ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

EVALUATION OF EFFECTIVENESS OF TRAFFIC CALMING AT ROUNDABOUTS WITHIN NIFAS SILK LAFTO SUB CITY

By
Emebet Tesfay Gebremedhin

The Thesis Submitted to School of Graduate Studies of Addis Ababa University In Partial Fulfillment of the Requirement for the Degree of Master of Science in Civil and Environmental Engineering (Road and Transport Engineering Stream)

Advisor

Bikila Teklu (Dr.)

NOVEMBER, 2015
ADDIS ABABA

SCHOOL OF POST GRADUATE STUDIES
ADDIS ABABA UNIVERSITY

EVALUATION OF EFFECTIVENESS OF TRAFFIC CALMING AT ROUNDABOUTS WITHIN NIFAS SILK LAFTO SUB CITY

BY

EMEBET TESFAY GEBREMEDHIN

APPROVED BY BOARD OF EXAMINERS:

Dr.BikilaTeklu ________________ ____________
Advisor Signature Date

Mr.Raeed Ali ________________ ____________
Co-advisor Signature Date

Dr.Getu Segni ________________ ____________
Internal Examiner Signature Date

Dr.Habtamu Zelelew ________________ ___________
External Examiner Signature Date

Mr.Jibril Akmel _______________ ___________
Chairman, Department Committee Signature Date

DEDICATION

This thesis is dedicated to my beloved mother Freweyni Tewelde I lost her when I was a child.

DECLARATION

First, I declare that this thesis is my original work and that all sources of materials used for this thesis haven been properly acknowledged.

Emebet Tesfay ______________________________

Name Signature

ACKNOWLEDGEMENTS

First, I would like to thank my advisor Dr.Bikila Teklu and my co-advisor Mr.Raeed Ali for their consistent supervision, crucial remarks, valuable suggestions and comments throughout the thesis work, beginning from proposal preparation up to the completion of the research.

My gratitude goes to family for helping me through the difficulties in the whole duration and generously funding my graduate program in Addis Ababa University, especially my uncle Ato Yemane Tewelde and his wife W/ro Abeba Mola for their continuous support.

I am very thankful to Federal Police Criminal Directorate Director, Addis Ababa Police Commission and Nifas Silk Lafto Sub City Police Commission Staffs for their technical and professional help.

Lastly but not least, my appreciation is to my friends and my colleagues for help throughout the whole process.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AACRA	Addis Ababa City Road Authority
AADT	Annual Average Daily Traffic
AAPC	Addis Ababa Police Commission
AASHTO	American Association of State of Highway and Transport Officials
BDEM	Bureau of Design and Environment Manual
IJTTE	International Journal of Traffic and Transportation Engineering
NSLSC	Nifas Silk Lafto Sub City
NSLSCPC	Nifas Silk Lafto Sub City Police Commission

ABSTRACT

Roundabout is a type of intersection that indirectly provides traffic control without the use of traffic signally. Roundabout can provide safety and traffic flow benefits when compared to stop controlled and signal controlled intersections.

Road traffic accidents at roundabouts in Addis Ababa have increased over the years. This supported by Nifas Silk Lafto Sub City Traffic Police (2003/06) accident statistics, which shows that 16, 38, 89 and 71 both fatal and non-fatal accidents occurred in the years respectively. This problem will continue and it may more difficult in the future due to the rapid growth of population and vehicle numbers in Addis Ababa Therefore, it is essential to evaluate the effectiveness of roundabout in terms of road users' safety and general geometric condition of roundabout.

The aim of this study to assess and evaluate the effectiveness of traffic calming at roundabout with regard to speed and users safety within Nifas Silk Lafto Sub City. This research examined effectiveness of the four roundabouts (Karl, German, City Tip and Kore). This research achieved by carry out a field survey to assess general geometric condition of roundabouts, a questionnaire to users with regard to safety perception and analyzed the data using SPSS. Spot speeds measuring using Laser technology and calculated using equation of 85th percentile speed.

Results indicated that zebra crossing, movement around the roundabout, design of roundabout, sidewalks and guardrails are better safety regarding to pedestrian perception questionnaire. Evaluation of geometric conditions such as geometric configuration, geometry of the elements of a roundabout, pavement marking and pavement condition has a negative influence on driver behavior. In addition, enough confirmation of 85% of the observed vehicles travels at and below entering roundabout such as Karl, German, City Tip and Kore with regard to 46km/h, 54km/h, 65km/h and 55km/h respectively below AACRA speed limit is 60km/h except City Tip roundabout. Therefore, drivers have good driving behavior change due to typically slowdown and good communication with other road users with regard to speed .

Keywords :(Roundabout, Effectiveness Perception, Spot speed study and Safety).

1. INTRODUCTION

1.1. Background

Roundabout is a type of intersection that indirectly provides traffic control without the use of stop signs or traffic signals. These roundabouts, if properly designed, can provide safety and traffic flow benefits when compared to stop controlled and signal controlled intersections. Due to the safety and operational benefits that roundabouts provide, they become increasing. This increase in roundabout construction has prompted an increase in research regarding roundabout effectiveness and how they affect the various aspects of transportation systems (Mcintosh, 2011).

Therefore, Roundabout is one of traffic calming device to create circular flow pattern to reduce vehicle-to-vehicle conflict at intersections and to reduce vehicle speeds. Besides, Left turns are not interfering to through traffic and vehicles enter under yield control instead of stop control then they have lower headways and higher capacities.

Addis Ababa has different types of roundabouts within ten sub city. As well as, constructed with different topography, design type and traffic flow. Hence, they are appropriate with regard to design, safety and traffic flow when comparing with other traffic calming measures intersections. Due to the safety and operational benefits, that roundabout become increasingly in number in Addis Ababa in recent years. This increase in roundabout construction has prompted in research regarding roundabout effectiveness.

Nifas Silk Lafto sub city is select as case study. The district is located in the southwestern part of the Addis Ababa. It bounded by Kolfe Keranio, Lideta, Kirkos, Bole and Akaky Kaliti sub cities. This sub city has eleven roundabouts at different wereda shown table1.1below.

The number of motor vehicles is rapidly increasing in our country as all over the world. This exposed a traffic flow for roads, which they were subjected to a pressure exceeding the capacity of them (Dömnez, 2012).Therefore, in Addis Ababa, the number of vehicles as well as pedestrians is increasing by 2.1% number of vehicles and 3.8% annual growth rate of population . From ten sub cities, Nifas Silk Lafto Sub City selected due to high number of roundabouts, passing heavy traffic and high number of pedestrians flow around them.

Table 1-1 Roundabouts in Nifas Silk Lafto sub city

Item number	Name of roundabout	Location
1	Haile Garment	Wereda 1
2	Jemmo	Wereda 1
3	Mekanisa Lebu	Wereda 1
4	Varnero	Wereda 1
5	German	Wereda 2
6	City Tip	Wereda 2
7	Kore	Wereda 2
8	Karl	Wereda 3
9	Epharm	Wereda 3
10	Abo Mazoria	Wereda 3
11	Gofa Gebreil	Wereda 6

1.2. Statement of the problems

In Addis Ababa uses of roundabouts as a way of to improve intersections performance refer to benefits including less server crashes than other intersections crashes; increased traffic capacity demand , improve traffic flow and have aesthetics values. Now days it is road traffic accidents in Addis Ababa have increased over the years. This is supported by Nifas Silk Lafto Sub City Traffic Police (2003/06) accident statistics, which shows that 16, 38, 89 and 71 both fatal and non-fatal accidents occurred in the years respectively. This problem will continue and it may more difficult in the future due to the rapid growth of population and vehicle numbers in Addis Ababa. Therefore, it is essential to evaluate the effectiveness of roundabout in terms of road users' safety and general geometric condition of roundabout.

1.3. Research objectives

Traffic calming schemes that generally incorporate physical measures such as speed breaker, roundabout, road narrowing are design to reduce vehicle speeds. This research attempted only roundabout to evaluate the effectiveness within Nifas Silk Lafto Sub City.

The general objective of this research is-

- ✓ To assess and evaluate the effectiveness of traffic calming at roundabout in existing road network.

The specific objectives are-

- ✓ To evaluate perception of pedestrians towards roundabouts with regard to safety.
- ✓ To assess driving behavior changes when entering the roundabout in terms of speed change.
- ✓ To assess roundabout safety index.

1.4. Methodology

The methodology of this thesis has three parts: a field survey for verify geometric condition of roundabout, questionnaire for both drivers and pedestrians with regard to safety and spot speed study to collect speed data. The methodology detail is illustrated in Figure 1.1.

