Cools et al. 2010). Various weather conditions such as snow, rain, ice, darkness, and fog, as well as their effect on traffic flow, have been studied over the years. Speed, flow, density, travel time, and capacity are just a few of the traffic characteristics that are frequently affected. Traffic engineers now incorporate weather-based information into traffic operations due to various weather-related effects.[39]

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2.5. The Difference Between Signalized Intersection and Un-Signalized Intersection

The distinction is easily discernible in terms of geometric features, construction methods, and traffic regulations..[40]

- Signalized intersection

Signalized intersection is a point where two or more roads intersect, and traffic signal lights were installed to control traffic, pedestrians, and bicycles so that they could cross safely and legally.

- Un-signalized intersection

  The un-signalized intersection is similar to signalized intersection all other features and users, but it does not have a traffic signal to control it. Instead, traffic police were present to enforce the rule of traffic, which allows each traffic phase to proceed at its own pace while other phases wait. Pedestrians and bicyclists closely observe the traffic police's actions, which indicate when it is safe to proceed.

2.6. Major Geometric Elements of a Signalized Intersection

The traffic control signs, the number of roads crossing, the number of lanes per road direction, and the width of the roads crossed are the geometric elements of an intersection.

To provide the service being installed, traffic control lights must function and work properly in order to control and safely allow drivers and pedestrians to continue their journey.
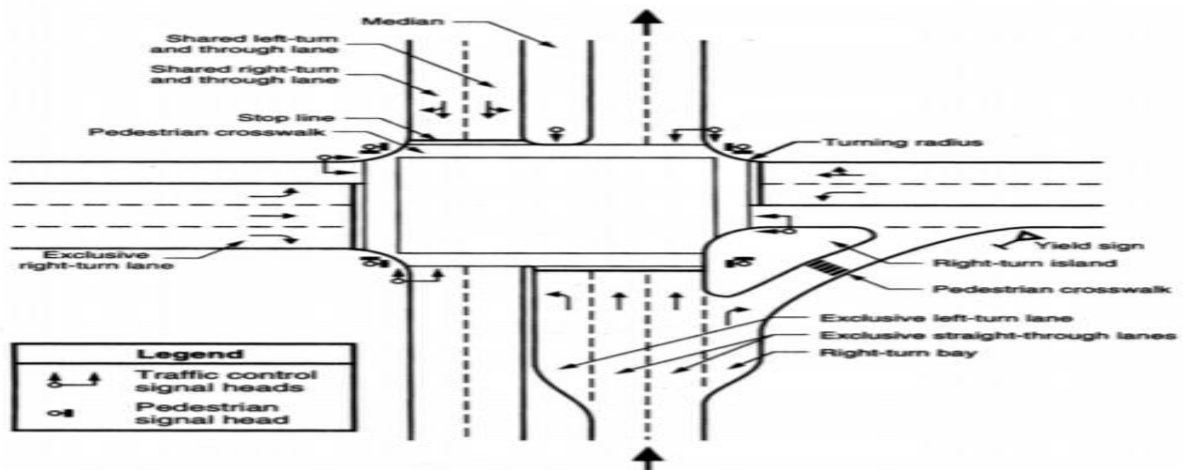
Figure 2.1. Signalized intersection Design.

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Every intersection has four roads crossing it, and the number of lanes per direction varies per intersection, i.e. Pianza signalized intersection, Mexico signalized intersection, and Immigration signalized intersection all have three lanes in each direction, whereas Meskel square has four lanes in each direction.

The proportioning of visible elements of highway facilities is known as geometric design. It entails the layout of horizontal and vertical alignments, as well as cross-section elements like the shoulder, median, curb, barrier, and sidewalk. At intersections, traffic demands and the proper accommodations of traffic control devices influence these elements and their configurations. Although the design of an intersection is influenced by factors specific to its location or situation, it follows the following design principles in general:

1. Intersections on a given street or highway should be as consistent as possible in their design.

2. The intersection's layout should be as straightforward as possible.

3. All intersection elements should be designed in accordance with the approach design speeds.

4. There should be no steep grades or sharp horizontal or vertical curves on the approach roads.

5. Traditional intersections should be as close to right angles as possible, unless a roundabout is considered.

6. All movements approaching and passing through the intersection should have enough sight distance.

7. The layout of the intersection should promote smooth flow and discourage wrong-way movements.

8. On high-speed and/or high-volume facilities, auxiliary turn lanes should be provided in traditional intersections.

9. Entrance maneuvers onto high-speed facilities benefit from acceleration lanes.

ten. The provision of safe roadside clear zones and horizontal clearance must be given special consideration in the design.

11th. The intersection arrangement should not necessitate any quick or difficult decisions.

12. Inventive+ phrasing an intersection's layout should be simple and straightforward.

13. In urban areas, bicycle and pedestrian traffic are an important part of the demand traffic volume and must be accommodated.

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14. On the approaches to intersections, advance guidance and/or lane assignment should be provided.

Three-leg (T or Y), four-leg, multi-leg, or circular at-grade intersections are the most common. The type of intersection is determined first, followed by the development of an appropriate geometric plan that reflects appropriate design and operational criteria within the physical constraints. Roundabouts are circular intersections where all approaches are subject to yield control (entries). FDOT currently recommends a two-lane limit for the circulatory roadway, though additional lanes may be considered for spiral or "Turbo" roundabouts. When more than two lanes are required to accommodate certain movements, spiral or turbo roundabouts are commonly used.

Functional classification refers to the classification of roads into systems based on the type of service they provide in relation to the overall road network, as determined by Federal Highway Administration procedures. Arterial roads, collector roads, and local roads are the three basic functional categories, each of which can be subdivided into principal, major, and minor levels. These levels can be further subdivided into rural and urban areas. [15]

Functional Classification Codes:

 1 = Interstate

2 = Other Freeways and Expressways

3 = Other Principal Arterial

4 = Minor Arterial

5 = Major Collector

6 = Minor Collector

7 = Local

Functional classifications and the standards that go with them are predetermined controls that the designer has little control over. The standards are minimum values, and where possible and practical, values above the minimum should be used [PPM]. Specific design features should be assessed using the procedures outlined in the Highway Safety Manual.[15]

On the SHS, at-grade intersections are typically controlled by stop signs (also known as stop controlled intersections), roundabouts, or traffic signals (i.e., signalized). All approaches to roundabouts, as well as certain channelized movements at intersections and interchanges, are yield controlled. A number of geometric design features, such as lane assignments, sight distance, and storage length of auxiliary lanes, are directly affected by the type of intersection control.[15]

Urban, suburban, and rural areas are the most common classifications. The development and types

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of land use, the density of the street and highway network, the nature of travel patterns, and the ways in which these elements are related are all fundamentally different in each of these area types. As a result, the considerations and requirements for each of these areas differ in terms of intersection design. The Department may designate specific projects or segments of projects to include Transportation Design for Livable Communities (TDLC) features in certain areas. For information on TDLC considerations, features, and requirements for these types of projects access management has an impact on intersection design in terms of access points, median openings, and their proximity to intersections. Some driveways are large enough to be considered intersections in and of themselves.[15]

The selection of many of the project standards and criteria used to design a roadway project is governed by design speed, which is a major design control. The intersection's design elements, such as control mode selection, island location and design, taper lengths, and sight distance requirements, will be influenced by the mainline design speed. Vehicles turning at intersections with minimum-radius turns must travel at speeds of less than ten miles per hour. While it is sometimes desirable and feasible to design for turning vehicles to operate at higher speeds, at most at-grade intersections, it is often necessary to use lower turning speeds for safety and economy. Approaching vehicle speeds, design vehicle, type of intersection, control mode, pedestrian volume, and through and turning volumes all influence the speeds for which intersection curves should be designed.

The weight, dimensions, and operating characteristics of a design vehicle are used to establish highway design controls for accommodating vehicles of a specific class. Each design vehicle has larger physical dimensions and a smaller minimum turning radius than almost all other vehicles in its class for geometric design purposes. The horizontal and vertical alignments, lane widths, inscribed circle diameter, turning radii, lane assignments, intersection sight distance, storage length of auxiliary lanes, and acceleration and deceleration lengths on auxiliary lanes are all affected by the design vehicle chosen. A variety of design vehicles are included in the AASHTO Green Book. These vehicles' dimensions are displayed. The functional classification of a roadway, as well as the proportions of the various types and sizes of vehicles expected to use the facility, influence the design vehicle selection. One of the semi-trailer vehicles should be considered in the design of SHS facilities to accommodate truck traffic. In densely populated areas, intersections may be designed to meet all of the requirements of the Intersection Design Guide.[15]

Florida Intersection Design Guide 2013, Page 3-9 Passenger Vehicles, but the bigger vehicles need to swing wide. It should be noted that the WB-62 design vehicle modified with a 53-foot trailer and a 41-foot KCRT distance (the pin at the center of the rear tandem axle) accommodates FS 316.515 to maximum dimensions. This "WB-62FL" semitrailer is illustrated in Figure 3-1 and should be used for the design of turning roads in Florida. If special conditions exist, a larger design vehicle can be

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used. For information on different turn radii used for accommodating different design vehicles, see Section 3.13.1 and Table 3-11. Computer generated rotation templates enable the road designer to select a design vehicle and simulate the expected rotation. Any proposed intersection design/layout should be tested with the software or with path templates to ensure that they can handle the rotating movements of the design vehicle. The example of a swept path template to test the turning range suitability for a WB-62FL design vehicle is shown in Figure 3-1.[15]
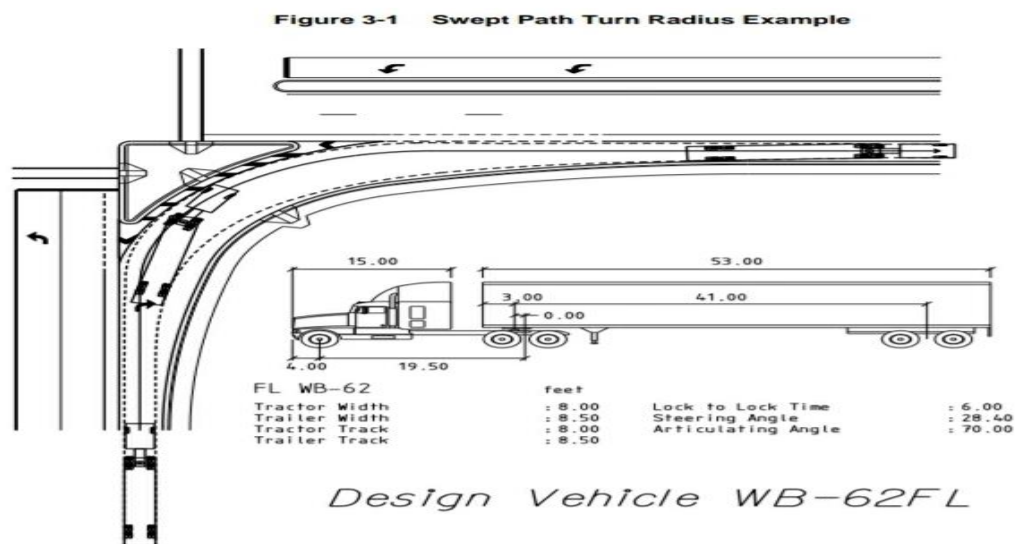
Figure 2.2. Design vehicle.

Pedestrian traffic can be an important part of demand traffic and should be factored into the intersection design from the start. Pedestrians and bicyclists should be considered in the design of all new or major reconstruction projects. Chapter 8 of the Plans Preparation Manual specifies required bicycle and pedestrian facilities; decisions on additional pedestrian and bicycle facilities and/or features are made with input from District Pedestrian/Bicycle Coordinators and District "Americans with Disabilities Act (ADA)" Coordinators. At intersections, return radii must balance the needs of pedestrians and design vehicles. To accommodate a vehicle's turning ability, larger radii are required, while smaller radii are required to reduce pedestrian crossing distance. In situations where large radii are unavoidable, pedestrian refuge channelization islands should be considered. Curb extensions can be used to reduce the crossing distance [PPM] in urban areas with a parking lane. Pedestrian facilities must be designed to accommodate people who are blind or who use wheelchairs or other mobility devices. Where marked crosswalks intersect the raised sidewalk, curb ramps should be installed.

Additional information on curb ramps can be found in Section 3.10.4.[15]

When on-street bicycle lanes and/or off-street shared use paths reach an intersection, they must be maintained. Furthermore, even in areas where bicycle facilities are not available, the inclusion of bicycle lanes on intersection improvement projects should be considered. There are two types of bicycle lanes: designated and undesignated. Bicycle lane signs and special pavement markings identify designated bicycle lanes. Edge stripes separate undesignated bicycle lanes from traffic lanes, but there are no bicycle lane signs or special pavement markings. The choice between designated and undesignated bicycle lanes is based on the expected use (e.g., the continuity of the bicycle route, the presence of logical route termini for bicyclists, etc.). Table 3-4 shows the required width of bicycle lanes. The FDOT standard 5 feet paved shoulder on roadways with flush shoulders provides for a bicycle lane that can be designated or undesignated. A 4-foot width measured from the gutter lip is required on curb and gutter roadways. When FDOT Type F curb and gutter is used, the face of the curb will be 5.5 feet wide. Although the 1.5-foot gutter width is not part of the rideable surface area, it does provide Intersection Design Guide.[15]

Useable clearance to the curb face, according to the Florida Intersection Design Guide 2013, Geometric Design Page 3-13. Where parking is available, the bike lane should be located between the parking lane and the travel lane and should be at least 5 feet wide. At intersections with right turn lanes, the bicycle lane should continue adjacent to the through lane between the through lane and the right turn lane and be 5 feet wide, with a minimum width of 4 feet. One example of this treatment is the suburban or rural intersection depicted in the previous chapter (Figure 2-4). The Design Standards, Index 17346 and 17347, include standard drawings for various bicycle lane configurations. Bicycle lanes at roundabouts should be terminated at bypass ramps to allow access to the sidewalk before entering the circulatory roadway. Bicyclists can "command the lane" and travel through the roundabout in the circulatory roadway, or they can divert onto the sidewalk and cross the intersection along pedestrian paths (riders must yield to pedestrians). [15]

The angles at which two highways intersect can have a significant impact on the intersection's safety and operational characteristics. Angle of intersection influences both individual vehicle operations and the nature of vehicle/vehicle collisions. Acute "skew" intersection angles, with the exception of roundabouts, result in large open pavement areas within the intersection. Such intersections are not only more expensive to construct and maintain, but they are also operationally undesirable for the following reasons: 1. Vehicles crossing the intersection are exposed to conflicts from crossing traffic for a longer period of time. This may be especially important on STOP-controlled approaches on high-speed highways. 2. The road user's sight angle to one of the crossing legs narrows. This makes detecting safe crossing gaps more difficult. 3. Pedestrians and bicyclists are exposed to conflicting vehicles for longer periods of time. 4. Because of the skew, vehicular movements are more difficult.

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Large truck turns may necessitate additional pavement and channelization that would not otherwise be required. The more open pavement there is, the more likely it is that vehicles will deviate from the designated routes. [NCHRP 279] Formalized adverbial possible, approaching roadways should intersect at right angles. Angles greater than 75 degrees but less than 90 degrees should be maintained normally. Angles as low as 60 degrees may be acceptable where there are expensive or severe constraints.[15]

However, because of the large population of older road users in the state of Florida, angles less than 75 degrees are generally not recommended [FHWA]. Where there are severe skew angles, the need for improvements should be evaluated, with a primary focus on examining crash rates and patterns. A high incidence of right-angle crashes, particularly those involving vehicles approaching from acute angles, may indicate a skew problem [NCHRP 279]. A modern roundabout can be used to eliminate right-angle crashes, resulting in a reduction in crash severity. Reconfigurations like the ones shown in Figure 3-2 should be used whenever possible.[40]

Figure 3-2   Intersection Reconfigurations
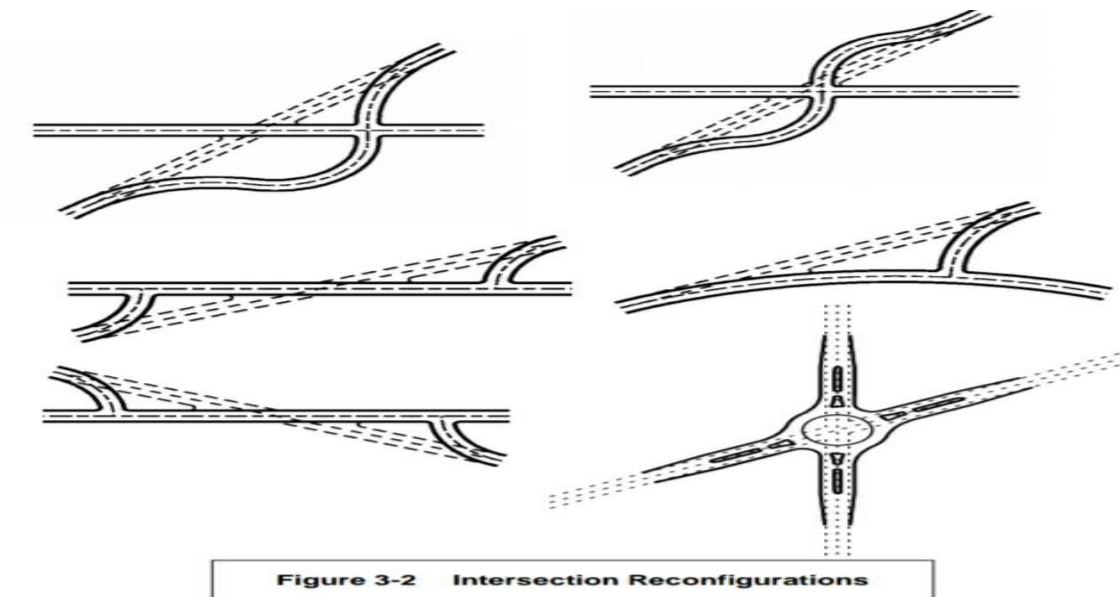
Table 2.3. Intersection Reconfiguration.