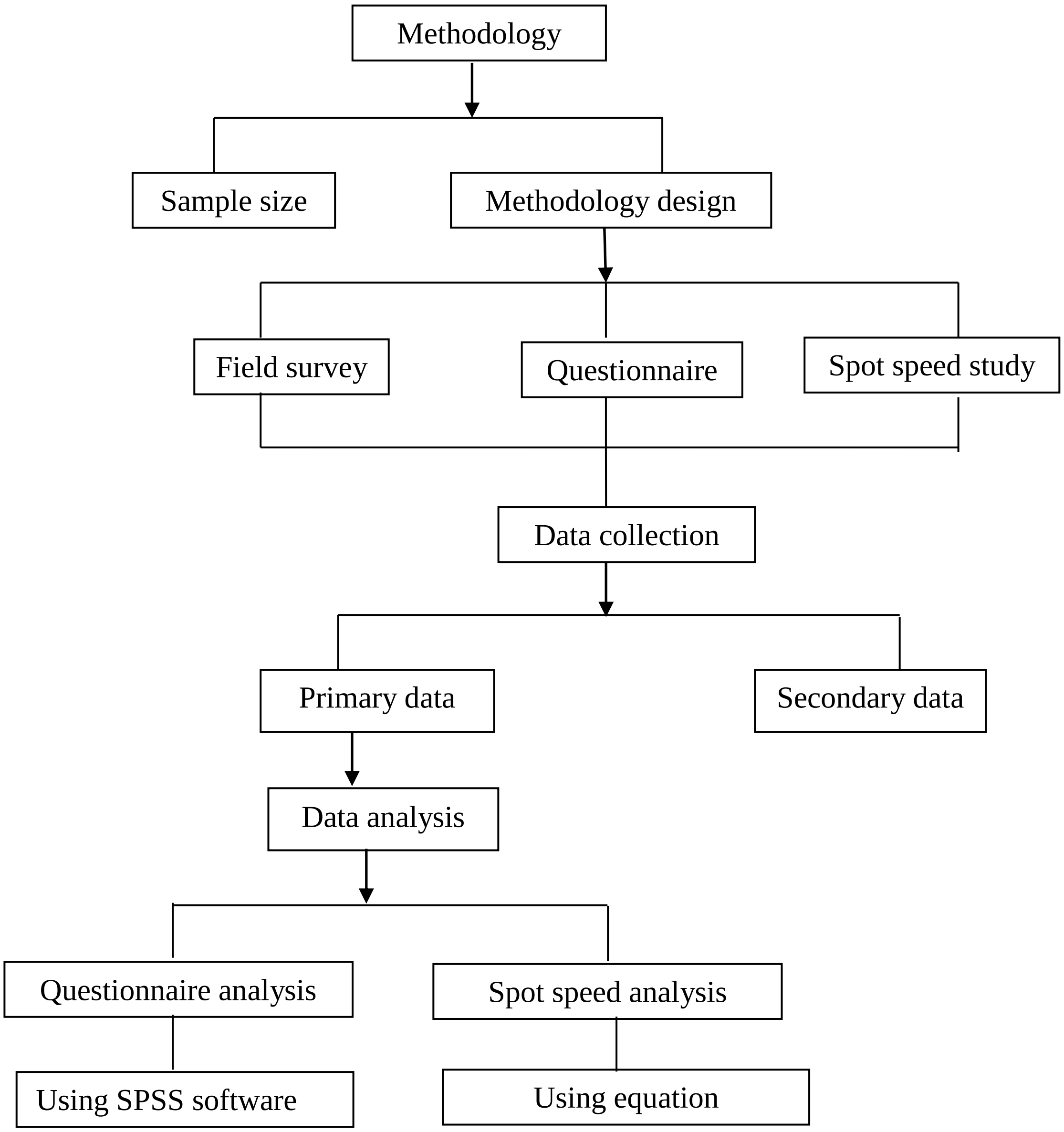


Figure 1.1 Methodology detail

1.5. Scope of the study

This study is mainly concerned with evaluation of effectiveness of traffic calming at roundabout in Nifas Silk Lafto sub city. The primary purpose of roundabout is to reduce the number of accidents by reducing vehicle speed without enforcement of drivers and reducing accidents of pedestrians. Therefore, the motivation of the study can be state as follows:

- ✓ The study restrained to a particular sub city, it could be helpful to have a deeper knowledge about the traffic calming in general and roundabout in particular.
- ✓ The findings obtained from the study would be helpful to gain information and knowledge about the pedestrian safety, appropriate drivers speed at approaches of roundabout and to build up roundabout reduce the number accident with encouraging properly geometric elements.
- ✓ Finally, it also helps to carry out further research to refine the conceptual and methodology of the present study.

1.6. Limitation

One of the main objectives of this thesis is assess and evaluate the effectiveness of traffic calming at roundabout within Nifas Silk Lafto sub city. To do such kind of research, one will obviously need to collect primary and secondary source of data. However, due to due to lack of technical person to collect spot speed data and lack of relevant and up to date information's or data is from different authorities, the research focused on selected roundabouts and road users.

1.7. Structure of thesis

This thesis consists of five chapters and an appendix. Chapter 1 is an introduction to the research and includes seven sections such as background, statement of the problem, research objectives, methodology, scope of study, limitation and structure of thesis. Chapter 2 discusses the theoretical framework for the study. Chapter 3 presents the research methodology in detail. Chapter 4 focuses on the analysis and results. Chapter 5 focuses conclusions and recommendations of the research. Appendix A contains questionnaires and Appendix B contains spot speed study**.**

2. LITERATURE REVIEW

In this context, the development and hypothesis of Traffic calming at roundabout can be examine. Firstly, what is the philosophy of traffic calming is verify. Secondly, roundabout described. Thirdly, Effectiveness of roundabout ideas explained. Finally, Effectiveness measures at roundabout with different perspective defined.

2.1. Overview of traffic calming

Traffic calming is the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alternative driver behavior, improve conditions for non-motorized street users, and improve conditions for no motorized street users. It also applies to a number of transportation techniques developed to educate the public and provide awareness to unsafe driver behavior. In addition, a systematic planning and evaluation procedure was developed to help in the assessment and selection of different calming measures. The procedure accounts for characteristics such as road hierarchy, area characteristics, environmental concerns, cost and ease of maintenance, and user safety (Mobushar, 1999).

Traffic calming is a way of reducing vehicle speeds by self-enforcing traffic engineering methods and is commonly applied in urban and residential road safety management and in the road safety management of through routes in towns and villages.

The main changes in accident types after installation of the traffic calming schemes are:

- ✓ Pedestrian accidents decreased in all categories, particularly fatal accidents
- ✓ Single vehicle accidents increased very slightly in number, but there was a reduction in severity
- ✓ Head-on accidents decreased in number and severity
- ✓ Rear-end accidents decreased in number and severity (Finbarr and Anne, 1996).

Transportation engineers, initially through the identification of areas with a high probability of accidents and then through the protection of paths with the introduction of the traffic calming device more suited to the features of the study area. This tool will also be useful to officers and technicians of public authorities in the definition of regulations and design criteria for urban roads to contribute to the sustainable development of towns. More specifically by using simulation to overcome analytical models assumptions to analyze in detail any geometric and functional configuration for a possible intervention to reduce traffic speed and to evaluate the probability of pedestrian collision and for identifying and positioning traffic calming devices (As IJTTE, 2012).

Therefore, extremely speed and numerous vehicles are common objections in Addis Ababa city. To address these problems, many authorities were inducing to adopt apparently easy solutions, such as installing stop signs. Installation of stop signs without proper warrants is never recommending. As a result, traffic calming recommends an alternative solution. Traffic calming involves physical alterations to a road, which cause or encourage motorists to decrease driving speed and increasing pay attention to the driving task In order to reduce speeds, volumes and collision severity need for improving safety of pedestrians and improving access for all traffic calming measures.

2.2. Roundabouts: theory and classifications

Modern Roundabouts were first introducing in the early 1960s in England. These facilities were introduced in order to solve the problems of the existing rotaries and traffic circles. Using the principal that entering traffic yields to circulating traffic, or the “give way” rule, roundabouts proved to be a much more efficient intersection than the rotaries, and in many cases, signalized intersections (Erik, 2001).

Roundabouts are neither feasible nor appropriate at all intersections. Sufficient right-of-way must be available. Typically, a modern roundabout has an outer diameter of approximately 100 feet (30 m). This allows for large enough deflections to reduce speeds to an appropriate level. However, more land can be saved with a roundabout than with signalization, because approach roads can be kept narrower. Capacity constraints and limited rights-of-way eliminate from consideration many busy urban intersections, especially those located in central business districts. Crash reductions resulting from conversion of conventional intersections to modern roundabouts can be attributed primarily to 2 factors: reduced traffic speeds and elimination of specific types of motor vehicle conflicts that frequently occur at angular intersections. These conflicts include left turns against opposing or oncoming traffic, front-to-rear conflicts (often involving the lead vehicle stopping or preparing to stop for a traffic signal or stop sign), and right-angle conflicts at traffic signals and stop signs (Richard A et al, 2001).

Modern roundabouts provide substantially better operational and safety characteristics than older traffic circles and rotaries. Therefore, many countries have adopted them as a common intersection form and some have developed extensive design guides and methods to evaluate the operational performance of modern roundabouts (BDEM, 2013).

Roundabout is a one-way circular intersection without traffic signals in which traffic flows around a center island. Roundabouts feature yield control for all entering traffic, channelized approaches and appropriate geometric curvature to ensure that travel speeds on the circulatory roadway are typically less than 48.28 km/h. Roundabouts must designed to meet the needs of all users: drivers, pedestrians, pedestrians with disabilities and bicyclists. When designing roundabouts, special considerations must give to the needs of pedestrians with visual disabilities who are unable to judge adequate gaps in traffic at roundabouts. Proper site selection and pedestrian channelization are essential to making roundabouts accessible to all users. Roundabouts can also design for trucks and larger vehicles (Bruce *et al*, 1999).