2.7. Appropriate Site Selection for Signalized Intersection

The type of intersection chosen at each location is influenced by a variety of factors:[40]

❖ Functional class of intersection streets

❖ Design level of traffic

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- ❖ Number of intersecting legs

- ❖ Topography

- ❖ Access requirements

- ❖ Traffic volumes, patterns, and speed

- ❖ Availability of right of way

- ❖ Desired type of operation

Even though many of the intersection design examples are from cities, the principles can be applied to rural areas as well. Different types of traffic control have minor design variations, but all intersection types lend themselves to the following types of control:

- • Cautionary or non-stop control

- • Stop control for minor approaches

- • Four-way stop control

- • Both fixed-time and traffic-actuated signal control

2.8. Safety Evaluation of Signalized Intersection

In recent years, the Ethiopian metropolis of Addis Ababa has seen a surge in the installation of left-turn waiting areas (LWA) at signalized intersections, similar to what has happened in China metros. Left-turning vehicles can enter the intersection at the start of the through green phase (of the same approach) and wait for the exclusive left-turn signal at the LWA, thanks to the design.

Although the LWA layout can effectively reduce the likelihood of stranded and queue overflow of left-turn vehicles, a study is being conducted to evaluate the safety performance of signalized intersections with LWA, such as the one referred to here. The paper uses the traffic conflict technique (represented by post-encroachment time), compares the discrepancy of conflict types between intersections with and without LWA, and develops severity models to identify the factors that contribute to left-turn conflicts. The presence of secondary conflicts, left-turn volume, driving outside the LWA, running red light, and rear-end conflicts all significantly increase the severity of traffic conflicts at the LWA, according to the findings. The findings are being used to make recommendations for revising the current LWA design standard and, as a result, improving the safety of signalized intersections with LWA in Ethiopia.[41]

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2.9. Capacity Evaluation of Signalized Intersection

The capacity evaluation of signalized intersections is one of the topics being discussed, so in order to define the capacity, methods should be used to rank and categorize the capacity's performance, and this will be based on the HCM standards to get the point across.

A traffic signal's primary purpose is to resolve conflicts between vehicles, cyclists, and pedestrians vying for time and space at an intersection. The goal of the design is to ensure that the method of resolving conflicts provides the desired level of safety, capacity, and performance.

The HCM, chapter 18, signalized intersections, defines the LOS at a signal in terms of the average control delay experienced by each vehicle on the approach. To distinguish between levels of service, threshold values are provided.

To quantify the signal operation, the following terminology is used:

1. Traffic volume, v, (vph)

2. Saturation flow rate, S, (vphg)

3. Flow rate, y, calculated as v/s

4. Effective green time, g(Sec)

5. Cycle length, c(Sec)

6. Green ratio, calculated as g/C

7. Capacity, c, calculated as sg/c

8. Degree of saturation, X, calculated as v/c, i.e.vc/sg

 9. Control delay, D, estimated by the procedure prescribed by the HCM

Allowable left turns must yield to incoming traffic, shared lanes for through and left turning movements, multi-phase operation, and other factors add to the complexity. All of these issues are dealt with by the HCM through operations. The capacity, c, of a signalized intersection approach is calculated by multiplying the saturation flow rate by the proportion of time the signal controlling the approach is in effective green. The overall phase time for the approach (Green + Yellow + All-red) minus the wasted time associated with starting and stopping the movement is described as effective green.[40]

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C = sg/c

Where:

s = is the saturation flow rate (Vphg)

g = is the effective green time per cycle (Sec)

c = is the cycle length (Sec)

2.9.1. Signalized Intersection Characteristics

A set of factors that are involved in some way in the intersection design process are included in the characteristics of signalized intersections. Some characteristics are designed to act as controls, while others are the result of design choices. A summary of these characteristics can be found in the table below.[40]

Table 2. 1. Characteristics of signalized intersection

Physical characteristics	Traveled roadway
	Curbs
	Sidewalks
	Medians
	Islands
	Inscribed circle diameter
	Drainage features
	Physical obstacles
Operational characteristics	Lane configuration and usage
	Traffic control mode
	Pedestrian control provision
	Lane delineation
	Turn prohibitions
	Crosswalk configuration

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	Signal phasing and timing
	Accessibility features
Traffic characteristics	Vehicular volumes
	Composition
	Peaking characteristics
	Pedestrian volume
	Bicycles volumes
	Safety performance
Site characteristics	Roadway classification
	Site location
	Roadside development
	Institutional proximity(schools, etc.)
Road user characteristics	Age
	Special requirements

2.10. Bayesian Networks

2.10.1 Bayesian Network Concepts

A belief network, also known as a Bayesian Network, is a probabilistic graphical model that consists of a joint probability distribution over set variables and the corresponding local univariate distributions. It comes from the recursive use of Bayesian networks to decompose the joint distribution of the nodes given the direct acyclic graph to individual distributions of the nodes. It represents knowledge about an uncertain domain, with each node representing a random variable and the edge between them representing probabilistic dependence among the corresponding random variables.

Bayesian Networks have recently gained popularity among researchers, and they've been used in a variety of applications, including engineering, machine learning, text mining, weather forecasting, cellular networks, medical diagnosis, natural language processors, speech recognition, signal processing, and error control codes. It was also clarified that overfitting is avoided using a

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combination of Bayesian statistics and Bayesian networks. This is due to a misunderstanding about Bayesian networks, which differ from Bayesian statistics. Bayesian networks have nodes that represent not only random variables but also beliefs, hypotheses, and latent, manifest variables.

Bayesian networks have a structure that is ideal for combining prior knowledge with observed data. The advantage of Bayesian networks is that they can be used even if data is missing. Using directed acyclic graphs and factorized probability functions, Bayesian networks captured factorized probability information from data. It generates a model that includes a larger number of variables.[42]

2.10.2 Bayesian Network Methods

Several types are involved, chiefly amongst which are:

a. Multinomial Bayesian Network: where variables are taking to be discrete such that each variable has a finite set of possible values

b. Gaussian Bayesian Network: where variables are assumed to have a multivariate normal distribution $N(\mu, \sum)$ thus assumed to be continuous

c. Hybrid Bayesian Networks: where variables are used to both the discrete and continuous

But this study is applied using Multinomial Bayesian Network since the data were discrete and every variable has a finite set of possible values.[42]

2.10.3. Brief Discussion About Bayesian Networks

Bayesian Networks (BNs) are the result of a marriage between graph theory and probability theory, which enable us to model probabilistic and causal relationships for many types of decision-support problems.[43]

A BN is made up of a directed acyclic graph (DAG) that represents dependencies between related nodes (variables) and a set of local probability distributions attached to each node (called a node probability table – NPT in this study paper) that quantify the strength of these dependencies. Many real-world problems have been successfully solved using BNs.[44]

Bayesian networks are graphical models where nodes represent random variables (the two terms are used interchangeably in this article) and arrows represent probabilistic dependencies between them. [44]

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The graphical structure G = (V, A) of a Bayesian network is a directed acyclic graph (DAG), where V is the node (or vertex) set and A is the arc (or edge) set. The DAG defines a factorization of the joint probability distribution of V = {X1, X2, . . ., Xv}, often called the global probability distribution, into a set of local probability distributions, one for each variable. The form of the factorization is given by the Markov property of Bayesian networks (Korb and Nicholson 2004, section 2.2.4), which states that every random variable Xi directly depends only on its parents Π_{Xi}:

$$P(X_1, \dots, X_v) = \prod_{i=1}^{v} P(X_i | \pi_{Xi})$$

The correspondence between conditional independence (of the random variables) and graphical separation (of the corresponding nodes of the graph) has been extended to an arbitrary triplet of disjoint subsets of V by Pearl (1988) with the d-separation (from direction-dependent separation).[43]

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CHAPTER THREE

RESEARCH METHODOLOGY

The methodology applied for the research task was the critical aspect for ensuring the proper output which aligns with the objective or the research questions raised. Hence, this part of the thesis discusses the methodology that comes after and the reason for the selection of the methods to directly address the work problems mentioned earlier in Chapter One. It looks at relevant factors, which have affected the safety evaluation at signalized intersections by using; interviews, questionnaires, geometry observations, and data collection. On the other hand, it was a process for collecting, analyzing, and interpreting information to provide a recommendation to the research findings. The methodology of this research work consists of two major pillar components. First was using field observations which includes assessing the general geometric condition which evaluated in such; general geometric configuration, geometric elements of a signalized intersection, and road users' accidents/facilities. Secondly, it was providing questionnaires and interviews included asking drivers and pedestrian with regard to their experience and safety perception.

Since the empirical method is linked and depends on the geometric elements of the signalized intersection, it was difficult to find the necessary geometric elements on the signalized intersection which might be a problem during safety evaluation. Besides, the analytical method was preferred for the thesis R-software with some geometric elements since it is modeling.

Bayesian networks has needed in order to do which method to use since it has three different types under and it has been done some basic groundwork calculations for the development of the model in the first stage and has let the software modeled it; which is capable to handle the model development which has done with the analysis and had given the results and by checked twice the model developed to has made sure it is reliable and correct.

3.1. Descriptive Study Area

The study area, has been selected for this research where had four signalized intersections located in the heart of Addis Ababa City. It had geographical coordinates in between 9^0 14' 50" N latitudes and 40^0 48' 97" E longitude, with an estimated land area of 527 km^2 while has found in an area of an average altitude of 2,355 meters above the mean sea level. It lies in the center of a weatherly zone which is an average of 17^0C, wind speed of 8km/h, and 69% of humidity. The population (drivers, pedestrians, and bicyclists) which usually uses are mass in number, also many embassies and the headquarter of African Union had found in.

The selected four signalized intersections are Piassa signalized intersection, Immigration signalized intersection, Mexico signalized intersection and Meskel Square signalized intersection.

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The four signalized intersections in Addis Ababa city which were selected are located in different sub-cities and has different legs per direction of each phase and represented others had selected for their necessary geometric elements had collected while found out the accidents mostly has happened at the peak hour time.

These four signalized intersections were selected based on the principle of a possible representative of the target population of signalized intersections in terms of size, user numbers, and their influential locations.

Before the commencement of the research, there were many signalized intersections which some of them are newly installed traffic signal which comes when some of an un-signalized intersection has changed into signalized for the safety reasons. Some of the signalized intersections were built nearly 20 years ago, some are aged in between ten up to fifteen years and some are newly built. Secondary data are collected from Addis Ababa Police Commission and near traffic police stations to the signalized intersections; where primary data collected as interviews and questionnaires have provided for the intersection user of all, but specific data on per signalized intersection is not being prepared rather prepared as all signalized intersections while the near traffic police stations near to as in the sub-city are not arrange data as per intersection but did as a whole in the area.
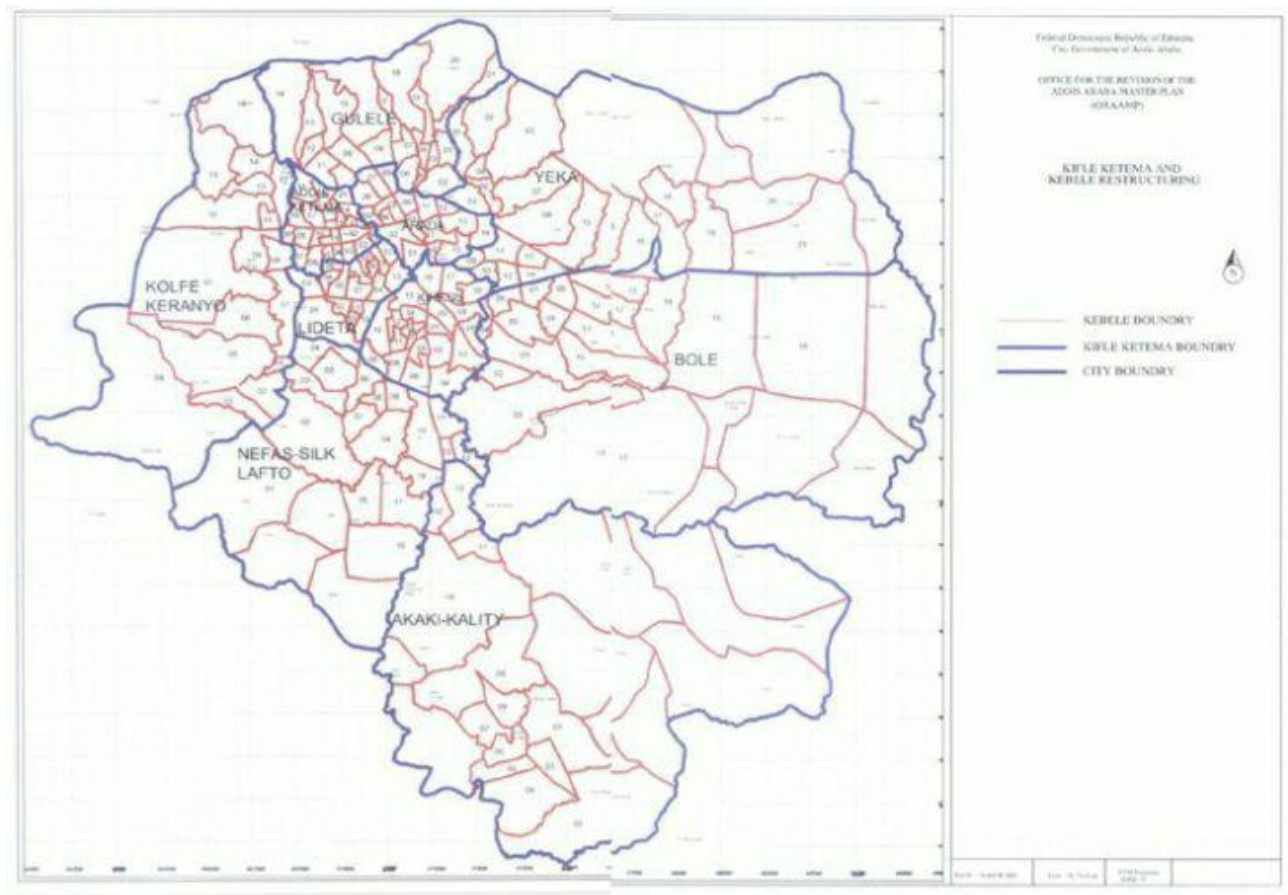
Figure 3.1. Addis Ababa City Map

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Figure 3.2. Meskel square Signalized Intersection digital photo taken by Google Earth.

Figure 3.3. Mexico Signalized Intersection digital photo taken by Google Earth.

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Figure 3.4. Piassa Signalized Intersection Digital Photo Taken by Google Earth.

Figure 3.5. Immigration Signalized Intersection Digital Photo Taken by Google Earth.

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3.2. Research Design

The descriptive and analytical methods, have used in this research study. In this research area, both quantitative and qualitative studies were conducted. A qualitative study provides an impression of the findings, whereas a quantitative study has used to describe the numerical aspects of the research findings, which has based on the safety evaluation and software's used gave a critical results .

Problem

Formulation of Research

Identification data required

Primary data

Secondary data

- Interview
- Site visit
- Location of RTA spot

- o RTA Fatalities and Injury
- o RTA of the four intersections, in two sub-cities in Addis Ababa

- Data: -
  a. Filtering
  b. Editing
  c. Coding
- Preparing RTA data from police station.

Set the criteria to select the most unsafe signalized intersection and then double check it

Enter the input data for analysis and design to different software's like (i.e. R software, Google Earth, Ms. Excel and Etc.)

A. From the Google Earth, locate the intersections.

B. Collect data recommendations of the intersections safety from consultants and contractors concerning

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- General characteristics of RTA on the intersections and identification of black spot

- Discuss the occurrences of RTA on the intersections

- The traffic accidents cause of related to the traffic lights, pedestrians, vehicles and weather

The effects of traffic lights, pedestrians, drivers, vehicles and weather on the safety of the signalized intersections

Conclusions

Recommendations

3.3. Population

The study of the population includes those who are existing within the range of study areas, drivers who cross the signalized intersections, traffic polices who are involved at the site, pedestrians, bicyclists, accident data, Addis Ababa Police Commission, near to traffic police stations, and signalized intersection geometry.

3.4. Sampling Size and Sample Techniques

3.4.1 Sample Size

Purposive sampling had used to provide the sample inspections chosen. There are numerous mathematical equations that may be used to determine the size of a finite or infinite statistical sample. I discovered that the infinite statistical sample size equation is used here since the population to be targeted is large for these four signalized crossings in the heart of Addis Ababa city.

Furthermore, the population size is determined using three criteria that are commonly used to establish the proper sample size: precision, confidence or risk, and the degree of variability in the qualities being measured. Although the target group of users at these four signalized junctions is higher, we do not know the variability in the percent who will participate in the study and complete the questionnaire.

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Assume p=0.5 as a result (maximum variability). Furthermore, let's say we want a 95 percent confidence level and a 5% precision. The resulting sample size is shown in Cochran's (1963:75) equation, which has been adjusted by Glenn D. Israel.[45]

$$n_0 = ZZ^2 pq/e^2$$

$$= (1.96)^2 (0.5) (0.5) / (0.05)^2$$

$$= 385 \text{ respondents}$$

As a result, the population sample size was determined to be 385, and data was collected at four separate signalized intersections in Addis Ababa, Ethiopia.

3.4.2. Sample Techniques

The sample inspection has used different way of sampling techniques to fulfill the objective of the research**.**

- Using post road traffic accident data from Addis Ababa city police commission office and nearby traffic police stations office of each signalized intersections

- Questionnaire surveys and interviews were designed to allow the researcher to identify the general cause and contributing factors of safety evaluation to signalized the intersection capacity.

- The field survey was performed on the existing signalized intersection geometric design element using a road safety checklist with HCM standards.

3.5. Research Approach

The research approach in this thesis work involved both quantitative and qualitative approaches. Quantitative data and analysis has used to determine the level of service of signalized intersection and to has measured the congestion levels quantitatively. The main source of the quantitative data has observation, direct field measurements, and secondary data. While qualitative data from the questionnaire and the interview has used to determine the driving behavior at signalized intersection and factors that affect priority right. Observations, collecting relevant data, and subsequent of the data help to generate an inductive conclusion to evaluate the capacity and level of service of a signalized intersection. Since it has impossible to assess some of the pillars of safety evaluations like driving behavior and pedestrian behavior at all signalized intersections, the researcher put a lot of effort, representative samples have been taken at specific times where the traffic and pedestrian volume has high to derive a generalized conclusion. However, the selected sites of the research have under two sub-cities; which had connected to the highly populated roots and passes through the central business districts of the city and have increased graph of traffic and pedestrian volume year

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after year.

The research method followed and designed has to address the key questions of the research answered properly. To assess whether the signalized intersections has congested or not, a key question "Does good traffic safety exists at this signalized intersection?" has raised, and got an answer first usage indicator parameters.

The congestion indicator parameters used in this research has Level of Service(LOS) and road user's perception. The LOS creation has accorded to HCM-2016 and drivers view has collected used questionnaire and data has putted into the SPSS VERSION 26 software as a way of prepared to analysis so it has easily transferred to the analysis R software.

3.6. Data Collection Techniques and Equipments

For the accomplishment of the research, it has required data; which had been collected in a form of a questionnaire and it has the primary data of the task. Which had been used for the analysis and model development, as a way of sample form; questionnaire form will be shown here as a form for eased to have clue of the research readers

3.7. Study Variables

3.7.1. Dependent Variable

Safety evaluation at a signalized intersection

3.7.2. Independent Variable

      a) The capacity of a signalized intersection

      b) The geometry of the signalized intersection

      c) Speed of driver

      d) Traffic flow

      e) Roadside element

3.8. Software and Instruments

R software, SPSS software, GIS software, and Google Earth had all been used in this thesis.

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3.9. Method of Data Analysis

Bayesian networks analysis was employed for data analysis, which is advanced safety evaluation Modeled for the four different signalized intersections were built.

3.9.1. General Overview of Secondary Data

The secondary data was gathered from the AAPC and other adjacent traffic police offices at the four signalized intersections of Immigration, Meskel Square, Mexico, and Piassa. This study attempted to prevent traffic accidents by conducting a questionnaire at four signalized crossings in two sub-cities, Arada and Kirkos, with the goal of determining the direct impact of safety assessments at signalized crossings. Apart from that, there have been challenges encountered by the study during data collecting, particularly secondary data collection, because the data was not fully prepared and the exact locations of the accident were overlooked and placed in a broad manner.

3.9.2. Field Work

Field observations and measurements were made, and raw data was gathered from representative samples. The results of field measurements were compared to the HCM results. A questionnaire has been produced for all of the sites to determine the elements that affect safety evaluation and general safety characteristics, but the questions are the same. However, because the questionnaire was sent to a small sample of users of signalized intersections, more information was needed to determine the practical safety of signalized intersections. To determine the safety obstacles at the signalized intersection.

3.9.3. Design of Questionnaire

The questionnaire's questions and answers for each of the study topics had been addressed and answered in chapter one, and the questionnaire would also have covered general features of the signalized intersection's safety as well as the influencing elements. The capacity of the signalized junction is the most basic component that affects safety evaluation, and it had examined towards the end of this chapter. The same questionnaire had prepared for all samples of signalized intersections, and 96th questionnaires have distributed to all road users (i.e. drivers, pedestrians, and cyclists) who crossed the signalized intersection, with the exception of Meskel square signalized intersection, which received 97th questionnaires.

The total number of questionnaires distributed had 385, and all of them has returned to the researcher because of the method of distribution, which included hired a local translator that has accompanied the researcher to the selected intersections, and asked the targeted respondents to fill out 10

questionnaires per full day of work, which took 40 days to complete. Because each signalized junction has a unique geometric design, legs, and characteristics, the researcher attempted to pinpoint the problem at each one separately. Whatever questionnaire was used, the difficulties with safety were essentially the same.

3.9.4. Geometric Data

The geometric element of signalized intersection data has been used as an input for model development and design to understand the effects of the level of service of the signalized intersection. The names of the selected signalized intersections are as follows: (the name being adopted from the area or publicly declared by the city administration of Addis Ababa).

Signalized intersection name	Number of lanes	Width lanes(m)	Number of legs
1. Piazza	3 lanes	3.5	four legs
2. Immigration	3 lanes	3.5	four legs
3. Mexico	3 lanes	3.5	four legs
4. Meskel-square	4 lanes	3.5	>four legs

Geometric data had taken by measured with a tape meter and by observed on the signalized intersection existing sites.

3.10. Ethical Consideration

The ethical considerations have been concentrated in the context of quantitative and qualitative data for the achievement of the goal of this research work. To begin, a formal letter from JiT and official approval bodies from the Addis Ababa Police Commission were received, and data was collected as a manner to ensure that the actions were managed under the country's constitution and legality.

3.11. Data Quality Assurance

The data for this research study had gathered in two methods, depending on the source. The main data collection source (the first eyewitness to the occurrence); and the secondary data collection source (recorded events, books, and circumstance). As a result, the data's guarantee has well-known and accurate. The researcher would be certain of obtaining the data if he or she focused on the following points.

o Before collecting data, all source of population availability was checked.

o All questions and oral interviews were in simple and clear ways.

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CHAPTER FOUR

RESULTS AND DISCUSSIONS

This chapter had described the analysis and result of the questionnaire that has been used for the development of the models and every model had been analyzed and evaluated based on the signalized intersection, it has taken the questionnaire data from.

The models have developed based on the Multinomial Bayesian Network, where the models are; Immigration signalized intersection, Meskel-square signalized intersection, Mexico signalized intersection, and Piassa signalized intersection. It has added some additional information required to represent the geometric elements that address the safety evaluation.

4.1. General Characteristics of Safety Evaluation at the Signalized Intersection

Safety at signalized intersections had attempted to define to have asked experience and knowledge of traffic laws to some drivers, pedestrians, motorcyclists, and cyclists who had settled to know their degree of understanding of the safety at signalized intersections as well as acceptance of the rules at these areas; however, it was discovered that drivers did not always give priority to vehicles standing on the right side of the intersection.

Because of careless driving and disregard for traffic laws by pedestrians, motorcyclists, and cyclists, an accident may occur and even increase the causes of traffic accidents in an alarming number at the signalized intersection.

According to the Addis Ababa Police Commission report from 2015 to 2020 GC (2008-2012 EC), the number of accidents at signalized intersections has increased, as shown in the table below.

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Table 4.1. Traffic Accidents in Terms of Years, from Source of AAPC.

Signalized Intersection	Traffic Accidents in terms of year					Total	Percentage(%)
	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020		
Immigration	26	28	31	41	55	181	19
Meskel square	43	51	58	62	69	283	30
Mexico	38	41	45	55	68	247	26
Piassa	31	40	42	59	71	243	25
Total	138	160	176	217	263	954	100

4.1.1. Types of Traffic Accidents at a Signalized Intersection

The severity of the accidents that occurred at these four signalized intersections can be classified.

Only fatal injury, series injury, possible injury, and property damage are included in the severity classes (PDO). In all years, the number of traffic accidents has increased in all severity classes at Immigration signalizing intersection, Meskel square signalized intersection, Mexico signalized intersection, and Piassa signalized intersection.

Table 4.2. Yearly Traffic Accidents Based on Severity Class, From Source of AAPC.

Severity class	Yearly Traffic Accidents					Total	Percentage
	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020		
Fatal injury	18	14	16	29	39	116	1
Series injury	68	261	120	194	252	895	5
Possible injury	180	107	92	148	174	701	4
Property damage only	736	2,014	3,243	4,073	5,810	15,876	90
Total	1,002	2,396	3,471	4,444	6,275	17,588	100

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Table 4.3. Yearly Age of accident-causing drivers (2015/2016) based on Severity class, from source of AAPC.

Age of accident causing drivers(2015/2016)						
Number	Driver's Age	Damage caused by the accident				Total
		Death	Severe disability	Minor disability	Property damage	
1	Under 18 years of age	4	5	3	1	13
2	18-30 years	184	853	523	8,849	10,409
3	31-50 years	135	656	491	7,908	9,190
4	Over 51 years	73	323	97	2,466	2,959
5	Unknown	43	87	51	187	368
Total		439	1,924	1,165	19,411	22,939

Table 4.4. Yearly Age of accident-causing drivers (2016/2017) based on Severity class, from source of AAPC.

Age of accident causing drivers(2016/2017)						
Number	Driver's Age	Damage caused by the accident				Total
		Death	Severe disability	Minor disability	Property damage	
1	Under 18 years of age	6	58		3	67
2	18-30 years	208	897	422	11,335	12,862
3	31-50 years	112	764	407	8,879	10,162
4	Over 51 years	87	160	108	3,100	3,455
5	Unknown	50	117	36	193	396
Total		463	1,996	973	23,510	26,942

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Table 4.5. Yearly Age of accident-causing drivers (2017/2018) based on Severity class, from source of AAPC.

Age of accident causing drivers(2017/2018)						
Number	Driver's Age	Damage caused by the accident				Total
		Death	Severe disability	Minor disability	Property damage	
1	Under 18 years of age	8	32	48	448	536
2	18-30 years	150	816	533	9,749	11,248
3	31-50 years	171	774	342	10,206	11,493
4	Over 51 years	82	192	111	4,273	4,658
5	Unknown	48	89	40	252	429
Total		459	1,903	1,074	24,928	28,364

Table 4.6. Yearly Age of accident-causing drivers (2018/2019) based on Severity class, from source of AAPC.

Age of accident causing drivers(2018/2019)						
Number	Driver's Age	Damage caused by the accident				Total
		Death	Severe disability	Minor disability	Property damage	
1	Under 18 years of age	8	2	0	1	11
2	18-30 years	183	911	588	11,121	12,803
3	31-50 years	153	734	442	10,682	12,011
4	Over 51 years	30	178	80	3,923	4211
5	Unknown	84	101	33	292	510
Total		458	1,926	1,143	26,019	29,546

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Table 4.7 Yearly Age of accident-causing drivers (2019/2020) based on Severity class, from source of AAPC.

Age of accident causing drivers(2019/2020)						
Number	Driver's Age	Damage caused by the accident				Total
		Death	Severe disability	Minor disability	Property damage	
1	Under 18 years of age	9	65	12	7	93
2	18-30 years	188	881	477	11,520	13,066
3	31-50 years	168	728	340	11,004	12,240
4	Over 51 years	21	143	88	3,214	3,466
5	Unknown	65	100	25	275	465
Total		451	1,917	942	26,020	29,330

4.2. Questionnaire Analysis

The questionnaire analysis has gone in the direction of model development by addressing the questionnaire responders' responses and adding some information from sites that concern safety evaluation, and the objective has directly answered the research questions.

To begin, recall the affected factors that had been identified as having core parameters for the safety evaluation of the four signalized intersections, and there has been groundwork calculations to recognize the type of Bayesian networks to be used, and then it was fitted Multinomial Bayesian networks as the data's had been confirmed it has discrete data.

The variables are independent variables(nodes) or inputs to the models, and R software has used to operate the models in a distinctive manner. While thrice or fourth time's and even more had thoroughly checked the correctness of the variables and model fitness during the process by focused and payed attention about conditional independencies between random variables of the selected model to realize its a significant (which means if p-value is less than 0.05, it's significant) tells it's not fulfilled the assumption and has not reliable, where not significant (which means if p-value is greater than 0.05, it's not significant) tells it's fulfilled the assumption and has reliable. The signalized intersections that have been chosen were:

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    o   Immigration signalized intersection

    o   Meskel square signalized intersection

    o   Mexico signalized intersection

    o   Piassa signalized intersection

When it comes to obeying and following traffic laws at signalized intersections, users such as drivers, pedestrians, motorcyclists, and cyclists have openly defied, and their activities have directly impacted and harmed the safety of the intersection.

The priority rule at signalized intersections has perplexed drivers, motorcyclists, and cyclists, who appear to have no idea whether the priority rule has given the vehicles whose phase traffic lights have green at the signalized intersection or for the vehicles to run through red signal lights, but traffic lights may not function at times, which is the worst case scenario.

4.2.1. Bayesian Network Structure for Immigration Model

For the immigration model, conditional probability for the Bayesian Network node parameters (Multinomial Distribution).

Bayesian Network structure for Immigration Model

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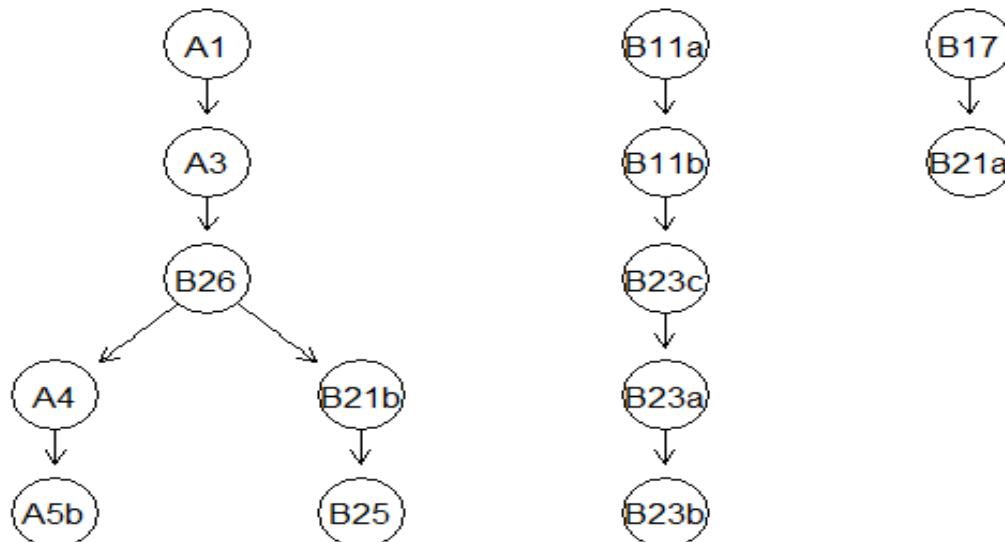
4.2.1.1. Immigration Model Explanation

As a result, the variables that approximate the person's age in the questionnaire are directly related to work experience, the frequency of crossing at the signalized intersection is directly related to how did the accident happen after impact, work experience in terms of year, and how did the accident happen after impact are both directly related to the speed of the arriver at the signalized intersection. Arrival speed at a signalized intersection is directly proportional to income level, and income level is proportional to education level.

The road condition is directly related to the weather, the weather is directly related to the light, the light is directly related to the time of the accident, and the time of the accident is directly related to the accident crash occurring during peak hour. The accident that occurs prior to impact is directly related to the details of the vehicle impact prior to the accident.

As specified in the model's ban list structure, education level, accident crash occurring during peak hour, and details of the impact on the vehicle up on accident are independent variables. The Immigration Model's Bayesian network structure had completely directed, which had allowed it, to fitted the parameters of local distributions in the way of conditional probability tables.

4.2.1.1.1. The Explanation of the Variables Based on Conditional Probabilities

Table 4.8. Education level.

Education level		Frequency	Percent
	None	10	10.4
	Primary level	11	11.5
	Secondary level	17	17.7
Valid	Diploma level	12	12.5
	Bachelor Degree level	21	21.9
	Master Degree level	19	19.8
	PHD Degree level	6	6.3
	Total	96	100.0

The majority of the respondent are bachelor degree level and master degree level which comprise of 21.90% and 19.80%. The least among the respondents is PhD level with 6.30%. Almost 50% of the respondents are educated from diploma level to PhD level, as shown Table 4.8.

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Table 4.9. Income level

Income level(ETB)		Frequency	Percent
Valid	$0	15	15.6
	$50-$150	38	39.6
	$150-$250	13	13.5
	$250-$500	21	21.9
	$500-more	2	9.4
	Total	96	100.0

With regard to income level, the majority of the respondent are income class of $50 to $150 and income class of $250 to $500 which comprises of 39.60% and 21.90%. The least among the respondents is income class with 9.40%. Almost 50% of the respondents are income classed from $50 to $150 income to $500 more. (see Table 4.9)

Table 4.10. Work experience

Work experience		Frequency	Percent
Valid	None	15	15.6
	1-3	3	3.1
	3-5	24	25.0
	5-10	40	41.7
	10-15	9	9.4
	15-more	5	5.2
	Total	96	100.0

With regard to work experience, majority of the respondents are those in experience of 5 years to 10 years which comprises of 25.00% and 41.70%. The least among the respondents is work experience class of 15 more years with 5.20%. Almost 50% of the respondent are experienced from 3-5 years to 15 more years. With this, it is likely that their responses are mostly acceptable referring from their experiences as shown in Table 4.10.

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Table 4.11. Response on slowing down in an intersection

Did you slow your speed when you approaching at the signalized intersection?		Frequency	Percent
Valid	Yes	72	75.0
	No	15	15.6
	Sometimes	9	9.4
	Total	96	100.0

With regard to the question on slowing speed when approaching a signalized intersection, majority of the respondent responded yes and no classes which comprises of 75.00% and 15.60%, respectively. The least among the respondents is sometimes class with 9.40%. Almost more than 70% of the respondents are used to slow their speed when approaching signalized intersection as shown in Table 4.11.

Table 4.12. Gender of the respondents.

Approximate sex of the person in the questionnaire		Frequency	Percent
Valid	Male	38	39.6
	Female	58	60.4
	Total	96	100.0

Majority of the respondents is female which comprises of 60.40% and least among the respondents is male with 39.60%. Almost 60% of the respondent are female.