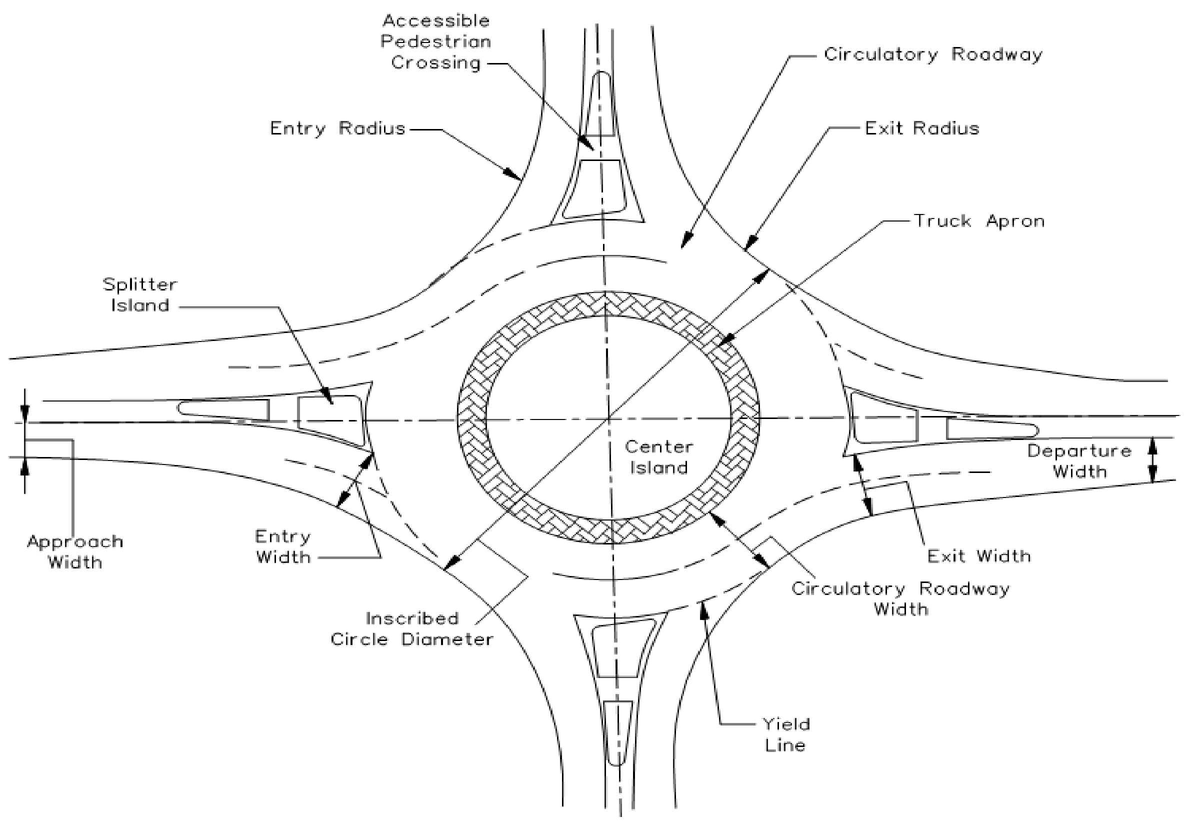


Figure 2.1 Basic geometric elements of roundabout (BDEM, 2013)

Classification of roundabout based on number of lanes is single lane, multilane and mini (BDEM, 2013).

- ✓ A single-lane roundabout can be assumed to operate acceptably if the sum of the entering and circulating volumes for each approach is less than 1000 V/H. Maximum entering design speeds based on a theoretical fastest path of 32 Km/h to 40 Km/h are recommended at single-lane roundabouts. Generally, the diameter of the inscribed circle of a single-lane roundabout ranges from 32 m to 46 m.
- ✓ Multilane roundabouts have at least one approach with at least two lanes on the entries or exits. At multilane roundabouts, maximum entering design speeds of 40 km/h to 48 km/h are recommended. Generally, the inscribed circle diameter of a multilane roundabout ranges from 46 m to 76 m. Roundabouts with three-or four-lane entries may require larger diameters of 55 m to 100 m to achieve adequate speed control and alignment.
- ✓ The mini roundabout is smaller than the typical single-lane roundabout. The smaller diameter is made possible by the use of a fully traversable central island to accommodate large vehicles, as opposed to the typical single-lane roundabout where the diameter must be large enough to accommodate a multi-unit within the circulatory roadway (and truck apron if applicable) without it needing to travel over the central island.

Classification of roundabout based on application (Thaweesak, 1998).

- ✓ Normal Roundabout: a roundabout with a one-way circulating roadway around a curbed central island 4 m (13 ft) or more in diameter.
- ✓ Mini or Small Roundabout: a roundabout with a one-way circulating roadway around a flush or slightly raised circular island less than 4 m (13 ft) in diameter.
- ✓ Double Roundabout: a single intersection with two normal or mini-roundabouts either contiguous or connected by a central link road or curbed island.
- ✓ Ring Junction: a two-way circular ring road that is access by external spoke roads by way of 3-leg mini-roundabouts or T-intersections.
- ✓ Roundabout Interchange: an interchange with one or more roundabouts. The most common types area freeway passing over or under one large roundabout which is joined

by ramps and the cross street, and a roundabout at the ramps intersection with the cross street.

- ✓ Signalized Roundabout: A roundabout in which traffic signals regulate one or more of the entries.

Therefore, roundabout is rotary intersections begin experiencing problems with congestion and safety. Besides, circular intersection forms have been part of the transportation system in the Addis Ababa. Supplementary, classification of roundabout is many regards to different application. However, for this research the above classification is enough to classify the selected roundabouts. Therefore, consider the above classification the selected roundabout classified based on number of lanes and sub divided as multilane type.

2.3. Effectiveness of roundabout for users

For roundabouts to perform effectively they must be easily identified in the road system, the layout must be apparent to approaching drivers and the approaches must encourage drivers to enter the intersection slowly. Adequate sight distance should be provided to enable drivers to observe the movements of other vehicles, cyclists, and pedestrians (AACRA, 2003).

Operation is difficult without reliable analytical models, planners and engineers must utilize to estimate of effectiveness. The total vehicle delay will be significantly reduced through implementation at roundabout at five-way intersection. The use of roundabouts is a proven safety strategy for improving intersection safety by eliminating or altering conflict types, reducing crash severity, and causing drivers to reduce speeds as they proceed into and through the intersections. This is true for urban, suburban, and rural environments in replacing two-way stop and signal controls. While overall crash frequencies have been reduced, the crash reductions are most pronounced for motor vehicles, less pronounced for pedestrians, and equivocal for bicyclists and motorcyclists depending on the study and bicycle treatments Therefore, roundabouts are effective type of traffic calming with fewer conflict points and lower speeds, and they provide for easier decision-making. Thus, are traffic-calming effect by reducing vehicle speeds using geometric design rather than relying exclusively on traffic control devices.

User behavior is dividing into two driver and pedestrian (Reuben, 2008).

A) Driver behavior

Common effects of being fatigued while driving are lack of attention, poor vigilance and perhaps even falling asleep behind the wheel. To avoid any ambiguity or misunderstanding a behavioral state is defined as follows: A behavior state is a condition (an emotional condition, mood or condition of fatigue or intoxication) that the driver finds himself in, that has a substantial effect on the way that the person drives. A driver in this state exhibits behavior that can be attributed to being overworked. Drivers' perception is various sensory organs these can be referred to as channels receive information about the world around us. Perception deals with extraction and analyses of raw sensory data in such a way that meaningful information is produced that can be used for further mental processing. There are many factors that can degrade the level of perception or how well something is perceive such as weather conditions, intoxication, age and the affective state of the driver (Neil E, 2008).

Observational and questionnaire surveys were conducted to assess how the proposed roundabout marking system affected driver behavior, level of service, and safety performance. Generally, drivers preferred the spiral-marking roundabout to conventional roundabouts, especially after trailing the new marking system. Inexperienced drivers, in particular, appreciated the spiral-marking system because of the increased safety level, reduced congestion level, and increased ease of navigation (S.C.Wong *et al*, 2012).

Drivers' behavior with respect to different road events, such as different curve radii, roundabouts or road altitude variation, is assessed in relation to driving-efficiency. Finally, drivers are ranked with respect to driving-efficiency using a grading system based on relevant driving parameters. the ability to limit the speed variations was the most important for driving-efficiency, as expected, but also the variations of angle on both throttle and brake pedals were identified as relevant. This work can be used as a platform for application of similar methods to larger sets of data and preferably using naturalistically collected driving. Therefore, the speed at which drivers choose to drive in various road and traffic conditions is an important to verify characteristic of their behavior and better understanding of the variety of those factors that influence the driver's speed choice (Cecilia and Lina , 2013).