Table 4.13. Approximate age of the person in the questionnaire.

Approximate age of the person in the questionnaire		Frequency	Percent
Valid	15-30	5	5.2
	30-40	33	34.4
	40-50	23	24.0
	50-60	28	29.2
	60-more	7	7.3
	Total	96	100.0

Majority of the respondents are 30-40 years of age classes and 50-60 years of age class which comprises of 34.40% and 29.20% respectively. (see Table 4.13). The least among the respondents is 15-30 years of age class with 5.20%. Almost 50% of the respondent are nearly old enough from 15-30 years' age class to 50-60 years' age class.

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Table 4.14. Responses on accident happen at the peak hour.

Did the accident happen at the peak hour time		Frequency	Percent
Valid	Yes	68	70.8
	No	28	29.2
	Total	96	100.0

With regard to the time when accident happen at the peak hour time, majority of the respondents answered yes which comprise of 70.80% and the least among the respondents responded no with 29.20%. This concluded that majority of the accidents happened during peak hours as shown in Table 4.14

Table 4.15. Specific time the accidents happen.

If yes, could you tell at what time did the accident happen		Frequency	Percent
Valid	8am-9am	44	45.8
	12pm-2pm	11	11.5
	5pm-7pm	14	14.6
	3pm-4pm	8	8.3
	10am-11am	19	19.8
	Total	96	100.0

Majority of the respondents stated that the accidents happened during peak hours between 8:00 to 9:00 in the morning and the rest happened during peak hours in the afternoon as shown in Table 4.15.

Table 4.16. Details of the impact to the vehicle upon the accident.

Please describe the details of the impact to the vehicle upon the accident.		Frequency	Percent
Valid	Hit in the rear, inside on the intersection	19	19.8
	Hit in the sides, inside the intersection	17	17.7
	Involving vehicles changing lanes, inside on the intersection	10	10.4
	Concert in collision, inside on the intersection	4	4.2
	Do not involved it	46	47.9
	Total	96	100.0

With regard to description details of the impact to the vehicle upon the accident, majority of the respondent responded that they did not involved in the accidents and hit in the rear inside on the

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intersection which comprise of 47.90% and 19.80%respectively as shown in Table 4.16. The least among the respondents is hit in the sides on the intersection with 4.20%. Almost 50% of the respondent are got accident at intersection from hit in the rear inside on the intersection to concert in collision inside on the intersection.

Table 4.17. Responses on how the accident happen, before impact.

How did the accident happen, before impact		Frequency	Percent
Valid	We were travelling	37	38.5
	We were trying to cross the intersection road	59	61.5
	Total	96	100.0

With regard to how did the accident happen before impact, majority of the respondent responded that they were trying to cross the intersection road (61.50%) and the least among the respondents (38.50% responded that they were travelling as shown in Table 4.17. Almost 50% of the respondent are pedestrian got incident.

Table 4.18. Responses on how the accident happen, after impact.

How did the accident happen, after impact		Frequency	Percent
Valid	Fatal injury, injury and property damage only	47	49.0
	Injury and property damage only	49	51.0
	Total	96	100.0

With regard to how did the accident happen after impact, the majority of the respondent are injury and property damage only which comprise of 51.00% and the least among the respondents is fatal injury, injury and property damage only 49.00%. Almost 50% of the respondent are responded that the accident resulted is injury and property damage only as shown in Table 4.18

Table 4.19. Weather conditions.

Weather conditions		Frequency	Percent
Valid	Sunny	28	29.2
	Rainy	56	58.3
	Foggy	12	12.5
	Total	96	100.0

Majority of the respondents answered that the weather condition during the accidents was rainy season which comprises of 58.30% and the sunny season was 29.20% as shown in Table 4.19. The least among the respondent is foggy with 12.50%.

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Table 4.20. Road conditions.

Road Conditions		Frequency	Percent
Valid	Dry	33	34.4
	Wet	63	65.6
	Total	96	100.0

As shown in Table 4.20, the road condition was wet when the accident happened as responded by more than half of the respondents.

Table 4.21. Light conditions.

Light conditions		Frequency	Percent
Valid	Bright	76	79.2
	Dark	20	20.8
	Total	96	100.0

Majority of the respondents, (79.20%) answered that the accident happened during daytime where the light condition was bright.

Table 4.22. Factors affecting safety of the signalized intersection.

What are the factors affecting safety of the signalized intersection		Frequency	Percent
Valid	Geometric design of the intersection	26	27.1
	Traffic congestion	23	24.0
	Non-properly functioning traffic lights	9	9.4
	Road side elements	20	20.8
	Pedestrian	18	18.8
	Total	96	100.0

With almost the same percentages of responses, they agreed that geometric design of intersection, traffic congestion, road side elements and pedestrian with 27.10%, 24.00%, 20.80%, and 18% respectively, as shown in Table 4.22, are the common factors that affect the safety of signalized intersection. The least response comes from non-properly functioning traffic lights with 9%.

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Table 4.23. What is the frequency of your crossing at the signalized intersection?

What is the frequency of your crossing at the signalized intersection		Frequency	Percent
Valid	Regularly	80	83.3
	Occasionally	12	12.5
	Rarely	4	4.2
	Total	96	100.0

Majority of the respondent are regularly and occasionally crossing an intersection which comprise of 83.30% and 12.50% respectively. The least among the respondents is rarely crossing with 4.20%.

Table 4.24. Speed when approaching at signalized intersection.

What speed were you driving when approaching at the signalized intersection, if you were the driver or if you were pedestrian or eye witness can you tell (Km/hrs.)		Frequency	Percent
Valid	35-45 Kph	14	14.6
	45-55 Kph	45	46.9
	55-65 Kph	35	36.5
	65-above Kph	2	2.1
	Total	96	100.0

With regard to the speed when approaching at the signalized intersection, majority of the respondent responded a speed of 45-55 Kph and 55-65 Kph which comprise of 46.90% and 36.50% respectively. The least among the respondents is 65-above class speed with 2.10%.

4.2.1.3. Checking Reliability and Model Fitting

The safety evaluation of the immigration signalized intersection model had reliable and fitted. It has checked in a way of the testament of the nodes(variables) by focused the conditional independencies between random variables of the selected model to their significance (meant if p-value is less than 0.05, it's significant) tells it's not fulfilled the assumption and has not reliable, where not-significant (meant if p-value is greater than 0.05, it's not significant) tells it's fulfilled the assumption and has fitted and reliable.

Conditional independence tests for discrete data has worked in way the conditional probability tables implied by the graphical structure of the network through the observed frequencies $\{n_{ijk}, i = 1, ..., R, j = 1, ..., C, k = 1, ..., L\}$ for the random variables X and Y and all the configurations of the conditioning variables Z. It's also confirms that the structure of a BN encodes a set of conditional

independencies between random variables, X = (X1, X2, ..., Xn), which can be used to represent the joint distribution in compact factored form, while followed the Markov assumption, which states that each node is conditionally independent of its non-descendants (nodes that are not parents) in the network, given the value of its parent nodes. The rest see it in appendix. The conditional independencies between random variables of B25 to A3 given B21b are not significant, as shown in appendix b. [X_{cal}^2 = 22.987, P_{value} = 0.5205].

4.2.2. Bayesian Network Structure for Meskel square Model

Bayesian Network structure for Meskel Model
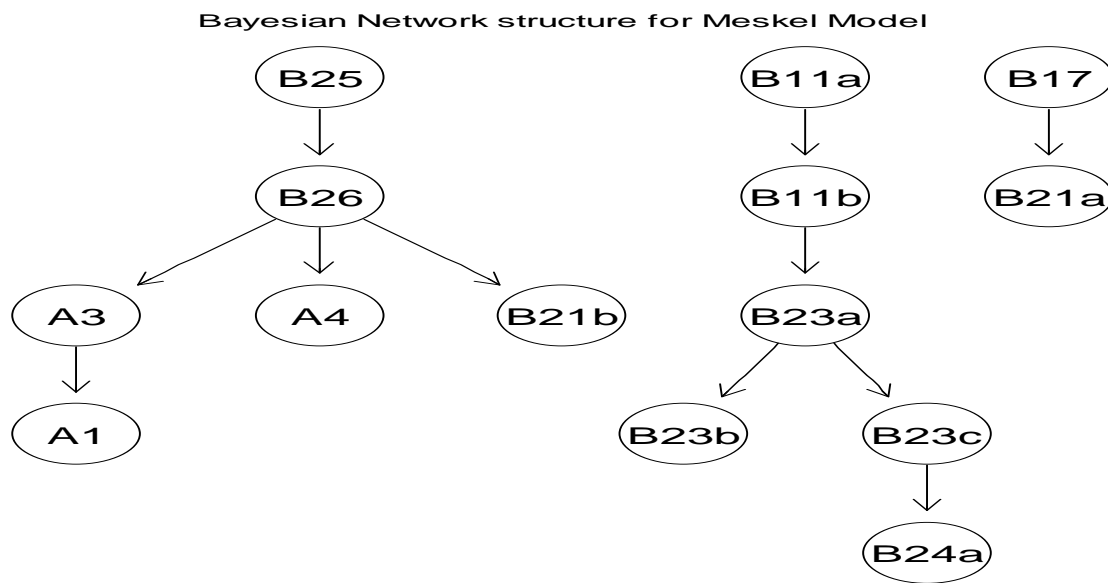
4.2.2.2. Meskel-square Model Explanation

As a result, the variables that education level is directly related to work experience, the work experience is directly related to speed when approaching at signalized intersection, work experience is directly influenced to speed when approaching at signalized intersection, while responses on how accident happen before impact is connected to speed when approaching at signalized intersection and speed when approaching at signalized intersection is connected to frequency crossing of the respondents at signalized intersection.

Responses on how accident happen after impact is connected to details of the impact to the vehicle upon the accident. Factors affecting safety of the signalized intersection is directly being influenced

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to light condition and the light and road conditions are influenced by weather condition is connected to specific time the accident happens is also linked to responses on accident happen at the peak hour.

The road condition is directly related to the weather, the weather is directly related to the light, the light is directly related to the time of the accident, and the time of the accident is directly related to the accident crash occurring during peak hour. The accident that occurs prior to impact is directly related to the details of the vehicle impact prior to the accident. As specified in the model's ban list structure, education level, accident crash occurring during peak hour, and details of the impact on the vehicle up on accident are independent variables.

4.2.2.2.1. The Explanation of the Variables Based on Conditional Probabilities

Table 4.25. Education level.

Education level		Frequency	Percent
Valid	None	8	8.2
	Primary level	9	9.3
	Secondary level	11	11.3
	Diploma level	14	14.4
	Bachelor Degree level	21	21.6
	Master Degree level	26	26.8
	PHD Degree level	8	8.2
	Total	97	100.0

The majority of the respondent are master degree level and bachelor degree level which comprise of 26.80% and 21.60%. The least among the respondents is PhD level with 8.20%. Almost 50% of the respondents are educated from diploma level to PhD level. This will give an intelligent response on the subject matter of the research.

Table 4.26. Income level.

Income level		Frequency	Percent
Valid	$0	14	14.4
	$50-$150	29	29.9
	$150-$250	23	23.7
	$250-$500	17	17.5
	$500-more	14	14.4
	Total	97	100.0

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With regard to income level, the majority of the respondent are income class of $50 to $150 and income class of $150 to $250 which comprises of 29.90% and 23.70%. The least among the respondents is $500 to more income class with 14.40%. Almost 50% of the respondents are income classed from $50 to $150 income to 150 to $250. (see Table 4.26)

Table 4.27. Work experience.

Work experience(in terms of year)		Frequency	Percent
Valid	None	14	14.4
	3-5	31	32.0
	5-10	39	40.2
	10-15	11	11.3
	15-more	2	2.0
	Total	97	100.0

With regard to work experience, the majority of the respondents are those in experience of 5 years to 10 years which comprises of 32.00% and 40.20%. The least among the respondents is work experience class of 15 more years with 2.00%. Almost 50% of the respondent are experienced from 3-5 years to 15 and more years. With this, it is likely that their responses are mostly acceptable referring from their experiences as shown in Table 4.27.

Table 4.28. Response on slowing down in an intersection

Did you slow your speed when you approaching at the signalized intersection?		Frequency	Percent
Valid	Yes	72	75.0
	No	15	15.6
	Sometimes	9	9.4
	Total	96	100.0

With regard to the question on slowing speed when approaching a signalized intersection, majority of the respondent responded yes and no classes which comprises of 75.00% and 15.60%, respectively. The least among the respondents is sometimes class with 9.40%. Almost more than 70% of the respondents are used to slow their speed when approaching signalized intersection as shown in Table 4.28.

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Table 4.29. Gender of the respondents.

Approximate gender of the person in the questionnaire		Frequency	Percent
Valid	Male	41	42.3
	Female	56	57.7
	Total	97	100.0

Majority of the respondents is female which comprises of 57.70% and least among the respondents is male with 42.30%. Almost 50% of the respondent are female.

Table 4.30. Approximate age of the person in the questionnaire.

Approximate age of the person in the questionnaire		Frequency	Percent
Valid	15-30	1	1.0
	30-40	31	32.0
	40-50	26	26.8
	50-60	34	35.1
	60-more	5	5.2
	Total	97	100.0

Majority of the respondents are 50-60 years of age classes and 30-40 years of age class which comprises of 35.10% and 32.00% respectively. (see Table 4.30). The least among the respondents is 15-30 years of age class with 5.20%. Almost 50% of the respondent are nearly old enough from 30-40 years' age class to 60-more years' age class.

Table 4.31. Responses on accident happen at the peak hour

Did an accident crash happen at the peak hour time		Frequency	Percent
Valid	Yes	74	76.3
	No	23	23.7
	Total	97	100.0

With regard to the time when accident happen at the peak hour time, majority of the respondents answered yes which comprise of 76.30% and the least among the respondents responded no with 23.70%. This concluded that majority of the accidents happened during peak hours as shown in Table 4.31.

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Table 4.32. Specific time the accidents happen.

If yes, could you tell at what time did the accident happen		Frequency	Percent
Valid	8am-9am	23	23.7
	12pm-2pm	19	19.6
	5pm-7pm	32	33.0
	3pm-4pm	8	8.2
	10am-11am	15	15.5
	Total	97	100.0

Majority of the respondents stated that the accidents happened during peak hours between 5:00 to 7:00 in the evening and the rest happened during peak hours in the afternoon as shown in Table 4.32.

Table 4.33. Details of the impact to the vehicle upon the accident.

Please describe the details of the impact to the vehicle upon the accident		Frequency	Percent
Valid	Hit in the rear, inside on the intersection	34	35.1
	Hit in the sides, inside on the intersection	17	17.5
	Involving vehicles changing lanes, inside on the intersection	1	1.0
	Concert in collision, inside on the intersection	1	1.0
	Do not involved it	44	45.4
	Total	97	100.0

With regard to description details of the impact to the vehicle upon the accident, majority of the respondent responded that they did not involve in the accidents and hit in the rear inside on the intersection which comprise of 45.40% and 35.10% respectively as shown in Table 4.33. The least among the respondents is concert in collision, inside on the intersection with 1.00%. Almost 50% of the respondent are got accident at intersection from hit in the rear inside on the intersection to concert in collision inside on the intersection.

Table 4.34. Responses on how the accident happen, before impact.

How did the accident happen, before impact		Frequency	Percent
Valid	They were travelling	5	5.2
	We were travelling	47	48.5
	We were trying to cross the intersection road	45	46.4
	Total	97	100.0

With regard to how did the accident happen before impact, majority of the respondent responded that we were travelling and We were trying to cross the intersection road which comprises of

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48.50% and 46.40%. The least among the respondents (5.20%) responded that they were travelling as shown in Table 4.34. Almost 50% of the respondent are passengers got incident.

Table 4.35. Responses on how the accident happen, after impact.

	How did the accident happen, after impact	Frequency	Percent
Valid	Fatal injury, injury and property damage only	65	67.0
	Injury and property damage only	31	32.0
	Property damage only	1	1.0
	Total	97	100.0

With regard to how did the accident happen after impact, the majority of the respondent are fatal injury, injury and property damage only and injury and property damage only which comprises of 67.00% and 32.00%. The least among the respondents is property damage only with 1.00%. Almost 60% of the respondent are responded that the accident resulted is fatal injury, injury and property damage only as shown in Table 4.35.

Table 4.36. Weather conditions.

	Weather conditions	Frequency	Percent
Valid	Sunny	57	58.8
	Rainy	26	26.8
	Foggy	14	14.4
	Total	97	100.0

Majority of the respondents answered that the weather condition during the accidents was sunny season which comprises of 58.80% and the rainy season was 26.80% as shown in Table 4.36. The least among the respondent is foggy with 14.40%.

Table 4.37. Road Conditions.

	Road Conditions	Frequency	Percent
Valid	Dry	57	58.8
	Wet	40	41.2
`	Total	97	100.0

As shown in Table 4.37, the road condition was dry when the accident happened as responded by more than half of the respondents.

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Table 4.38. Light conditions.

	Light condition	Frequency	Percent
	Bright	62	63.9
Valid	Dark	35	36.1
	Total	97	100.0

Majority of the respondents, (63.90%) answered that the accident happened during daytime where the light condition was bright.

Table 4.39. Factors affecting safety of the signalized intersection.

What are the factors affecting safety of the signalized intersection		Frequency	Percent
	Geometric design of the intersection	46	47.4
	Traffic congestion	8	8.2
Valid	Non-properly functioning traffic lights	19	19.6
	Road side elements	10	10.3
	Pedestrian	14	14.4
	Total	97	100.0

With almost 50% of the respondents agreed that geometric design of the intersection, non-properly functioning traffic lights, pedestrian and road side elements with 47.40%, 19.60%, and 14.40% respectively, as shown Table 4.39 are the common factors that affect the safety of signalized intersection. The least response comes from traffic congestion with 8.20%.