B) Pedestrian behavior

A greater emphasis on rigorous pedestrian education is necessary to compliment improved design of crossing treatments for modern roundabouts. Road authorities have proven capability to mandate improved engineered designs for pedestrian crossing treatments, but improving pedestrian assertiveness should also be evaluated for its effectiveness in pedestrian accessibility to roundabout intersections. Therefore, crossing at modern roundabouts is challenging due to the established curved vehicle trajectories and complicated by the absence of a pedestrian signal at most crossings and the capacity to respond to pedestrian safety is an important component of efforts to prevent road traffic injuries. Most pedestrian are not consider preventing from accident at crossing roundabouts because they believe drivers awareness. (Mark *et al*, 2010).

2.4. Effectiveness measures at roundabout

Spot Speed studies are conducting to estimate the distribution of speeds of vehicles in a stream of traffic at a particular location on a highway by carried out recording the speeds of a sample of vehicles at a specified location. Spot speed data are gathering using Laser technology. This technology is selecting because it is the latest one have Federal police commission also.

Laser Technology is velocity speed gun is able to measure automobile speeds between 0 and 320km/h from maximum measurement distance as far as 1,200 meters. To ensure accurate readings, the path of the emitted radar from the device must coincide with the path of the automobile as closely as possible. Error increases as the angle of the reading diverges from the vehicle path. By attempting to approximate a straight-on path of measurement, readings have an accuracy of ±2 km/h (Laser technology manual, 2013).

Speed percentile was tools used to determine effective and adequate speed limits. The speed percentile most important to understand was 85th percentile speeds. The 85th percentile is the speed at which 85% of the observed vehicles are traveling at or below speed. This percentile is used in evaluating/recommending posted speed limits based on the assumption that 85% of the drivers are traveling at a speed they perceive to be safe .In other words, the 85^{th} percentile of speed is normally assumed to be the highest safe speed for a roadway section (Garber and Hoel,2009).

Body of Laser Technology (Source: Google)

Conflict points occur, where one vehicle path crosses, merges with, diverges from, or queues behind, the path of another vehicle, a pedestrian. Conflicts occur at dual-lane roundabouts are generally low-speed sideswipe conflicts that typically have low severity. Therefore, although the number of conflict points increases at multilane roundabouts when compared with a single-lane roundabout, the overall severity of conflicts is generally less than with alternative intersection control. There are more potential conflicts in case of dual-lane intersections with four dual-lane approaches 16 pedestrian-vehicle conflicts (Rana Salah-ud.D, 2009).

In the Addis Ababa, street design has evolved to accommodate the needs of vehicles, often at the expense of pedestrian needs. According to the Addis Ababa Police Commission (AAPC), traffic crashes caused 1360 injuries and 336 deaths in 2006 E.C. However, the total number of traffic-related fatalities increased since 2003 but traffic fatalities have little variation since 2003, fatalities have consistently represented 32% to 42% of the total accidents Addis Ababa may be more dangerous than other cities upon looking into the demographics of crashes. It is clear that Young age 18-30 and 31-50 two groups may be more likely to walk places, are particularly at risk.

In 2005,The 18-30 and 31-50 age group represented 43% and 26% respectively of all injured in traffic crashes; meanwhile, the 51 and up group represented 15% of all fatalities (AAPC, 2006).Therefore, analysis statistics indicates that fatality rate per vehicle registered and non-fatality per vehicle registered in Nifas silk lafto sub city police commission at roundabout is shown in table 2.1 and figure 2.2.

Table 2.1 Accidents from 2003 up to 2006 at roundabout (NSLSCPC, 2006).

Years	Fatal injuries(number)	Non-fatal injuries (number)	Total injuries (number)
2003	12	4	16
2004	22	16	38
2005	39	50	89
2006	41	30	71

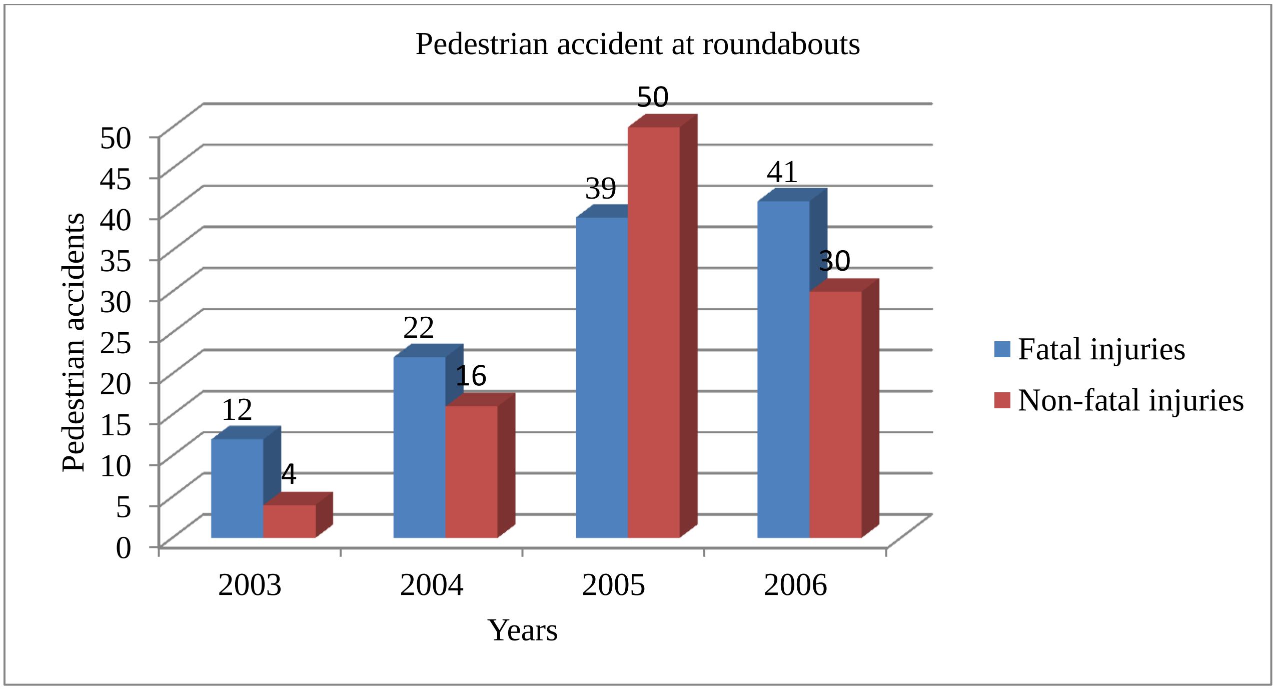


Figure 2.2 Accidents at roundabouts (NSLSCPC, 2006).

3. METHODOLOGY

The method of this thesis consists of three major components. The first component using field survey includes assessing the general geometric condition with respect to AACRA standards. The evaluation include general geometric configuration, geometry of the elements of a roundabout and road users facilities. Second, a questionnaire includes asking both pedestrians and drivers with regard to experience and safety perception. Lastly, spot speed study to collect speed data using laser technology.

3.1. Sample size method

Sample size of pedestrians and drivers is determined by using Eq.3.1, sample size is determining. Therefore, the researcher desired to estimate, with 95% confidence, the proportion of people asking a questionnaire. Then, statistician assign the values $\hat{p}$ =0.5 and$\hat{q}$=0.5 (Bluman, 2009). The sample size obtained by using these values will be large enough to ensure the specified degree of confidence. Hence, the researcher desired to be accurate within 5% of the true proportion.

$$n = \hat{p}\hat{q}\left(\frac{z\alpha/_{2}}{E}\right)^{2} \text{ ....Eq.3.1}$$

$z_{\alpha/2}$=1.96

α=1- confidence interval

E=5%

Where:

$\hat{p}$ =sample proportion

$\hat{q}$=1-$\hat{p}$

$z_{\alpha/2}$= 95% of confidence interval

E= 5% maximum error of the estimate

Substitute in equation 3.1. Then it gives this result for drivers and pedestrians

n=384

Hence, sample size of pedestrians and drivers is 384 in numbers for each. In order to select sample size of roundabouts the researcher first assessed the areas in the sub city for short period. Besides, there are 11 numbers of roundabouts and one-third of total roundabouts are taking as a sample size. Therefore, sample size is four roundabouts with regard to clear topography to collect spot speed data.

3.2. Data collection

Data for this collected from two sources, these sources are primary and secondary data. Several techniques were employed to collect primary data. Field survey, questionnaire and spot speed study. The field survey was performed to make general observations about roundabout general condition and to identify general condition of roundabout appropriate for road users. Questionnaire is conduct with pedestrians and drivers. Besides, pedestrians and drivers' asking questionnaire around roundabout and at a station that is conventional for stopping area respectively.

The selected roundabouts collected speed data such as Karl, German, City Tip and Kore square roundabouts in Nifas Silk Lafto sub city. Spot speed collected from crossing vehicles along roundabouts using equipment (Laser Technology) during non- peak hour of between 3:30am and 4:00 am local time morning.

Karl roundabout collected on Wednesday, April 28, 2015, German roundabout collected on Thursday, April 29, 2015, City Tip roundabout collected Monday, May 5, 2015 and Kore roundabout collected on Wednesday, May 6, 2015.