Table 4.40. What is the frequency of your crossing at the signalized intersection?

What is the frequency of your crossing at the signalized intersection		Frequency	Percent
	Regularly	80	82.5
Valid	Occasionally	15	15.5
	Rarely	2	2.1
	Total	97	100.0

Majority of the respondent are regularly and occasionally crossing an intersection which comprise of 82.50% and 15.50% respectively. The least among the respondents is rarely crossing with 2.10%.

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Table 4.41. Speed when approaching at signalized intersection.

What speed were you driving when approaching at the signalized intersection, if you were the driver or if you were pedestrian or eye witness can you tell (Km/hrs.)		Frequency	Percent
	35-45 Kph	12	12.4
	45-55 Kph	43	44.3
Valid	55-65 Kph	40	41.2
	65-above Kph	2	2.1
	Total	96	100.0

With regard to the speed when approaching at the signalized intersection, majority of the respondent responded a speed of 45-55 Kph and 55-65 Kph which comprise of 44.30% and 41.20% respectively. The least among the respondents is 65-above class speed with 2.10%.

4.2.3.3. Checking Reliability and Model Fitting

The safety evaluation of the Meskel-square signalized intersection model had reliable and fitted. It has checked in a way of the testament of the nodes(variables) by focused the conditional independencies between random variables of the selected model to their significance (meant if p-value is less than 0.05, it's significant) tells it's not fulfilled the assumption and has not reliable, where not-significant (meant if p-value is greater than 0.05, it's not significant) tells it's fulfilled the assumption and has fitted and reliable.

Conditional independence tests for discrete data has worked in way the conditional probability tables implied by the graphical structure of the network through the observed frequencies $\{n_{ijk}, i = 1, ..., R, j = 1, ..., C, k = 1, ..., L\}$ for the random variables X and Y and all the configurations of the conditioning variables Z. It's also confirms that the structure of a BN encodes a set of conditional independencies between random variables, X = (X1, X2, ..., Xn), which can be used to represent the joint distribution in compact factored form, while followed the Markov assumption, which states that each node is conditionally independent of its non-descendants (nodes that are not parents) in the network, given the value of its parent nodes. See further in appendix b.

The conditional independencies between variables of A3 to B25 given is not significant [$X_{cal}^2 = 13.542$, $P_{value} = 1$].

data: A3 ~ B25 | A1
mi = 13.542, df = 56, p-value = 1
alternative hypothesis: true value is greater than 0

4.2.3. Bayesian Network Structure for Mexico Model

Bayesian Network structure for Mexico Model
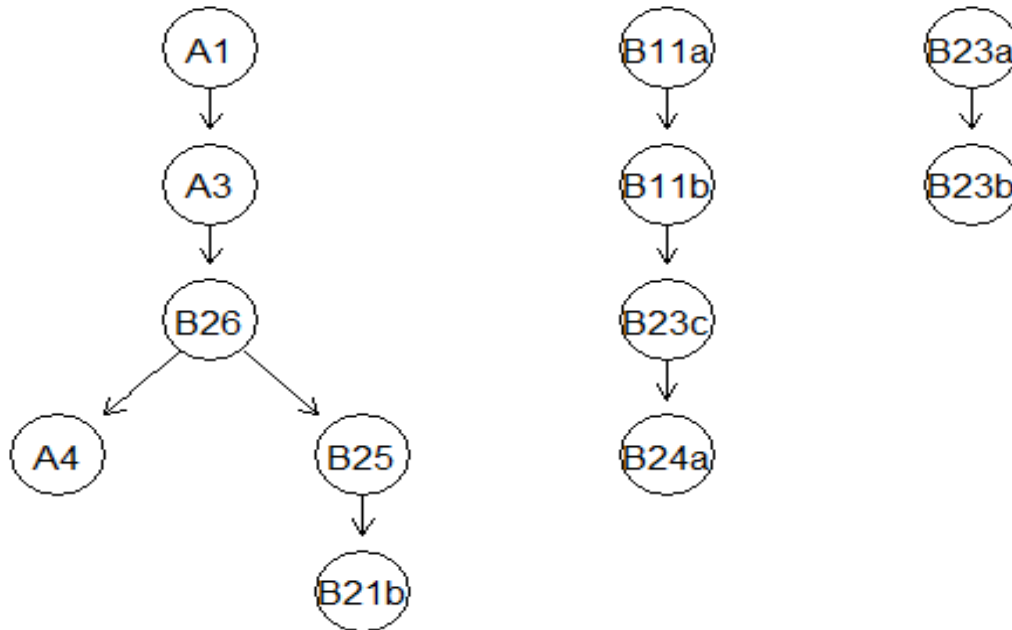
4.2.3.2. Mexico Model Explanation

In the result, the variables of this Mexico signalized intersection were arranged as tabular forms and the meaning of each table were attached it is probability conditional explanation to ease the way of understanding and enable the node structures of the model get meaning has given for their enhancement and strengths based on the dependence and independence variables in the node structure.

As a result, the variables that work experience is directly related to speed when approaching at signalized intersection while responses on how accident happen before impact is connected to frequency crossing of the respondents at signalized intersection and both work experience and frequency crossing of the respondents at signalized intersection is influenced by speed when approaching at signalized intersection and its connected to income level which linked to education level.

Factors affecting safety of the signalized intersection is directly being influenced to light condition and the light is influenced by specific time the accident happens is also linked to responses on accident happen at the peak hour. While road condition is influenced by weather conditions.

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4.2.3.2.1. The Explanation of the Variables Based on Conditional Probabilities

Table 4.42. Education level.

Education level		Frequency	Percent
Valid	None	10	10.4
	Primary level	9	9.4
	Secondary level	13	13.5
	Diploma level	14	14.6
	Bachelor Degree level	20	20.8
	Master Degree level	21	21.9
	PHD Degree level	9	9.4
	Total	96	100.0

The majority of the respondent are master degree level and bachelor degree level which comprise of 21.90% and 20.80%. The least among the respondents is PhD level with 9.40%. Almost 50% of the respondents are educated from diploma level to PhD level. (see Table 4.42)

Table 4.43. Income level.

Income level		Frequency	Percent
Valid	$0	16	16.7
	$50-$150	31	32.3
	$150-$250	19	19.8
	$250-$500	18	18.8
	$500-more	12	12.5
	Total	96	100.0

With regard to income level, the majority of the respondent are income class of $50 to $150 and income class of $150 to $250 which comprises of 32.30% and 19.80%. The least among the respondents is $500 to more income class with 12.50%. Almost 50% of the respondents are income classed from $50 to $150 income to 150 to $250. (see Table 4.43)

Table 4.44. Work experience.

Work experience(in terms of year)		Frequency	Percent
Valid	None	16	16.7
	1-3	3	3.1
	3-5	26	27.1
	5-10	43	44.8

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10-15	3	3.1
15-more	5	5.2
Total	96	100.0

With regard to work experience, the majority of the respondents are those in experience of 5 years to 10 years which comprises of 27.10% and 44.80%. The least among the respondents is work experience class of 10 to 15 years with 3.10%. Almost 50% of the respondent are experienced from 3-5 years to 15 and more years. With this, it is likely that their responses are mostly acceptable referring from their experiences as shown in Table 4.44.

Table 4.45. Responses on slowing down in an intersection.

Did you slow your speed when you approaching at the signalized intersection		Frequency	Percent
	Yes	69	71.9
Valid	No	16	16.7
	Sometimes	11	11.5
	Total	96	100.0

With regard to the question on slowing speed when approaching a signalized intersection, majority of the respondent responded yes and no classes which comprises of 71.90% and 16.70%, respectively. The least among the respondents is sometimes class with 11.50%. Almost more than 70% of the respondents are used to slow their speed when approaching at the signalized intersection as shown in Table 4.45.

Table 4.46. Gender of the respondents.

Approximate gender of the person in the questionnaire		Frequency	Percent
	Male	30	31.3
Valid	Female	66	68.7
	Total	96	100.0

Majority of the respondents is female which comprises of 68.70% and least among the respondents is male with 31.30%. Almost 50% of the respondent are female.

Table 4.47. Approximate age of the person in the questionnaire.

Approximate age of the person in the questionnaire		Frequency	Percent
	15-30	2	2.1
	30-40	33	34.4
Valid	40-50	18	18.8
	50-60	40	41.7

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	60-more	3	3.1
	Total	96	100.0

Majority of the respondents are 50-60 years of age classes and 30-40 years of age class which comprises of 41.70% and 34.40% respectively. (see Table 4.47). The least among the respondents is 15-30 years of age class with 2.10%. Almost 50% of the respondent are nearly old enough from 30-40 years' age class to 60-more years' age class.

Table 4.48. Responses on accident happen at the peak hour.

Did an accident happen at the peak hour time		Frequency	Percent
Valid	Yes	72	75.0
	No	24	25.0
	Total	96	100.0

With regard to the time when accident happen at the peak hour time, majority of the respondents answered yes which comprise of 75.00% and the least among the respondents responded no with 25.50%. This concluded that majority of the accidents happened during peak hours as shown in Table 4.48.

Table 4.49. Specific time the accidents happen.

If yes, could you tell at what time did the accident happen		Frequency	Percent
Valid	8am-9am	16	16.7
	12pm-2pm	31	32.3
	5pm-7pm	25	26.0
	3pm-4pm	14	14.6
	10am-11am	10	10.4
	Total	96	100.0

Majority of the respondents stated that the accidents happened during peak hours between 12:00 to 2:00 in the lunch time and the rest happened during peak hours in the afternoon as shown in Table 4.49.

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Table 4.50. Details of the impact to the vehicle upon the accident.

Please describe the details of the impact to the vehicle upon the accident		Frequency	Percent
Valid	Hit in the rear, inside on the intersection	25	26.0
	Hit in the sides, inside on the intersection	12	12.5
	Involving vehicles changing lanes, inside on the intersection	28	29.2
	Concert in collision, inside on the intersection	3	3.1
	Do not involved it	28	29.2
	Total	96	100.0

With regard to description details of the impact to the vehicle upon the accident, majority of the respondent responded that involving vehicles changing lanes, inside on the intersection and hit in the rear inside on the intersection which comprise of 29.20% and 26.00% respectively as shown in Table 4.50. The least among the respondents is concert in collision, inside on the intersection with 3.10%. Almost 50% of the respondent are got accident at intersection from hit in the rear inside on the intersection to concert in collision inside on the intersection.

Table 4.51. Responses on how the accident happen, before impact.

How did the accident happen, before impact		Frequency	Percent
Valid	They were travelling	5	5.2
	We were travelling	40	41.7
	We were trying to cross the intersection road	51	52.0
	Total	96	100.0

With regard to how did the accident happen before impact, majority of the respondent responded that We were trying to cross the intersection road and we were travelling which comprises of 52.00% and 41.70%. The least among the respondents (5.20%) responded that they were travelling as shown in Table 4.51. Almost 50% of the respondent are pedestrian got incident.

Table 4.52. Responses on how the accident happen, after impact.

How did the accident happen, after impact		Frequency	Percent
Valid	Fatal injury, injury and property damage only	42	43.7
	Injury and property damage only	54	56.3
	Total	96	100.0

With regard to how did the accident happen after impact, the majority of the respondent is injury and property damage only with 56.30% and the least among the respondents is Fatal injury, injury and

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property damage only with 43.70%. Almost 50% of the respondent are responded that the accident resulted is injury and property damage only as shown in Table 4.52.

Table 4.53. Weather conditions.

Weather conditions		Frequency	Percent
Valid	Sunny	12	12.5
	Rainy	74	77.1
	Foggy	10	10.4
	Total	96	100.0

Majority of the respondents answered that the weather condition during the accidents was rainy season which comprises of 77.10% and the sunny season was 12.50% as shown in Table 4.53. The least among the respondent is foggy with 10.40%.

Table 4.54. Road Conditions.

Road Conditions		Frequency	Percent
Valid	Dry	13	13.5
	Wet	83	86.5
	Total	96	100.0

As shown in Table 4.54, the road condition was wet when the accident happened as responded by more than half of the respondents.

Table 4.55. Light condition.

Light condition		Frequency	Percent
Valid	Bright	67	69.8
	Dark	29	30.2
	Total	96	100.0

Majority of the respondents, (69.80%) answered that the accident happened during daytime where the light condition was bright.

Table 4.56. Factors affecting safety of the signalized intersection.

What are the factors affecting safety of the signalized intersection		Frequency	Percent
Valid	Geometric design of the intersection	23	24.0
	Traffic congestion	27	28.1
	Non-properly functioning traffic lights	8	8.3

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Road side elements	15	15.6
Pedestrian	23	24.0
Total	96	100.0

With almost the same percentages of responses, they agreed that traffic congestion, geometric design of intersection, pedestrian and road side elements with 28.10%, 24.00%,24.00% and 15.60% respectively, as shown in Table 4.56, are the common factors the affect the safety of signalized intersection. The least response comes from non-properly functioning traffic lights with 8.30%.

Table 4.57. What is the frequency of your crossing at the signalized intersection?

What is the frequency of your crossing at the signalized intersection		Frequency	Percent
Valid	Regularly	80	83.3
	Occasionally	15	15.6
	Rarely	1	1.0
	Total	96	100.0

Majority of the respondent are regularly and occasionally crossing an intersection which comprise of 83.30% and 15.60% respectively. The least among the respondents is rarely crossing with 1.00%.

Table 4.58. Speed when approaching at the signalized intersection.

What speed were you driving when you are approaching at the signalized intersection, if you were the driver or if you were pedestrian or eye witness can you tell (Km/hrs.)		Frequency	Percent
Valid	35-45 Kph	23	24.0
	45-55 Kph	30	31.3
	55-65 Kph	37	38.5
	65-above Kph	6	6.3
	Total	96	100.0

With regard to the speed when approaching at the signalized intersection, majority of the respondent responded a speed of 55-65 Kph and 45-55 Kph which comprise of 38.50% and 31.30% respectively. The least among the respondents is 65-above class speed with 6.30%.

4.2.3.3. Checking Reliability and Model Fitting

The safety evaluation of the Mexico signalized intersection model had reliable and fitted. It has checked in a way of the testament of the nodes(variables) by focused the conditional independencies between random variables of the selected model to their significance (meant if p-value is less than

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0.05, it's significant) tells it's not fulfilled the assumption and has not reliable, where not-significant (meant if p-value is greater than 0.05, it's not significant) tells it's fulfilled the assumption and has fitted and reliable.

Conditional independence tests for discrete data has worked in way the conditional probability tables implied by the graphical structure of the network through the observed frequencies $\{n_{ijk}, i = 1, \dots, R, j = 1, \dots, C, k = 1, \dots, L\}$ for the random variables X and Y and all the configurations of the conditioning variables Z. It's also confirms that the structure of a BN encodes a set of conditional independencies between random variables, X = (X1, X2, ..., Xn), which can be used to represent the joint distribution in compact factored form, while followed the Markov assumption, which states that each node is conditionally independent of its non-descendants (nodes that are not parents) in the network, given the value of its parent nodes. See the appendix b.

The conditional independencies between variables of B21b to B26 given B25 is not significant [X_{cal}^2 = 0.83035, P_{value} = 1].

data: B21b ~ B26 | B25
mi = 0.83035, df = 12, p-value = 1
alternative hypothesis: true value is greater than 0

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4.2.4. Bayesian Network Structure for Piassa Model

As a result, the variables of this Piassa signalized intersection had been arranged as tabular forms, and the interpretation of each table has been attached it is probability conditional explanation to ease the way of understanding and facilitate the model's node structures provide meaning has given for their enhancement and strengths based on the dependence and independence variables in the node structure.

Bayesian Network structure for Piassa Model
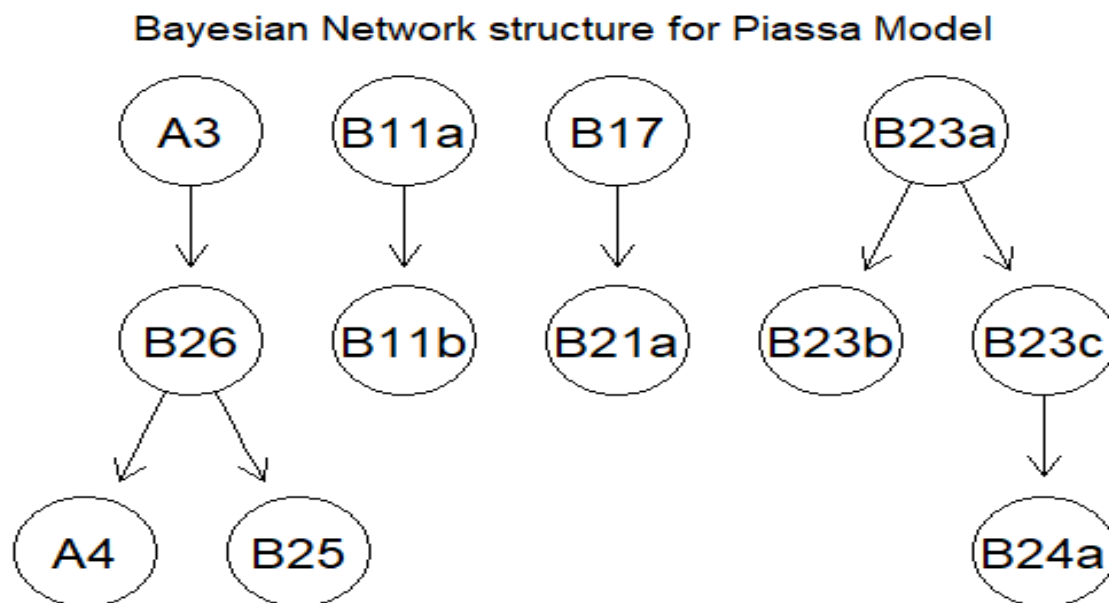
4.2.4.1. Piassa Model Explanation

In the result, the variables of this Piassa signalized intersection were arranged as tabular forms and the meaning of each table were attached it is probability conditional explanation to ease the way of understanding and enable the node structures of the model get meaning has given for their enhancement and strengths based on the dependence and independence variables in the node structure.