The secondary data sources were accident data and AADT. These data for accident and AADT were collected from the police files of Nifas Silk Lafto sub city and AACRA respectively.

3.3. Data analysis

The methodologies employed to analyze the data were both qualitative and quantitative methods.

The questionnaire characterized by close ended questions such as yes or no answers this questionnaire guide is prepare to collect individuals safety perception of roundabout and analyzing the data using SPSS. Thus, the organized data are interpreted in tables.

Field survey demonstrates in order to compare roundabout geometric condition with respect to AACRA manual standard using Auto-cad. The evaluation include general geometric configuration, geometry of the elements of a roundabout and facilities of road users. The second data that is collected in the field using spot speed study and the analysis of speed of vehicles using 85% formulas.

4. ANALYSIS AND RESULTS

Analysis and results includes field study result, questionnaire analysis and results, and spot speed analysis and results. First, field study results to describe about the selected roundabouts. Second is questionnaire analysis and results. Third, spot speed analysis and results. Lastly, comparison each of roundabout is describing.

4.1. Field survey results

General Geometric Configuration of Karl roundabout

A) Number of legs

Roundabout can have between three and six legs. Furthermore, it is always preferable to add a leg to the roundabout rather than maintain or create a secondary intersection nearby. Therefore, AACRA manual limit to a maximum of four legs with legs at approximately 90° for multi-lane roundabouts. Karl round about is a four-leg intersection. This is in the standard limit.

B) Arrangement of the Legs

The central island is optimally located when all the axes of the legs cross through the center of the roundabout. Since this configuration is not always possible, the island should first be center on the main axis. On Karl roundabout, all approach legs have symmetrical arrangement of legs.

Geometry of the elements of Karl roundabout

According to general observations, the main geometric elements of this roundabout are central island, circulatory roadway, splitter island, truck apron, crosswalk marking (zebra crossing) and sidewalks see in figure 4.1. Similarly, it connected by dual carriageways of each direction then, geometric elements, as recommend by AACRA in order to achieve safe and efficient operation are present in Table 4.1.

Table 4.1 Comparison of current condition of Karl roundabout with AACRA Standard

No.	Geometric Elements	Current Condition	AACRA standard
1	Central island diameter	26m	See table 4.2
2	Roundabout lanes	Two lanes	Maximum 2
3	Number of exit lanes	Three lanes	Not more than circulating lane
4	Circulating carriageway width	Around 11m	See table 4.2
5	Entry and exit lane width	Around 4m	3.4 - 4.0m lane width
6	Splitter island	yes	
	Length	15m,17m and 18m	Minimum 2.4m
	Area	>10m^2	8 - 10m^2

Table 4.2 Initial selection of minimum central island diameters of two lane roundabouts (AACRA, 2003).

Speed environment (km/h)	Central island diameter (m)	Circulating width (m)
40	15	11.10
50	15	11.10
60	25	10.30
70	30	10.00
80	40	9.60
90	40	9.60
100	40	9.60

Karl roundabout has a diameter round 26m, which is usable with design speed environment of around 60km/hr.

Significant observations of the field survey are detail as following:

- ✓ Relatively high traffic volumes and low pedestrian volumes during observation period.
- ✓ Central island flat and landscaped.
- ✓ All approaches have adequate intersection sight distance, allowing drivers to see conflicting traffic (from the left) from long distances.
- ✓ No yield signs were present in all directions

Pedestrians' facility

A pedestrian crossing is a point on a road where pedestrians traverse the road. Pedestrian crossings, sometimes referred to as crosswalks, found at intersections or along road stretches. Marked crossings are designate by markings on the road, commonly white stripes. Pedestrians need only cross one direction of traffic at a time at each approach as they traverse roundabout.

Pedestrians at roundabout, face two conflicting vehicular movements on each approach conflict with entering vehicles; and conflict with exiting vehicles. In addition roundabout intersections with multiple approach lanes, an additional conflict is added with each additional lane that a pedestrian must cross.

Pedestrians are accommodating at pedestrian crosswalks around the perimeter of the roundabout. By providing space to pause on the splitter island, pedestrians can consider one direction of conflicting traffic at a time, which simplifies the task of crossing the street. The low vehicular speeds through a roundabout also allow more time for drivers and pedestrians to react to one another and to reduce the consequences of error. For pedestrian safety, wide and rapid entrances (and exits) should avoid. At the entrance of the crosswalks, the sidewalk curb should be lower and a refuge should be design on the splitter islands involved.

Therefore, the pedestrian facility is well providing in all approach legs but from Lideta entry pedestrian did not see coming vehicle from far because have high slope.

Drainage and pavement marking

Drainage with the circulatory roadway sloping away from the central island, inlets generally placed on the outer curb line of the roundabout. However, inlets may be required along the central island for a roundabout designed on a constant grade through an intersection. As with any intersection, inlets are not place in crosswalks. If the central island is large enough, the designer may consider placing inlets in the central island. Low points on approach roadway profiles should be beyond a raised corner island to prevent water from being trapped and causing ponding. Therefore, Karl roundabout have drainage system but it is not functional.

Pavement markings used in work zones should be the same layout and dimension as those used for the final installation. Because of the confusion of a work area and the change in traffic patterns, additional pavement markings used clearly show the intended direction of travel. Therefore, needs improvement pavement markings to get drivers in correct lane before entering roundabout.

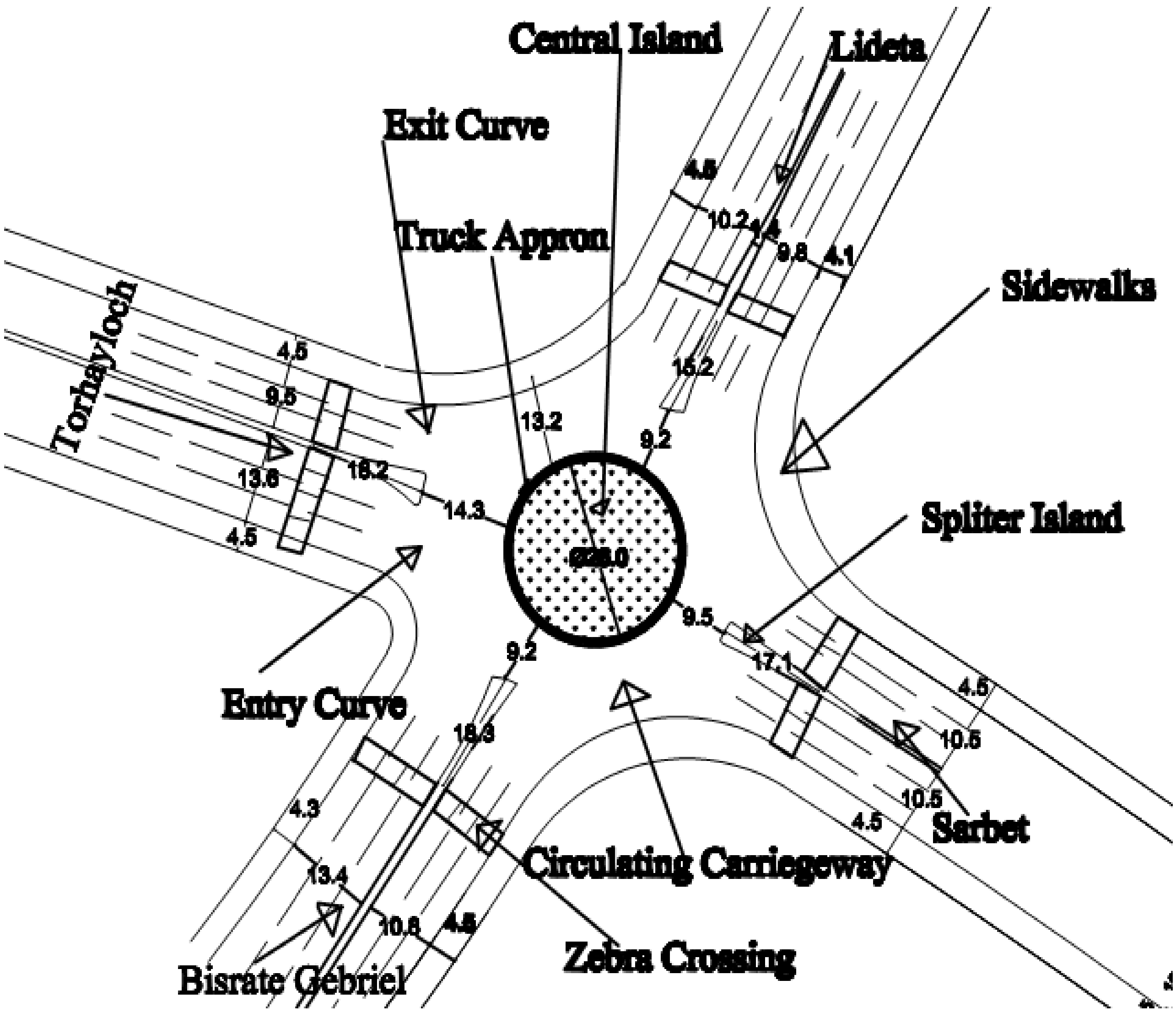


Figure 4.1 Geometric elements of Karl roundabout

General Geometric Configuration of German roundabout

A) Number of Legs

Roundabout can have between three and six legs. Furthermore, it is always preferable to add a leg to the roundabout rather than maintain or create a secondary intersection nearby. AACRA manual limit to a maximum of four legs with legs at approximately 90° for multi-lane roundabouts. German round about is a five-leg intersection. This is beyond the standard limit.

B) Arrangement of the Legs

The central island is optimally located when all the axes of the legs cross through the center of the roundabout. Since this configuration is not always possible, the island should first be center on the main axis. On German roundabout, the approach leg from Mekanisa produces undesirable tangential entrance and a sight off to the left.

Geometry of the elements of German roundabout

According to general observations, the main geometric elements of this roundabout are central island, circulatory roadway, splitter island, truck apron, crosswalk marking (zebra crossing) and sidewalks see in figure 4.2. Similarly, it connected by dual carriageways of each direction then, geometric elements, as recommend by AACRA in order to achieve safe and efficient operation are present in Table 4.3.

Table 4.3 Comparison of current condition of German roundabout with AACRA Standard

No.	Geometric Elements	Current Condition	AACRA standard
1	Central island diameter	51m	See table 4.2
2	Roundabout lanes	Three lanes	Maximum 2
3	Number of exit lanes	Two and three lanes	Not more than circulating lane
4	Circulating carriageway width	Around 20m	See table 4.2
5	Entry and exit lane width	Around 3.8m	3.4 - 4.0m lane width
6	Splitter island	yes	
	Length	13m,18m ,25m,29m and 30m	Minimum 2.4m
	Area	>$10m^2$	8 - $10m^2$

German roundabout has a diameter mere than 51m, which is much beyond the maximum requirement. Therefore, as recommend by AACRA manual diameter increased with regards tp the following conditions:

- ✓ The roundabout has more than four legs.
- ✓ The angle between any adjacent roundabout legs is considerably less than or greater than 90^0
- ✓ There are shoulders and no kerb on some or all of the carriageways.
- ✓ There are medians on the some of the approaches
- ✓ Circulating carriageways is greater width than that shown in table 4.2.

Significant observations of the field survey are detail as followed:

- ✓ Relatively high traffic volumes and high pedestrian volumes during observation period
- ✓ Central island flat, landscaped
- ✓ Some approaches have adequate intersection sight distance, allowing drivers to see conflicting traffic (from the left) from long distances
- ✓ All yield signs were present in all directions

Pedestrians' facilities

A pedestrian crossing is a point on a road where pedestrians traverse the road. Pedestrian crossings, sometimes referred to as crosswalks, found at intersections or along road stretches. Marked crossings are designate by markings on the road, commonly white stripes. Pedestrians need only cross one direction of traffic at a time at each approach as they traverse roundabouts.

Pedestrians at roundabouts, face two conflicting vehicular movements on each approach conflict with entering vehicles; and conflict with exiting vehicles. In addition roundabout intersections with multiple approach lanes, an additional conflict is added with each additional lane that a pedestrian must cross.

Pedestrians are accommodating at pedestrian crosswalks around the perimeter of the roundabout. By providing space to pause on the splitter island, pedestrians can consider one direction of conflicting traffic at a time, which simplifies the task of crossing the street. The low vehicular speeds through a roundabout also allow more time for drivers and pedestrians to react to one another and to reduce the consequences of error.

Therefore, for pedestrian safety, wide and rapid entrances (and exits) should avoid. At the entrance of the crosswalks, the sidewalk curb should be lower and a refuge should be design on the splitter islands involved. The pedestrian facility is well providing in all approach legs. However, all approach legs pedestrian cross length is large.

From the observation point of view pedestrian crossing behavior are the following:

- ✓ Slow pedestrian speeds or running or hesitating;
- ✓ Jumping the guard grail of sidewalks around roundabouts
- ✓ Pedestrian crossing through after yield line approach to roundabout

Drainage and Pavement marking

Drainage with the circulatory roadway sloping away from the central island, inlets generally placed on the outer curb line of the roundabout. However, inlets may be required along the central island for a roundabout designed on a constant grade through an intersection. As with any intersection, inlets are not place in crosswalks. If the central island is large enough, the designer may consider placing inlets in the central island. Low points on approach roadway profiles should be beyond a raised corner island to prevent water from being trapped and causing ponding. Therefore, German roundabout have drainage system but it is not functional.

The pavement markings used in work zones should be the same layout and dimension as those used for the final installation. Because of the confusion of a work area and the change in traffic patterns, additional pavement markings used clearly show the intended direction of travel. Therefore, needs improvement pavement markings to get drivers in correct lane before entering roundabout.

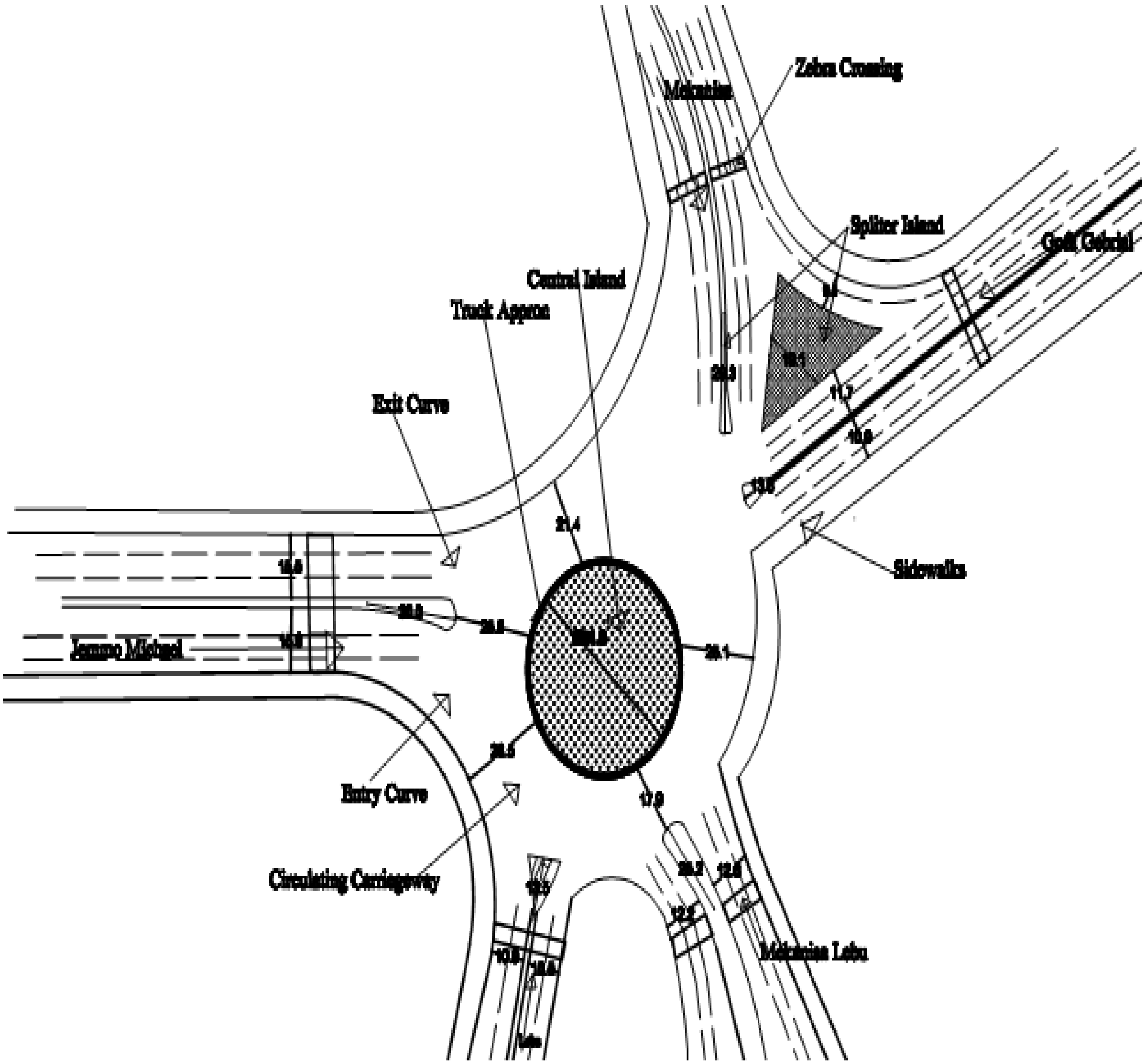


Figure 4.2 Geometric components of German roundabout

General Geometric Configuration of City Tip roundabout

A) Number of legs

Roundabout can have between three and six legs. Furthermore, it is always preferable to add a leg to the roundabout rather than maintain or create a secondary intersection nearby. AACRA manual limit to a maximum of four legs with legs at approximately 90°for multi-lane roundabouts. City Tip round about is a four-leg intersection. This is in the standard limit.

B) Arrangement of the Legs

The central island is optimally located when all the axes of the legs cross through the center of the roundabout. Since this configuration is not always possible, the island should first be center on the main axis. On City Tip roundabout, all approach legs have symmetrical arrangement of legs.