As a result, the variables that work experience and frequency crossing of the respondents at signalized intersection are directly related to speed when approaching at signalized intersection while speed when approaching at signalized intersection influenced by income level.

Specific time the accident happens is also influenced by responses on accident happen at the peak hour. Responses on how accident happen after impact is connected to details of the impact to the vehicle upon accident. Factors affecting safety of the signalized intersection is directly being

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influenced to light condition and the light condition and road condition are influenced by specific weather conditions.

4.2.4.2.1. The Explanation of the Variables Based on Conditional Probabilities

Table 4.59. Education level.

Education level		Frequency	Percent
Valid	None	2	2.1
	Primary level	11	11.5
	Secondary level	25	26.0
	Diploma level	20	20.8
	Bachelor Degree level	26	27.1
	Master Degree level	11	11.5
	PHD Degree level	1	1.0
	Total	96	100.0

Majority of the respondents are bachelor degree level and secondary level which comprise of 27.10% and 26.00%. The least among the respondents is PhD level with (1.00%). Almost 50% of the respondent are educated from secondary level to Master degree level as shown Table 4.59

Table 4.60. Income level.

Income level		Frequency	Percent
Valid	$0	18	18.8
	$50-$150	48	50.0
	$150-$250	13	13.5
	$250-$500	10	10.4
	$500-more	7	7.3
	Total	96	100.0

With regard to income level, the majority of the respondent are income class of $50 to $150 and income class of $150 to $250 which comprises of 50.00% and 13.50%. The least among the respondents is $500-more income class with 7.30%. Almost 60% of the respondents are income classed from $50 to $150 income to 150 to $250. (see Table 4.60).

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Table 4.61. Work experience

Work experience		Frequency	Percent
Valid	None	15	15.6
	1-3	3	3.1
	3-5	24	25.0
	5-10	40	41.7
	10-15	9	9.4
	15-more	5	5.2
	Total	96	100.0

With regard to work experience, majority of the respondents are those in experience of 5 years to 10 years which comprises of 25.00% and 41.70%. The least among the respondents is work experience class of 15 more years with 5.20%. Almost 50% of the respondent are experienced from 3-5 years to 15 more years. With this, it is likely that their responses are mostly acceptable referring from their experiences as shown in Table 4.61.

Table 4.62. Response on slowing down in an intersection

Did you slow your speed when you approaching at the signalized intersection?		Frequency	Percent
Valid	Yes	67	69.8
	No	16	16.7
	Sometimes	13	13.5
	Total	96	100.0

With regard to the question on slowing speed when approaching a signalized intersection, majority of the respondent responded yes and no classes which comprises of 69.80% and 16.70%, respectively. The least among the respondents is sometimes class with 13.50%. Almost more than 60% of the respondents are used to slow their speed when approaching signalized intersection as shown in Table 4.62.

Table 4.63. Gender of the respondents.

Approximate sex of the person in the questionnaire		Frequency	Percent
Valid	Male	68	70.8
	Female	28	29.2
	Total	96	100.0

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Majority of the respondents is male which comprises of 70.80% and least among the respondents is female with 29.20%. Almost 70% of the respondent are male.

Table 4.64. Approximate age of the person in the questionnaire.

Approximate age of the person in the questionnaire		Frequency	Percent
Valid	15-30	6	6.3
	30-40	55	57.3
	40-50	15	15.6
	50-60	14	14.6
	60-more	6	6.3
	Total	96	100.0

Majority of the respondents are 30-40 years of age classes and 40-50 years of age class which comprises of 57.30% and 15.60% respectively. (see Table 4.64). The least among the respondents is 15-30 years of age class with 6.30%. Almost 70% of the respondent are nearly old enough from 15-30 years' age class to 50-60 years' age class.

Table 4.65. Responses on accident happen at the peak hour.

Did an accident happen at the peak hour time		Frequency	Percent
Valid	Yes	65	67.7
	No	31	32.3
	Total	96	100.0

With regard to the time when accident happen at the peak hour time, majority of the respondents answered yes which comprise of 67.70% and the least among the respondents responded no with 32.30%. This concluded that majority of the accidents happened during peak hours as shown in Table 4.65.

Table 4.66. Specific time the accidents happen

If yes, could you tell at what time did the accident happen		Frequency	Percent
Valid	8am-9am	17	17.7
	12pm-2pm	13	13.5
	5pm-7pm	35	36.5
	3pm-4pm	22	22.9
	10am-11am	9	9.4

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	Total	96	100.0

Majority of the respondents stated that the accidents happened during peak hours between 5:00 to 7:00 in the evening time and the rest happened during peak hours in the morning as shown in Table 4.66.

Table 4.67. Details of the impact to the vehicle upon the accident.

Please describe the details of the impact to the vehicle upon the accident		Frequency	Percent
Valid	Hit in the rear, inside on the intersection	18	18.8
	Hit in the sides, inside on the intersection	14	14.6
	Involving vehicles changing lanes, inside on the intersection	17	17.7
	Concert in collision, inside on the intersection	4	4.2
	Do not involved it	17	17.7
	Hit us on the intersection	26	27.1
	Total	96	100.0

With regard to description details of the impact to the vehicle upon the accident, majority of the respondent responded that Hit us on the intersection and hit in the rear inside on the intersection which comprise of 27.10% and 18.80% respectively as shown in Table 4.67. The least among the respondents is concert in collision, inside on the intersection with 4.20%. Almost 50% of the respondent are got accident at intersection from hit in the rear inside on the intersection to Hit us on the intersection.

Table 4.68. Responses on how the accident happen, before impact.

How did the accident happen, before impact		Frequency	Percent
Valid	I was controlling the traffic	12	12.5
	They were travelling	2	2.1
	We were controlling the traffic	7	7.3
	We were travelling	31	32.3
	We were trying to cross the intersection road	44	45.8
	Total	96	100.0

With regard to how did the accident happen before impact, majority of the respondent responded that We were trying to cross the intersection road and we were travelling which comprises of 45.80% and

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32.30%. The least among the respondents (2.10%) responded that they were travelling as shown in Table 4.68. Nearly 50% of the respondent are pedestrian got incident.

Table 4.69. Responses on how the accident happen, after impact.

	How did the accident happen, after impact	Frequency	Percent
	Fatal injury, injury and property damage only	51	53.1
Valid	Injury and property damage only	42	43.8
	Property damage only	3	3.1
	Total	96	100.0

With regard to how did the accident happen after impact, the majority of the respondent is fatal injury, injury and property damage only with 53.10% and 43.80%. The least among the respondents is property damage only with 3.10%. Almost 50% of the respondent are responded that the accident resulted is fatal injury, injury and property damage only as shown in Table 4.69

Table 4.70. Weather conditions.

	Weather conditions	Frequency	Percent
	Sunny	39	40.6
Valid	Rainy	45	46.9
	Foggy	12	12.5
	Total	96	100.0

Majority of the respondents answered that the weather condition during the accidents was rainy season which comprises of 46.90% and the sunny season was 40.60% as shown in Table 4.70. The least among the respondent is foggy with 12.50%.

Table 4.71. Road Conditions.

	Road Conditions	Frequency	Percent
Valid	Dry	39	40.6
	Wet	57	59.4
	Total	96	100.0

As shown in Table 4.71, the road condition was wet when the accident happened as responded by more than half of the respondents.

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Table 4.72. Light conditions.

Light conditions		Frequency	Percent
Valid	Bright	71	74.0
	Dark	25	26.0
	Total	96	100.0

Majority of the respondents, (74.00%) answered that the accident happened during daytime where the light condition was bright.

Table 4.73. Factors affecting safety at signalized intersection.

What are the factors affecting safety at signalized intersection		Frequency	Percent
Valid	Geometric design of the intersection	32	33.3
	Traffic congestion	22	22.9
	Non-properly functioning traffic lights	16	16.7
	Road side elements	1	1.0
	Pedestrian	25	26.0
	Total	96	100.0

With almost the nearly same percentages of responses, they agreed that geometric design of intersection, pedestrian, traffic congestion and non-properly functioning traffic lights with 33.30%, 26.00%, 22.90% and 16.70% respectively, as shown in Table 4.73 are the common factors the affect the safety of signalized intersection. The least response comes from road side elements with 1.00%.

Table 4.74. What is the frequency of your crossing at the signalized intersection?

What is the frequency of your crossing at the signalized intersection		Frequency	Percent
Valid	Regularly	46	47.9
	Occasionally	46	47.9
	Rarely	4	4.2
	Total	96	100.0

Majority of the respondent are regularly and occasionally crossing at an intersection which comprise of 47.90% and 47.90% respectively. The least among the respondents is rarely crossing with 4.20%.

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Table 4.75. Speed when approaching at the signalized intersection.

What speed were you driving when approaching at the signalized intersection, if you were the driver or if you were pedestrian or eye witness can you tell (Km/hrs.).		Frequency	Percent
Valid	35-45 Kph	7	7.3
	45-55 Kph	33	34.4
	55-65 Kph	29	30.2
	65-above Kph	27	28.1
	Total	96	100.0

With regard to the speed when approaching at the signalized intersection, majority of the respondent responded a speed of 45-55 Kph and 55-65 Kph which comprise of 34.40% and 30.20% respectively. The least among the respondents is 35-45 Kph class speed with 7.30%.

4.2.4.3. Checking Reliability and Model Fitting

The safety evaluation of the Piassa signalized intersection model had reliable and fitted. It has checked in a way of the testament of the nodes(variables) by focused the conditional independencies between random variables of the selected model to their significance (meant if p-value is less than 0.05, it's significant) tells it's not fulfilled the assumption and has not reliable, where not-significant (meant if p-value is greater than 0.05, it's not significant) tells it's fulfilled the assumption and has fitted and reliable.

Conditional independence tests for discrete data has worked in way the conditional probability tables implied by the graphical structure of the network through the observed frequencies $\{n_{ijk}, i = 1, ..., R, j = 1, ..., C, k = 1, ..., L\}$ for the random variables X and Y and all the configurations of the conditioning variables Z. It's also confirms that the structure of a BN encodes a set of conditional independencies between random variables, X = (X1, X2, ..., Xn), which can be used to represent the joint distribution in compact factored form, while followed the Markov assumption, which states that each node is conditionally independent of its non-descendants (nodes that are not parents) in the network, given the value of its parent nodes. See at the appendix b.

The conditional independencies between variables of A1 to B25 given B26 is not significant [$X_{cal}^2 = 19.064$, $P_{value} = 0.7486$].

data: A3 ~ B25 | B26
mi = 19.064, df = 24, p-value = 0.7486
alternative hypothesis: true value is greater than 0.

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4.3. General Factors that Decrease the Capacity of the Signalized Intersection and Possible Countermeasures

The results of a field survey and site visit were compared to Highway Capacity Manual Standards. As a result, possible countermeasures for the identified design problems or critical areas are proposed.

Table 76. Factors affecting signalized intersection capacity and countermeasures.

General problems of signalized intersection	Possible countermeasures
Medium width	Increase medium width. Install median islands(physical) on major road approaches. Install median islands(painted) on major road approaches.
Absence of road marks and signs	Improve road sign on the appropriate place.
Absence of important geometric feature of signalized intersection	Add important features such as deflection and yield lines.
Over speed	Speed limit when approaching. Speed control devices when going through.
Inadequacy of entry lane width	Increase the lane width.
Poor visibility	Improve sightlines realignment. Remove obstacles and adjust the lights.
The habit of not give priority for vehicles inside and pedestrians	Educate drivers as they give priority vehicles inside and respect the traffic lights and engage the traffic police at signalized intersection who's watching at and so do for the pedestrians and other users.

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Pedestrian cross the signalized intersection without waiting traffic lights	Teaching the pedestrians as they cross the road only at crossing sign and before crossing they should be see the coming vehicles from all sides and by waiting the traffic lights.
Yellow interval light	Increase yellow change interval.
Emergency vehicle	Install emergency vehicle pre-emption systems.
Pedestrian phasing	Add exclusive pedestrian phasing. Install pedestrian countdown signal heads. Install pedestrian signals. Convert signal from pedestrian mounted to mass arm. Install pedestrian storage area at corner. Install stop bars(pedestrian crosswalk).
Left-turn phase	Convert protected/permissive left-turn to permissive/protected. Provide protected left-turn phase.
Signal timing	Improve signal timing [to intervals specified by the ITE Determining Vehicle Change Intervals: A Proposed Recommendation Practice (1985)].
Visibility of signal heads	Improve visibility of signal heads(increase signal lens size, install new backboards, add reflective tape to existing backboards, and/or install additional signal heads).

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Unwarranted signals	Remove unwarranted signals.
Additional signals	Add signal(additional primary head)..
Right-turn lane	Install right-turn lane. Install right-turn lane(painted separation).
Flashing beacons	Install flashing beacons as advanced warning.
Advanced warning signs	Install advanced warning signs(positive guidance).
Bicycles box	Provide bicyclists box (advanced stop bar to leave dedicated space for cyclists).
Detect cameras for red-light	Install cameras to detect red-light running.

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CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1. Conclusions

The core objective of this research has the determination of the safety evaluation at the signalized intersection and had been analyzed the factors that have affected it. The data has been analyzed using R software version 4.0.4 and SPSS version 26.0; as the results of the research had shown:

Majority of the respondents in Immigration, Meskel square and Mexico intersections are educated from diploma level to PhD degree level but in Piassa the majority are from secondary level to master degree level. Majority of the respondents in Immigration, Meskel square, Mexico and Piassa intersections were experienced in work from 3-5 years to 15 and more years. Out of the all intersections, majority of the respondents are responded that they used to slow down their speed when approaching signalized intersections.

Majority of the respondents in Immigration, Meskel square and Mexico intersections were female but in Piassa the majority were male. Majority of the respondents in Immigration and Piassa intersections are aged from 15-30 years' age class to 50-60 years' age class but in Meskel square and Mexico respondents were between 30-40 years' age class to 60-more years' age class. Out of the all intersections, majority of the respondents are responded that the accidents happened during peak hours.

Majority of the accidents happened during peak hours between 8:00 till 9:00 am with regard to immigration. In Meskel square and Piassa it had happened during afternoon peak hour from 5:00 am till 7:00 pm and in Mexico it was happened between 12:00 pm till 2:00 pm. Majority of the respondents have got accident at the intersection from hit in the rear side on the intersection to concert in collision inside the intersection, but in Piassa majority of the respondents had got accident at intersection from hit in the rear side on the intersection to hit us on the intersection.

Majority of out of three intersections have respondents that they are pedestrians got incident while in Meskel square responded that the majority got incident are travelers. Majority of the respondents are responded that the accident resulted in a fatal injury, injury and property damage only at Meskel square and Piassa, but in Immigration and Mexico resulted injury and property damage only. Out of all the intersections, majority of the respondents are responded that the weather condition during accidents was rainy season.

Majority of the respondents claimed that the road condition was wet when accident happened at Immigration, Mexico and Piassa but the road condition was dry when the accident happened at Meskel square. Out of all the intersections, majority of the respondents are answered that the accident happened during daytime where the light condition was bright.

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Out of all the intersections, majority of the respondents have agreed that the geometric design of intersection, traffic congestion, road side elements, pedestrian including non-properly functioning traffic lights are the common factors that affect the safety of signalized intersections. Out of all the intersections, majority of the respondents are regularly and occasionally crossing at the intersections. Majority of the respondents are responded when vehicles approaching at the intersection, they were approached in speed between 45-55 Kph to 55-65 Kph.

5.2. Recommendations

Since traffic accidents at signalized intersections have increased significantly, the existing signalized intersection should be reconsidered in terms of geometric shape, i.e. entry lane width, median width, shoulder width, and curbs should be revised.

Some basic safety elements at signalized intersections did not exist; the AACRA should add basic elements such as bypass bridges for pedestrians, overpasses, left turns, and so on. It was suggested that all signalized intersections be made safe and well-controlled, as well as consider a way for pedestrians to pass safely for every situation.

Because the traffic accident data collected for this study was limited and collected by manpower in a short period of time, particularly for a few signalized intersections, the result developed by this research is only an insight into the theme of my research. In this regard, additional studies with video recording and more data collection should be conducted in order to develop the result and for use in the improvement of signalized intersection safety and service capacity, particularly Addis Ababa Police Commission is recommended to record the data's as per location, time, and location name, especially at signalized intersections where the accident has occurred because Finally, it is recommended that additional studies on traffic safety evaluation will better to being take places in anywhere on signaled or unsignaled roads in Addis Ababa using Bayesian Networks.

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APPENDEX A

Questionnaire

Dear respondents:

Iam Abdishakur Daib Aden, a student at Jimma Institute Technology, Jimma University; doing Master of science in Highway Engineering.

At the current time I'm dealing for the work handling of my thesis of the Masters of Highway Engineering, entitled: **"Developing Advanced Safety Evaluation Models Based on Unobserved Heterogeneity Across Different Signalized Intersections Using Bayesian Networks: A Case of Addis Ababa City."**

In view of this, Iam asking your intellectual cooperation to provide data to the attended document/questionnaire.

I have assured that the data gathered will be used for educational purposes and will be treated for with utmost confidentiality

Thank You

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Questionnaire:

1. Education Level(s):

A. None ☐   B. Primary level ☐   C. Secondary level ☐   D. Diploma level ☐

E. Bachelor degree level ☐   F. Master degree level ☐   G. PhD degree level ☐

2. Occupation: _____

3.Income level (in terms of ETB)?

A. $0-$50(0-2,095 ETB) ☐   B. $50-$150(2,095-6,286 ETB)   ☐

C. $150-$250(6,286-10,477 ETB) ☐   D. $250-$500(10,477-20,955 ETB) ☐

E. $500 and above (10,477 ETB and above)   ☐

4.Work experience (in terms of years)?

A. None ☐   B. 1 -3 ☐   C. 3 -5 ☐   D. 5-10 ☐   E. 10-15 ☐   F. 15-more ☐

5. A. Gender of the person in the questionnaire.

a. Male ☐   b. Female ☐

B. Age of the person in the questionnaire (in terms of years)

a. 15-30 ☐   b. 30-40 ☐   c. 40-50 ☐   d. 50-60 ☐   e. 60-more ☐

6. Did you experienced accident before?

☐ Yes   ☐ No

A. Were you a driver?

☐ Yes   ☐ No

B. If yes, were you have participated the car accident?

☐ Yes   ☐ No

C. What is your driving experience (in terms of year)?

a. 0-10 ☐   b. 10-20 ☐   c. Above 20 years ☐

D. Were you a pedestrian?

☐ Yes   ☐ No

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E. If yes, were you a victim of the incident?

☐ Yes ☐ No

F. In detail about what were you doing when the accident happens_____

_____

7. A. Did you/they have got injured?

☐ Yes ☐ No

B. If yes, how bad? And if no, could you tell? (in detail)

_____

8. A. If you were the driver or passenger, did you have wear a seat belt?

☐ Yes ☐ No

B. If no, why not you wear the seat belt? _____

C. If you were a motor-cyclist or cyclist were you wearing a crash safety helmet?

☐ Yes ☐ No

D. If no, why not you wear the crash safety helmet? _____

9. Does a good traffic safety exists at this signalized intersection?

a. Yes ☐ b. No ☐

10. Did the accident crash happen at the peak hour time?

a. Yes ☐ b. No ☐

A. If yes, could you tell at what time did the accident happen? (in terms of hours)

a. 8am-9am ☐ b. 12pm-2pm ☐ c. 5pm-7pm ☐

B. If not, at what time exactly accident happen? _____

11. Did an ambulance service or fire service attend to the scene?

☐ Yes ☐ No

12. A. If you were one of those have got the incident, did you attend hospital as a result of what happened?

☐ Yes ☐ No

B. If not, why? _____

C. If yes, were you hospitalized?

☐ Yes   ☐ No

D. If Yes, How many days? And if no, could you tell about your situation?

_____

13. Please describe the details of the impact to the vehicle upon the accident?

A. Hit in the rear on the intersection ☐   B. Hit in the sides on the intersection ☐

C. Involving vehicles changing lanes on the intersection ☐

D. Concert in collision, inside on the intersection   ☐

E. Do not involved it   ☐   F. Hit us on the intersection   ☐

14. At what speed were you driving when you approaching at the signalized intersection? if you were the driver? or if you were pedestrian/ eye witness can you tell? (in terms Km/hrs.)

a. 35-45 ☐   b. 45-55 ☐   c.55-65 ☐   d. 65-more ☐

15. Did Police attend the scene of accidents?   Yes ☐   No ☐

16. Total number of passengers in each vehicle or pedestrian involved in the accident?

_____

17. How did the accident happen, before and after impact?
A. Before: _____

B. After: _____

18. What happened immediately after the accident? Include anything said by you or other parties?

_____

19. What is the frequency of your crossing at the signalized intersection?
a. Regularly ☐   b. Occasionally ☐   c. Rarely ☐

20. Did you slow your speed, when you are arriving at the signalized intersection? Or if you were passenger were you travelling in a slow speed?
a. Yes ☐   b. No ☐   c. Sometimes ☐

21. What are the factors affecting driving behavior at the signalized intersection/
a. Geometric design of the intersection ☐   b. Traffic congestion ☐
c. Lights from buildings nearby at night ☐   d. Road side elements ☐
e. Pedestrian ☐

22. What were the Environmental conditions include road conditions?
A. Weather conditions: ☐ Sunny   ☐ Rainy   ☐ Foggy

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B. Road conditions: ☐ Dry ☐ Wet

C. Light conditions: ☐ Bright ☐ Dark

23. Have you reported any accidents and/or claims in the last 5 years?

☐ Yes ☐ No

24. If you were employed, did you take any time off work as a result of your injuries?

☐ Yes ☐ No

25.

A. Have you return to work?

☐ Yes ☐ No

B. If you cannot return to work, why not?

_____

26.

A. If you were an employee, does your contract of employment allow employers to recover wage advances made during your period of absence from work following this accident?

☐ Yes ☐ No

B. Did you lost overtime, shift allowance, bonuses or etc.?

☐ Yes ☐ No

C. On return to work did you had any change of job (i.e. lighter work)?

☐ Yes ☐ No

D. If Yes, is there a financial loss or gain?

☐ Yes ☐ No

27. What is the name of the signalized intersection you were at?

A. Immigration signalized intersection ☐   B. Piassa signalized intersection ☐

C. Mexico signalized intersection ☐   D. Meskel square signalized intersection ☐

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APPENDEX B

Results from the software

1. **Bayesian network model for Immigration**

Bayesian Network structure for Immigration Model
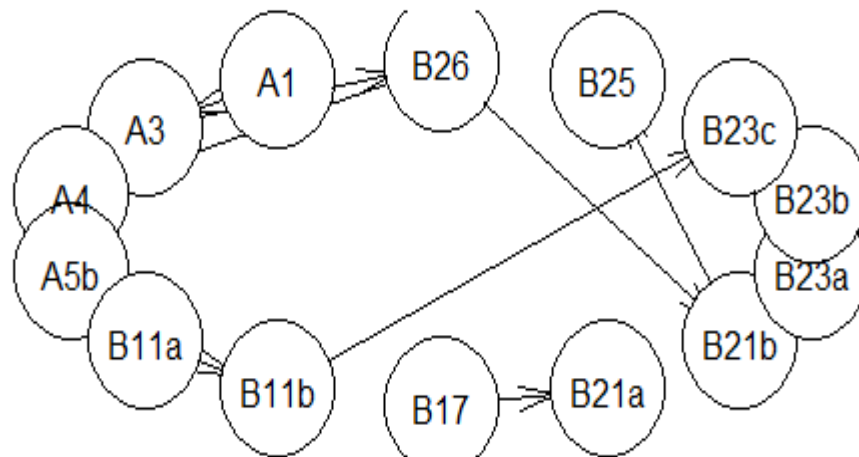
- **Checking Reliability and Model Fitting for Immigration**

The safety evaluation of the Immigration signalized intersection model had reliable and fitted. It has checked in a way of the testament of the nodes(variables) by focused the conditional independencies between random variables of the selected model to their significance (meant if p-value is less than 0.05, it's significant) tells it's not fulfilled the assumption and has not reliable, where not-significant (meant if p-value is greater than 0.05, it's not significant) tells it's fulfilled the assumption and has fitted and reliable.

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Conditional independence tests for discrete data has worked in way the conditional probability tables implied by the graphical structure of the network through the observed frequencies $\{n_{ijk}, i = 1, ..., R, j = 1, ..., C, k = 1, ..., L\}$ for the random variables X and Y and all the configurations of the conditioning variables Z. It's also confirms that the structure of a BN encodes a set of conditional independencies between random variables, X = (X1, X2, ..., Xn), which can be used to represent the joint distribution in compact factored form, while followed the Markov assumption, which states that each node is conditionally independent of its non-descendants (nodes that are not parents) in the network, given the value of its parent nodes.

The conditional independencies between variables of B25 to A3 given B21 is not significant [$X_{cal}^2 = 22987$, $P_{value} = 0.5205$]. the rest were following in a such: -

```
data:  B25 ~ A3 | B21b
mi = 22.987, df = 24, p-value = 0.5205
alternative hypothesis: true value is greater than 0


data:  B26 ~ A5b | A4
mi = 11.201, df = 48, p-value = 1
alternative hypothesis: true value is greater than 0


data:  A5b ~ B26 | A4
mi = 11.201, df = 48, p-value = 1
alternative hypothesis: true value is greater than 0


data:  A4 ~ B21b | B26
mi = 6.3151, df = 30, p-value = 1
alternative hypothesis: true value is greater than 0


data:  B23b ~ B23c | B23a
mi = 6.4884, df = 3, p-value = 0.09012
alternative hypothesis: true value is greater than 0
```

The above model information approves the Markov assumption, which states that each node is conditionally independent of its non-descendants (nodes that are not parents) in the network, given the value of its parent nodes stating the reliability of the fitted model for the Immigration data.

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IMMIGRATION MODEL RESULTS FROM R SOFTWARE

Variables	Level of category	Conditional Probability				
Education level	None	0.1042				
	Primary level	0.1146				
	Secondary level	0.1771				
	Diploma level	0.1250				
	Bachelor degree level	0.2188				
	Master degree level	0.1979				
	PHD degree level	0.0625				
		Income Level				
Education level	0$	50-150 ($)	150-250($)	250-500($)	>500$	
None	1.0000	0.0000	0.0000	0.0000	0.0000	
Primary	0.0909	0.7273	0.1818	0.0000	0.0000	
Secondary	0.0000	0.9412	0.0588	0.0000	0.0000	
Diploma	0.25000	0.5833	0.1667	0.0000	0.0000	
Degree	0.0476	0.3333	0.3333	0.2381	0.0476	
MSc/MB/A	0.0000	0.0000	0.0526	0.8421	0.1053	
PHD	0.0000	0.0000	0.0000	0.0000	1.0000	
		Work Experience				
Did you slow your speed when you arriving at the signalized intersection?	none	1-3	3-5	5-10	10-15	>15
Yes	0.0000	0.0278	0.3194	0.4583	0.1250	0.0694
No	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sometimes	0.0000	0.1111	0.1111	0.7778	0.0000	0.0000

	work Experience					
Age	none	1-3	3-5	5-10	10-15	>15
15-30	0.0667	0.6667	0.0417	0.0250	0.0000	0.0000
30-40	0.0000	0.3333	0.7500	0.3500	0.0000	0.0000
40-50	0.1333	0.0000	0.2083	0.4000	0.0000	0.0000
50-60	0.4667	0.0000	0.0000	0.2000	0.8889	1.0000
>60	0.3333	0.0000	0.0000	0.0250	0.1111	0.0000
Did an accident crash happen at the peak hour time?	Yes	No				
	0.7083	0.2917				
If yes, could you tell at what time did the accident happen?	8am-9am	0.6471	0.0000			
	10am-11am	0.0000	0.6964			
	12pm-2pm	0.1618	0.0000			
	3pm-5pm	0.0000	0.3036			
	5pm-7pm	0.1912	0.0000			
Please describe the details of the impact to the vehicle upon the accident (B17).	Hit in the rear	Hit in the sides	Involving vehicle changing lanes	Concern in collision	Do not involve it	
	0.1979	0.1771	0.1042	0.0417	0.4792	
	Please describe the details of the impact to the vehicle upon the accident (B17).					
How did the accident happen, before impact?	Hit in the rear	Hit in the sides	Involving vehicle changing lanes	Concern in collision	Do not involve it	
We were travelling	0.7895	0.8824	0.6000	0.0217	0.0000	
We were trying to cross the intersection road	0.2105	0.1176	0.4000	1.0000	0.9783	
	Your speed when you arriving at the signalized intersection?					
How did the accident happen, after impact?	Yes	No	Some times			
Fatal injury, injury and property damage only	0.4861	0.4000	0.4444			
Injury and property damage only	0.5189	0.4667	0.5556			
	Weather conditions					
Light condition	Sunny	Rainy	Foggy			

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Bright	0.3684	0.4737	0.1579		
Dark	0.0000	0.8500	0.1500		
	Weather conditions				
Road conditions					
Dry	1.0000	0.0536	0.1667		
Wet	0.0000	0.9464	0.8333		
	If yes, could you tell at what time did the accident happen?				
Light condition	8am–9am	10am–11am	12pm–2pm	3pm–5pm	5pm–7pm
Bright	0.9773	0.0000	0.7895	0.8750	1.0000
Dark	0.0227	1.0000	0.2105	0.1250	0.0000
	what is the frequency of your crossing at the signalized intersection?				
How did the accident happen, after impact?	Regularly	Occasionally	Rarely		
Fatal injury, injury and property damage only	0.0000	0.3333	0.6667		
Fatal injury, injury and property damage only	1.0000	0.0000	0.0000		
Injury and property damage only	0.7959	0.2041	0.0000		
	Income level (in Dollar)				
Your speed when you arriving at the signalized intersection?	0	50–150	150–250	250–500	>500
Yes	0.0000	0.8947	0.8462	0.8571	1.0000
No	1.0000	0.0000	0.0000	0.0000	0.0000
Sometimes	0.0000	0.1053	0.1538	0.1429	0.0000

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2. Bayesian network model for Meskel square

Bayesian Network structure for Meskel Model
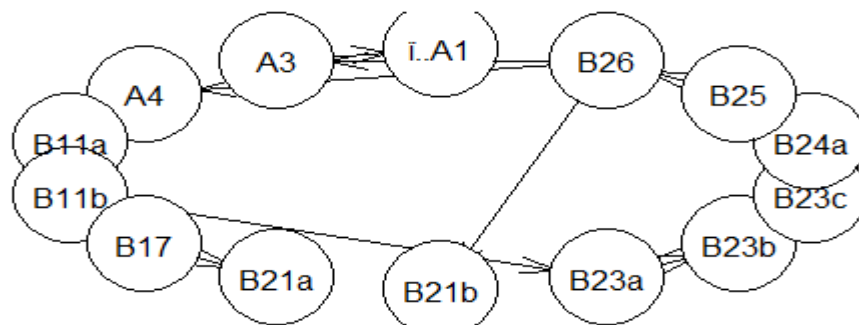
- **Checking Reliability and Model Fitting for Meskel square**

The safety evaluation of the Meskel-square signalized intersection model had reliable and fitted. It has checked in a way of the testament of the nodes(variables) by focused the conditional independencies between random variables of the selected model to their significance (meant if p-value is less than 0.05, it's significant) tells it's not fulfilled the assumption and has not reliable, where not-significant (meant if p-value is greater than 0.05, it's not significant) tells it's fulfilled the assumption and has fitted and reliable.

Conditional independence tests for discrete data has worked in way the conditional probability tables implied by the graphical structure of the network through the observed frequencies $\{n_{ijk}, i = 1, ..., R, j = 1, ..., C, k = 1, ..., L\}$ for the random variables X and Y and all the configurations of the conditioning variables Z. It's also confirms that the structure of a BN encodes a set of conditional independencies between random variables, X = (X1, X2, ..., Xn), which can be used to represent the joint distribution in compact factored form, while followed the Markov assumption, which states that each node is conditionally independent of its non-descendants (nodes that are not parents) in the network, given the value of its parent nodes.

The conditional independencies between variables of A3 to B25 given A1 is not significant [$X_{cal}^2 = 13.542$, $P_{value} = 1$]. and rest were following in a such: -

data: A3 ~ B25 | A1

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mi = 13.542, df = 56, p-value = 1
alternative hypothesis: true value is greater than 0

data: B26 ~ A1 | A3
mi = 2.8534, df = 60, p-value = 1
alternative hypothesis: true value is greater than 0

data: B25 ~ A4 | B26
mi = 0.62945, df = 30, p-value = 1
alternative hypothesis: true value is greater than 0

data: B25 ~ B21b | B26
mi = 0.8319, df = 24, p-value = 1
alternative hypothesis: true value is greater than 0

data: B23a ~ B24a | B23c
mi = 6.305, df = 16, p-value = 0.9845
alternative hypothesis: true value is greater than 0

data: B11b ~ B23b | B23a
mi = 0, df = 12, p-value = 1
alternative hypothesis: true value is greater than 0

data: B25 ~ B11a | B17
mi = 10.662, df = 10, p-value = 0.3845
alternative hypothesis: true value is greater than 0

The above model information approves the Markov assumption, which states that each node is conditionally independent of its non-descendants (nodes that are not parents) in the network, given the value of its parent nodes stating the reliability of the fitted model for the Meskel square data.