Geometry of the elements of a City Tip roundabout

According to general observations, the main geometric elements of this roundabout are central island, circulatory roadway, splitter island, truck apron, crosswalk marking (zebra crossing) and sidewalks see in figure 4.3. Similarly, it connected by multilane dual carriageways of each direction then, geometric features as recommend by AACRA in order to achieve safe and efficient operation are presented in Table 4.4.

Table 4.4 Comparison of current condition of City Tip roundabout with AACRA standard.

No.	Geometric Elements	Current Condition	AACRA standard
1	Central island diameter	19m	See table 4.2
2	Roundabout lanes	Two lanes	Maximum 2
3	Number of exit lanes	Two and three lanes	Not more than circulating lane
4	Circulating carriageway width	Around 11m	See table 4.2
5	Entry and exit lane width	Around 4m	3.4 - 4.0m lane width
6	Splitter island	yes	
	Length	14m and 17m	Minimum 2.4m
	Area	>10m2	8 - 10m^2

City Tip roundabout has a diameter round 26 m, which is usable with design speed environment of around 55km/hr.

Significant observations of the field survey are detail as followed:

- ✓ Relatively high traffic volumes and high pedestrian volumes during observation period
- ✓ Central island flat
- ✓ Needs improve signing and pavement markings to get drivers in correct lane before entering roundabout
- ✓ Some approaches have adequate intersection sight distance, allowing drivers to see conflicting traffic (from the left) from long distances but fourth approach has curved intersection.
- ✓ yield signs were present in two directions

Pedestrians' facility

A pedestrian crossing is a point on a road where pedestrians traverse the road. Pedestrian crossings, sometimes referred to as crosswalks, may be found at intersections or along road stretches. Marked crossings are designated by markings on the road, commonly white stripes. Pedestrians need only cross one direction of traffic at a time at each approach as they traverse roundabouts.

Pedestrians at roundabouts, face two conflicting vehicular movements on each approach conflict with entering vehicles; and conflict with exiting vehicles. In addition roundabout intersections with multiple approach lanes, an additional conflict is added with each additional lane that a pedestrian must cross.

Pedestrians are accommodating at pedestrian crosswalks around the perimeter of the roundabout. By providing space to pause on the splitter island, pedestrians can consider one direction of conflicting traffic at a time, which simplifies the task of crossing the street. The low vehicular speeds through a roundabout also allow more time for drivers and pedestrians to react to one another and to reduce the consequences of error. For pedestrian safety, wide and rapid entrances (and exits) should avoid. At the entrance of the crosswalks, the sidewalk curb should be lower and a refuge should be design on the splitter islands involved. Therefore, pedestrian facility is well providing in all approach legs.

Drainage and pavement marking

Drainage with the circulatory roadway sloping away from the central island, inlets generally placed on the outer curb line of the roundabout. However, inlets may be required along the central island for a roundabout designed on a constant grade through an intersection. As with any intersection, inlets are not place in crosswalks. If the central island is large enough, the designer may consider placing inlets in the central island. Low points on approach roadway profiles should be beyond a raised corner island to prevent water from being trapped and causing ponding. Therefore, Karl roundabout have drainage system but it is not functional.

Pavement markings used in work zones should be the same layout and dimension as those used for the final installation. Because of the confusion of a work area and the change in traffic patterns, additional pavement markings used clearly show the intended direction of travel. Therefore, needs improvement pavement markings to get drivers in correct lane before entering roundabout.

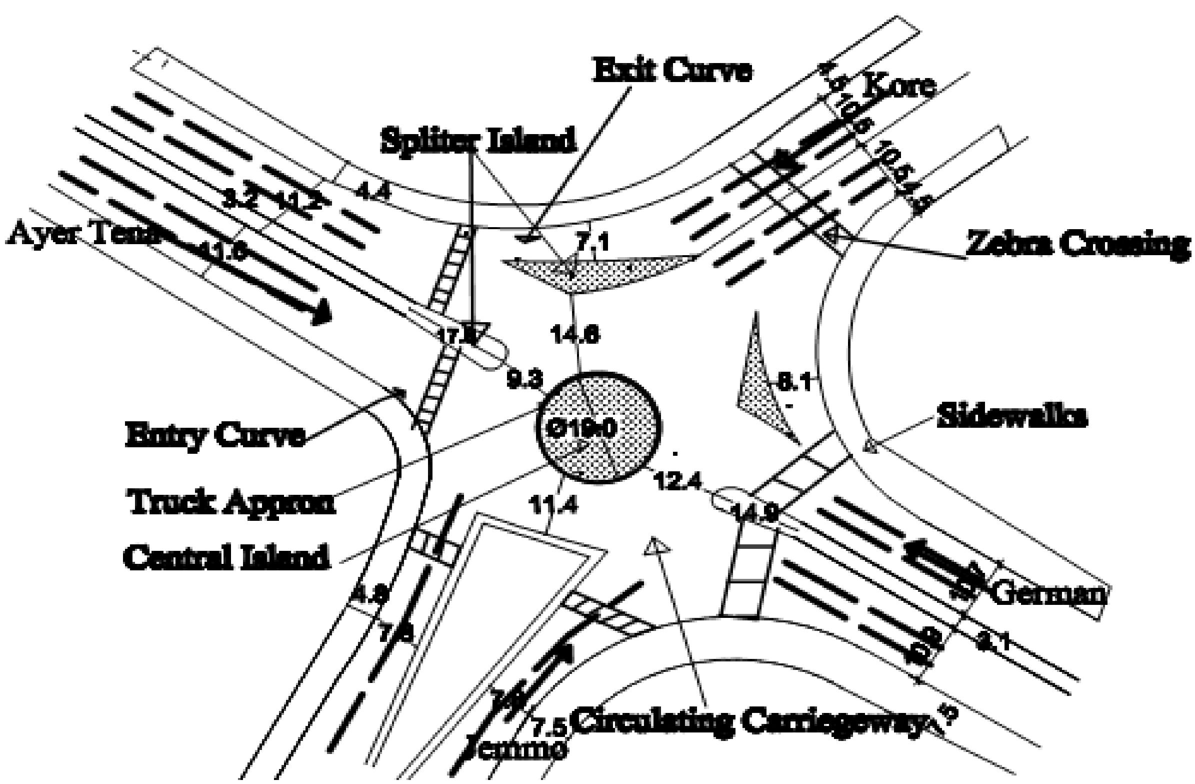


Figure 4.3 Geometric elements of City Tip roundabout

General Geometric Configuration of Kore roundabout

A) Number of Legs

Roundabout can have between three and six legs. Furthermore, it is always preferable to add a leg to the roundabout rather than maintain or create a secondary intersection nearby. AACRA manual limit to a maximum of four legs with legs at approximately 90°for multi-lane roundabouts. Kore round about is a four-leg intersection. This is in the standard limit.

B) Arrangement of the Legs

The central island is optimally located when all the axes of the legs cross through the center of the roundabout. Since this configuration is not always possible, the island should first be center on the main axis. On Kore roundabout, all approach legs have symmetrical arrangement of legs.

Geometry of the elements of Kore roundabout

According to general observations, the main geometric elements of this roundabout are Central Island, circulatory roadway, Splitter Island, truck apron, crosswalk marking (zebra crossing) and sidewalks see in figure 4.4. Similarly, it connected by multilane dual carriageways of each direction then, geometric features as recommend by AACRA in order to achieve safe and efficient operation are presented in Table 4.5

Table 4.5 Comparison of current condition of Kore roundabout with AACRA standard

No.	Geometric Elements	Current Condition	AACRA standard
1	Central island diameter	38m	See table 4.2
2	Roundabout lanes	Two lanes	Maximum 2
3	Number of exit lanes	Two and three lanes	Not more than circulating lane
4	Circulating carriageway width	Around 9m	See table 4.2
5	Entry and exit lane width	Around 4m	3.4 - 4.0m lane width
6	Splitter island	yes	
	Length	20m,27m and 28m	Minimum 2.4m
	Area	>10m2	8 - 10m^2

Kore roundabout has a diameter round 38 m, which is usable with design speed of around80km/hr.

Significant observations of the field survey are detail as followed:

- ✓ Relatively low traffic volumes and low pedestrian volumes during observation period
- ✓ Central island flat
- ✓ Needs improve signing and pavement markings to get drivers in correct lane before entering roundabout
- ✓ All approaches have adequate intersection sight distance, allowing drivers to see conflicting traffic (from the left) from long distances
- ✓ No yield signs in all directions

Pedestrians' facility

A pedestrian crossing is a point on a road where pedestrians traverse the road. Pedestrian crossings, sometimes referred to as crosswalks, may be found at intersections or along road stretches. Marked crossings are designated by markings on the road, commonly white stripes. Pedestrians need only cross one direction of traffic at a time at each approach as they traverse roundabouts.

Pedestrians at roundabouts, face two conflicting vehicular movements on each approach conflict with entering vehicles; and conflict with exiting vehicles. In addition roundabout intersections with multiple approach lanes, an additional conflict is added with each additional lane that a pedestrian must cross.