MESKEL SQUARE MODEL RESULTS FROM R SOFTWARE

Education level	Income Level(in terms of dollars)				
	0$	50-150 ($)	150-250($)	250-500($)	>500$
None	0.5714	0.0000	0.0000	0.0000	0.0000
Primary level	0.0714	0.2414	0.0435	0.0000	0.0000
Secondary level	0.0000	0.3448	0.0435	0.0000	0.0000
Diploma level	0.3571	0.1379	0.2174	0.0000	0.0000
Bachelor degree level	0.0000	0.2759	0.4348	0.1765	0.0000
Master degree level	0.0000	0.0000	0.2609	0.8235	0.4286
PhD degree level	0.0000	0.0000	0.0000	0.0000	0.5714

Income level	Did you slow your speed when you are arriving at the signalized intersection		
	Yes	No	Sometimes
0($)	0.0000	1.0000	0.0000
50-150($)	0.3182	0.0000	0.4706
150-250($)	0.2727	0.0000	0.2941
250-500($)	0.1969	0.0000	0.2353
>500($)	0.2121	0.0000	0.0000

Work experience(in terms of years)	Did you slow your speed when you are arriving at the signalized intersection		
	Yes(%)	No(%)	Sometimes(%)
None	0.0000	1.0000	0.0000
1-3	0.3333	0.0000	0.5294
3-5	0.5000	0.0000	0.3529
5-10	0.1364	0.0000	0.1176
10-15	0.0152	0.0000	0.0000
>15	0.0152	0.0000	0.0000

Variables	Response	Conditional probability(%)
Did an accident crash happen at the peak hour time?	Yes	0.7629
	No	0.2371

If yes, could you tell at what time did the accident happen	Did an accident crash happen at the peak hour time?	
	Yes(%)	No(%)

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8am–9am	0.3108	0.0000
10am–11am	0.0000	0.6522
12pm–2pm	0.2568	0.0000
3pm–4pm	0.0000	0.3478
5pm–7pm	0.4324	0.0000
Variable	Level of category	Conditional probability(%)
Please describe the details of the impact of the vehicle up on accident	Hit in the rear, inside on the signalized intersection	0.3505
	Hit in the sides, inside on the signalized intersection	0.1753
	Involving vehicles changing lanes, inside on the signalized intersection	0.0103
	Concert collision, inside on the signalized intersection	0.0103
	Do not involve it	0.4536
	Hit us, inside on the signalized intersection	0.0000

	How did the accident happen, before impact?		
Please describe the details of the impact of the vehicle up on accident?	They were travelling	They were travelling	They were travelling
Hit in the rear, inside on the signalized intersection	0.0588	0.9412	0.0000
Hit in the sides, inside on the signalized intersection	0.1176	0.8824	0.0000
Involving vehicles changing lanes, inside on the signalized intersection	1.0000	0.0000	0.0000
Concert collision, inside on the signalized intersection	0.0000	0.0000	1.0000
Do not involve it	0.0000	0.0000	1.0000
Hit us, inside on the signalized intersection	0.0000	0.0000	1.0000

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	Did you slow your speed when you arriving at the signalized intersection or were you travelling in a slow speed?				
How did the accident happen, after impact?	Yes(%)	No(%)		Sometimes(%)	
Fatal injury, injury and property damage only	0.4242	0.2858		0.2900	
Injury and property damage only	0.3636	0.2857		0.1765	
Property damage only	0.0152	0.0000		0.0000	
	If yes, could you tell at what time did the accident happen				
Weather conditions	8am-9am	10am-11am	12pm-2pm	3pm-4pm	5pm-7pm
Sunny	0.8696	1.0000	0.1875	0.3750	0.6000
Rainy	0.0000	0.0000	0.6875	0.1250	0.2000
Foggy	0.1304	0.0000	0.1250	0.5000	0.2000
	Weather conditions				
Road condition	Sunny(%)	Rainy(%)		Foggy(%)	Others(%)
Dry	1.0000	0.0000		0.0000	0.0000
Wet	0.0000	1.0000		1.0000	0.0000
	Weather conditions				
Light condition	Sunny(%)	Rainy(%)		Foggy(%)	Others(%)
Bright	1.0000	0.0000		0.3571	0.0000
Dark	0.0000	1.0000		0.6429	0.0000
	Light condition				
What are the factors affecting safety evaluation at signalized intersection	Bright(%)			Dark(%)	
Geometric design of the signalized intersection	0.5968			0.2571	
Traffic congestion	0.0968			0.0571	
Traffic signal lights do not function properly	0.0323			0.4857	
Road side elements	0.0968			0.1143	
Pedestrian	0.1774			0.0857	

Variables	Level of category	Conditional probability(%)	
What is the frequency of your crossing at signalized intersection	Regularly	0.8247	
	Occasionally	0.1546	
	Rarely	0.0206	
	What is the frequency of your crossing at signalized intersection		
Did you slow your speed when you arrives at signalized intersection	Regularly(%)	Occasionally(%)	Rarely(%)
Yes	0.8250	0.0000	0.0000
No	0.1750	0.0000	0.0000
Sometimes	0.0000	1.0000	1.0000

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3. Bayesian network model for Mexico

Bayesian Network structure for Mexico Model
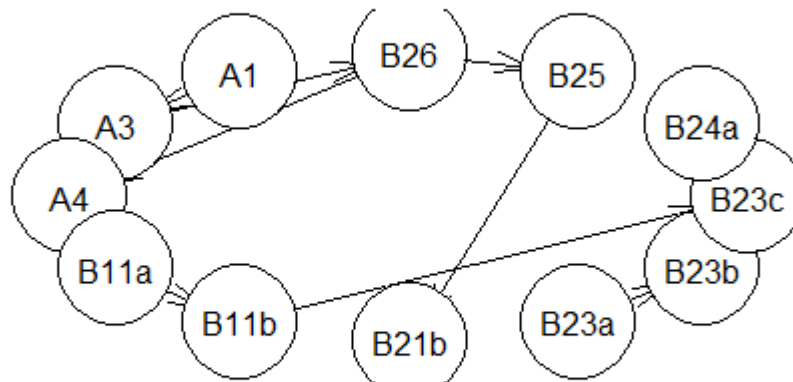
- **Checking Reliability and Model Fitting for Mexico**

The safety evaluation of the Mexico signalized intersection model had reliable and fitted. It has checked in a way of the testament of the nodes(variables) by focused the conditional independencies between random variables of the selected model to their significance (meant if p-value is less than 0.05, it's significant) tells it's not fulfilled the assumption and has not reliable, where not-significant (meant if p-value is greater than 0.05, it's not significant) tells it's fulfilled the assumption and has fitted and reliable.

Conditional independence tests for discrete data has worked in way the conditional probability tables implied by the graphical structure of the network through the observed frequencies $\{n_{ijk}, i = 1, ..., R, j = 1, ..., C, k = 1, ..., L\}$ for the random variables X and Y and all the configurations of the conditioning variables Z. It's also confirms that the structure of a BN encodes a set of conditional independencies between random variables, X = (X1, X2, ..., Xn), which can be used to represent the joint distribution in compact factored form, while followed the Markov assumption, which states that each node is conditionally independent of its non-descendants (nodes that are not parents) in the network, given the value of its parent nodes.

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The conditional independencies between variables of B21b to B26 given B25 is not significant [X_{cal}^2 = 0.83035, P_{value} = 1]. and rest were following in a such: -

data: B21b ~ B26 | B25
mi = 0.83035, df = 12, p-value = 1
alternative hypothesis: true value is greater than 0

data: A4 ~ A3 | B26
mi = 59.319, df = 60, p-value = 0.5006
alternative hypothesis: true value is greater than 0

data: B26 ~A1 | A3
mi = 9.8422, df = 60, p-value = 1
alternative hypothesis: true value is greater than 0

data: B24a ~ B11b | B23c
mi = 21.784, df = 32, p-value = 0.913
alternative hypothesis: true value is greater than 0

data: B25 ~ A3 | B26
mi = 8.8584, df = 24, p-value = 0.9979
alternative hypothesis: true value is greater than 0

The above model information approves the Markov assumption, which states that each node is conditionally independent of its non-descendants (nodes that are not parents) in the network, given the value of its parent nodes stating the reliability of the fitted model for the Mexico data.

MEXICO MODEL RESULTS FROM R SOFTWARE

Variables	Level of category	Conditional probability(%)
Education level	None	0.1041

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Primary level	0.0938			
Secondary level	0.1354			
Diploma level	0.1458			
Bachelor degree level	0.2083			
Master degree level	0.2188			
PhD degree level	0.0938			

	Income Level				
Education level	0$	50-150 ($)	150-250($)	250-500($)	>500$
None	1.0000	0.0000	0.0000	0.0000	0.0000
Primary Level	0.1111	0.6667	0.2222	0.0000	0.0000
Secondary Level	0.0000	0.9231	0.0769	0.0000	0.0000
Diploma Level	0.3571	0.4286	0.2143	0.0000	0.0000
Bachelor Degree Level	0.0000	0.3500	0.5500	0.1000	0.0000
Master Degree Level	0.0000	0.0000	0.0952	0.7619	0.1429
PHD Degree Level	0.0000	0.0000	0.0000	0.0000	1.0000

	Did you slow your speed when you arrives at signalized intersection		
Work experience(in terms of years)	Yes(%)	No(%)	Sometimes(%)
None	0.0000	1.0000	0.0000
1-3	0.0435	0.0000	0.0000
3-5	0.2899	0.0000	0.5455
5-10	0.5652	0.0000	0.3636
10-15	0.0435	0.0000	0.0000
>15	0.0579	0.0000	0.0909

Variables	Level of category	Conditional probability(%)

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Did the accident crash happen at the peak hour time	Yes		0.7500	
	No		0.2500	
If yes, could you tell at what time did the accident happen	Did the accident happen at the peak hour time			
	Yes(%)		No(%)	
8am-9am	0.2222		0.0000	
10am-11am	0.0000		0.4167	
12pm-2pm	0.4306		0.0000	
3pm-4pm	0.0000		0.5833	
5pm-7pm	0.3472		0.0000	
	What is the frequency of your crossing at signalized intersection			
How did the accident happen, after impact	Regularly(%)	Occasionally(%)	Rarely(%)	
Fatal injury, injury and property damage only	0.5125	0.0000	1.0000	
Injury and property damage only	0.4875	1.0000	0.0000	
Variables	Level of category		Conditional probability(%)	
Weather conditions	Sunny		0.1250	
	Rainy		0.7708	
	Foggy		0.1042	
	Others		0.0000	
	weather conditions			
Road condition	Sunny(%)	Rainy(%)	Foggy(%)	Others(%)

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Dry	1.0000	0.000	0.0000	0.0000
Wet	0.0000	1.0000	1.0000	0.0000
Mud	0.0000	0.0000	0.0000	0.0000
Oily	0.0000	0.0000	0.0000	0.0000

	If yes, could you tell at what time did the accident happen				
Light conditions	8am–9am	10am–11am	12pm–2pm	3pm–4pm	5pm–7pm
Bright	1.0000	0.9000	0.9677	0.8571	0.0000
Dark	0.0000	0.1000	0.0323	0.1428	1.0000

	Light condition	
what are the factors affecting safety evaluation at signalized intersection	Bright(%)	Dark(%)
Geometric design of the signalized intersection	0.2836	0.1379
Traffic congestion	0.3433	0.1379
Traffic signal lights do not function properly	0.0149	0.2414
Road side elements	0.1194	0.2414
Pedestrian	0.2388	0.2414

	Did you slow your speed when you arrives at signalized intersection		
what is the frequency of your crossing at signalized intersection	Yes(%)	No(%)	Sometimes(%)
Regularly	0.9275	1.0000	0.0000
Occasionally	0.0725	0.0000	0.9091
Rarely	0.0000	0.0000	0.0909

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	Income level				
Did you slow your speed, when you arrives at signalized intersection	0($)	50-150($)	150-250($)	250-500($)	>500($)
Yes	0.0000	0.9355	0.7895	0.9444	0.6667
No	1.0000	0.0000	0.0000	0.0000	0.0000
Sometimes	0.0000	0.0645	0.2105	0.0556	0.3333

4. Bayesian network model for Piassa

Bayesian Network structure for Piassa Model
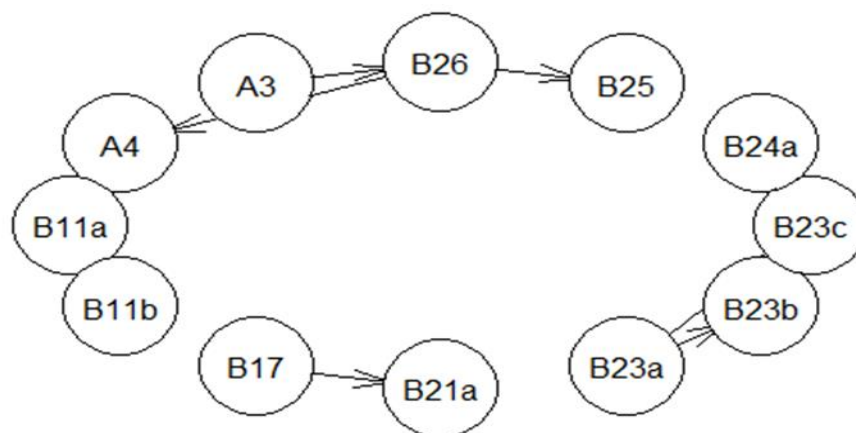
- **Checking Reliability and Model Fitting for Piassa**

The safety evaluation of the Piassa signalized intersection model had reliable and fitted. It has checked in a way of the testament of the nodes(variables) by focused the conditional independencies between random variables of the selected model to their significance (meant if p-value is less than 0.05, it's significant) tells it's not fulfilled the assumption and has not reliable, where not-significant (meant if p-value is greater than 0.05, it's not significant) tells it's fulfilled the assumption and has fitted and reliable.

Conditional independence tests for discrete data has worked in way the conditional probability tables implied by the graphical structure of the network through the observed frequencies $\{n_{ijk}, i = 1, ..., R, j = 1, ..., C, k = 1, ..., L\}$ for the random variables X and Y and all the configurations of the

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conditioning variables Z. It's also confirms that the structure of a BN encodes a set of conditional independencies between random variables, $X = (X1, X2, ..., Xn)$, which can be used to represent the joint distribution in compact factored form, while followed the Markov assumption, which states that each node is conditionally independent of its non-descendants (nodes that are not parents) in the network, given the value of its parent nodes.

The conditional independencies between variables of A3 to B25 given B26 is not significant [$X_{cal}^2 = 19.064$, $P_{value} = 0.7486$]. and rest were following in a such: -

data: A3 ~ B25 | B26
mi = 19.064, df = 24, p-value = 0.7486
alternative hypothesis: true value is greater than 0

data: A3 ~ A4 | B26
mi = 59.739, df = 72, p-value = 0.8485
alternative hypothesis: true value is greater than 0

data: B23a ~ B24a | B23c
mi = 12.1, df = 16, p-value = 0.7371
alternative hypothesis: true value is greater than 0

data: A3 ~ B23a | B17
mi = 36.908, df = 48, p-value = 0.8778
alternative hypothesis: true value is greater than 0

data: A3 ~ B11a | B17
mi = 15.492, df = 24, p-value = 0.9055
alternative hypothesis: true value is greater than 0

The above model information approves the Markov assumption, which states that each node is conditionally independent of its non-descendants (nodes that are not parents) in the network, given the value of its parent nodes stating the reliability of the fitted model for the Piassa data.

PIASSA MODEL RESULTS FROM R SOFTWARE

Variables	Level of category	Conditional probability(%)
Income level	0($)	0.1875
	50-150($)	0.5000

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	150-250($)		0.1354
	250-500($)		0.1042
	>500($)		0.0729
	Did you slow your speed when you arrives at signalized intersection		
work experience(in terms of years)	Yes(%)	No(%)	Sometimes(%)
None	0.0448	0.9375	0.0769
1-3 years	0.0896	0.0000	0.0000
3-5 years	0.3284	0.0000	0.3846
5-10 years	0.3284	0.0625	0.3077
10-15 years	0.1642	0.0000	0.0769
>15 years	0.0447	0.0000	0.1538
Variables	Level of category		Conditional probability(%)
Did the accident crash happen at the peak hour time	Yes		0.6771
	No		0.3229
	Did the accident crash happen at the peak hour time		
If yes, could you tell at what time did the accident happen	Yes(%)		No(%)
8am-9am	0.2615		0.0000
10am-11am	0.0000		0.2903
12pm-2pm	0.2000		0.0000
3pm-4pm	0.0000		0.7097

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5pm–7pm	0.5385	0.0000				
Variable	Level of category	Conditional probability(%)				
Please describe the details of the impact of the vehicle up on accident	Hit in the rear, inside on the signalized intersection	0.1875				
	Hit in the sides, inside on the signalized intersection	0.1458				
	Involving vehicles changing lanes, inside on the signalized intersection	0.1771				
	Concert collision, inside on the signalized intersection	0.0417				
	Do not involve it	0.1771				
	Hit us, inside on the signalized intersection	0.2708				
	Please describe the details of the impact to the vehicle upon the accident.					
How did the accident happen, before impact?	Hit in the rear, inside on the signalized intersection	Hit in the sides, inside on the signalized intersection	Involving vehicles changing lanes, inside on the signalized intersection	Concern in collision, inside on the signalized intersection	Do not involve it	Hit us, inside on the signalized intersection
I was controlling the traffic movement	0.0000	0.0000	0.0000	0.0000	0.8077	0.1923
They were travelling	0.0556	0.1000	0.0588	0.0000	0.0000	0.0000
We were travelling	0.6667	0.5714	0.6471	0.0000	0.0000	0.0000
We were trying to cross the	0.2778	0.4286	0.2941	1.0000	0.1765	8077

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intersection road						
Variables	Level of category		Conditional probability(%)			
Weather conditions	Sunny		0.3854			
	Rainy		0.4896			
	Foggy		0.1250			
	Others		0.0000			
	weather conditions					
Road condition	Sunny(%)	Rainy(%)		Foggy(%)		
Dry	1.0000	0.0000		0.0000		
Wet	0.0000	1.0000		1.0000		
Mud	0.0000	0.0000		0.0000		
	Weather conditions					
Light conditions	Sunny(%)	Rainy(%)		Foggy(%)		
Bright	0.9459	0.5319		0.9167		
Dark	0.0541	0.4681		0.0833		
	Light conditions					
What are the factors affecting safety evaluation at signalized intersection	Bright(%)		Dark(%)			
Geometric design of the signalized intersection	0.4085		0.1200			
Traffic congestion	0.2676		0.1200			
Traffic signal lights do not function properly	0.0000		0.6400			
Road side elements	0.0141		0.0000			

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Pedestrian	0.3099		0.1200		
	Did you slow your speed when you arrive at signalized intersection				
What is the frequency of your crossing at signalized intersection	Yes(%)		No(%)	Sometimes(%)	
Regularly	0.5522		0.3750	0.2308	
Occasionally	0.4478		0.6250	0.4615	
Rarely	0.0000		0.0000	0.3077	
	Income level(in terms of dollars)				
Did you slow your speed, when you arrive at signalized intersection or did you travel in slow speed; as a passenger	0($)	50-150($)	150-250($)	250-500($)	>500($)
Yes	0.1111	0.8333	0.9231	0.9000	0.5714
No	0.8333	0.0000	0.0000	0.1000	0.0000
Sometimes	0.0556	0.1667	`0.0769	0.0000	0.4286