Pedestrians are accommodated at pedestrian crosswalks around the perimeter of the roundabout. By providing space to pause on the splitter island, pedestrians can consider one direction of conflicting traffic at a time, which simplifies the task of crossing the street. The low vehicular speeds through a roundabout also allow more time for drivers and pedestrians to react to one another and to reduce the consequences of error.

Pedestrians are accommodating at pedestrian crosswalks around the perimeter of the roundabout. By providing space to pause on the splitter island, pedestrians can consider one direction of conflicting traffic at a time, which simplifies the task of crossing the street. The low vehicular speeds through a roundabout also allow more time for drivers and pedestrians to react to one another and to reduce the consequences of error. For pedestrian safety, wide and rapid entrances (and exits) should avoid. At the entrance of the crosswalks, the sidewalk curb should be lower and a refuge should be design on the splitter islands involved. Therefore, pedestrian facility is well providing in all approach legs.

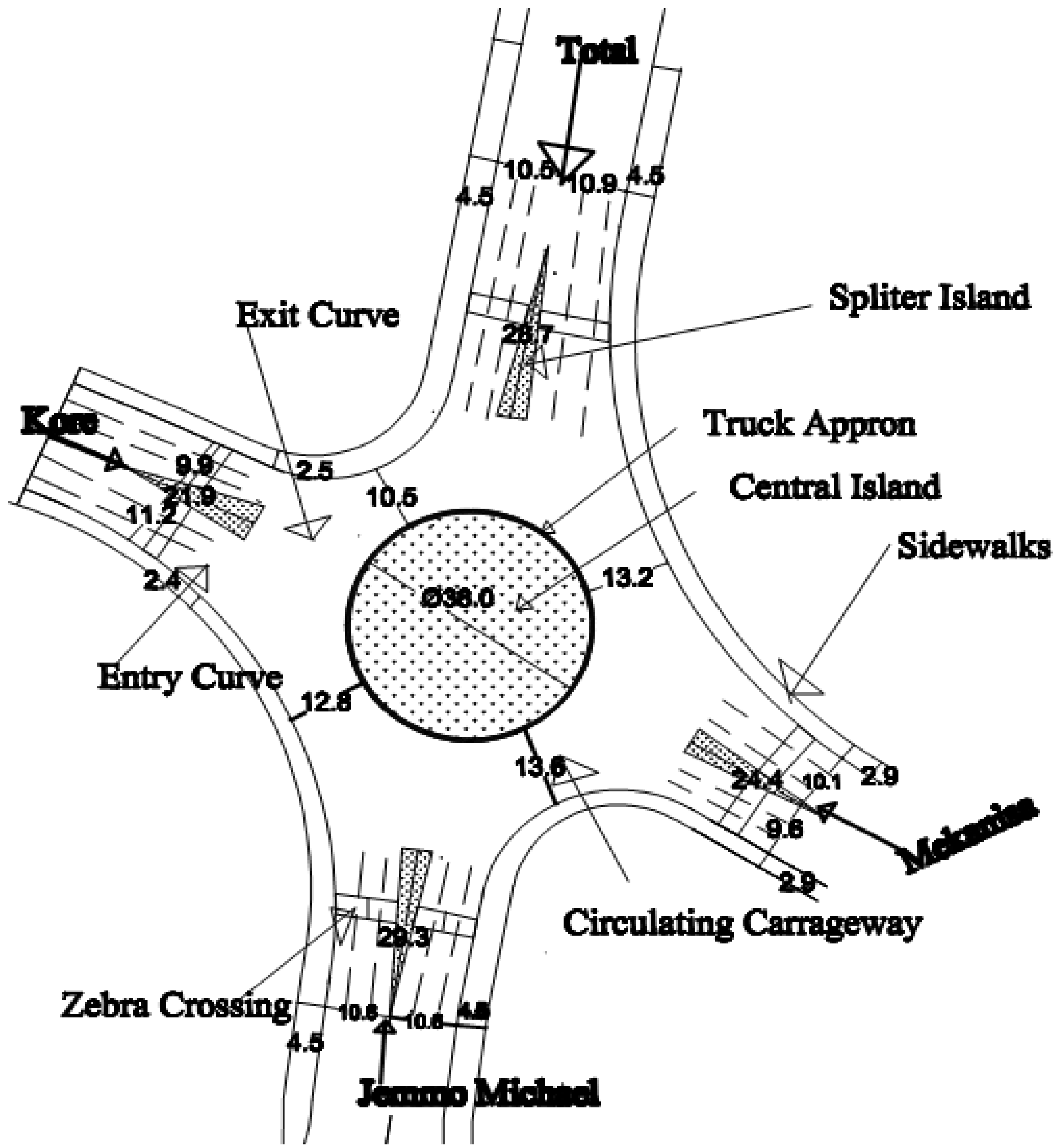


Figure 4.4 Geometric components of Kore roundabout

Influencing factors of driver behavior

Vehicle, road and traffic conditions are influencing driver's behavior. Driving involves a sequential process of perceiving and making sense of the situation, deciding on how to best respond given the driver's knowledge and goals, and taking some action. Some traffic control devices and road safety treatments are designed to provide information to drivers by means of an explicit alerting function. Such as speed limit signs and many hazard warning signs are designed to direct drivers' attention to road or traffic conditions and undertake recommended or required driving behaviors; the information is explicit as it relies on a driver consciously attending, comprehending, and responding to the information. Therefore, from the explanation selected roundabouts road condition one of the major influencing factors of driver behavior such as pavement marking and drainage system. In addition, Pavement condition of selected roundabouts is not good obtained areas with cracks and rutting. As a result, these conditions have effect on driving behavior.

4.2. Questionnaire results

4.2.1. Demographics

Based on the results, 56.30% of roundabouts respondents of pedestrians were female, while drivers' response was 78.60% male of roundabouts. Similarly, 55.71% females and 44.29% males' pedestrian were also. Greater than70% of pedestrians at roundabout was below 45 years old, while above 75% drivers were 45 years old or below in roundabouts. Level of Education also varied for both drivers and pedestrians. Pedestrians at roundabouts had about 54.70% of respondents with diploma and above while drivers over 78.00% with diploma and below. However, the percentage of level of education respondents at roundabouts with drivers and pedestrians were dissimilar. Demographics are summarizing in table 4.6.

Table 4.6 Demographic data of pedestrians and drivers.

Demographic	Response			
	Pedestrians		Drivers	
	No	%	No	%
Gender				
Male	168	43.80	302	78.60
Female	216	56.30	82	21.40
Age				
18-24	148	38.50	128	33.30
25-34	98	25.50	117	30.50
35-44	77	20.10	94	24.50
45-54	48	12.50	29	7.60
55+above	13	3.40	16	4.20
Level of Education				
Complete high school	174	45.30	234	60.90
Diploma	110	28.60	68	17.10
Bachelor degree	92	24.00	58	15.10
Master's degree	8	2.10	24	6.30

4.2.2. Frequency tables of both driver and pedestrian response

A) Driver response

Table 4.7 How frequently do you drive to reach destinations while pass through roundabout per day

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Regularly	215	56.0	56.0	56.0
	Occasionally	73	19.0	19.0	75.0
	Rarely	96	25.0	25.0	100.0
	Total	384	100.0	100.0	

Table 4.8 Does your driving behavior change when you enter to roundabout from a main road?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	292	76.0	76.0	76.0
	No	50	13.0	13.0	89.1
	Sometimes	42	10.9	10.9	100.0
	Total	384	100.0	100.0	

Table 4.9 Do you typically slow down enter to roundabout?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	330	85.9	85.9	85.9
	No	10	2.6	2.6	88.5
	Sometimes	44	11.5	11.5	100.0
	Total	384	100.0	100.0	

Table 4.10 Do you ever communicate with pedestrian, bicyclists, or other drivers in a non-verbal manner (e.g. eye contact, hand gestures) at roundabout?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	302	78.6	78.6	78.6
	No	8	2.1	2.1	80.7
	Sometimes	74	19.3	19.3	100.0
	Total	384	100.0	100.0	

Table 4.11 As a driver, have you ever had a collision with a pedestrian at roundabout?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	52	13.5	13.5	13.5
	No	332	86.5	86.5	100.0
	Total	384	100.0	100.0	

B) Pedestrian response

Table 4.12 How frequently do you walk to reach destinations crossing roundabout per day?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Regularly	245	63.8	63.8	63.8
	Occasionally	65	16.9	16.9	80.7
	Rarely	74	19.3	19.3	100.0
	Total	384	100.0	100.0	

Table 4.13 As a pedestrian, have you ever had a collision with a car at roundabout?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	41	10.7	10.7	10.7
	No	343	89.3	89.3	100.0
	Total	384	100.0	100.0	

Table 4.14 As a pedestrian, are you feel safe waiting on pedestrian island at roundabout?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	316	82.3	82.3	82.3
	No	68	17.7	17.7	100.0
	Total	384	100.0	100.0	

Table4.15 As a pedestrian, are you feel safe crossing the lane at roundabout compare with others traffic calming?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	298	77.6	77.6	77.6
	No	86	22.4	22.4	100.0
	Total	384	100.0	100.0	

Table 4.16 When pedestrians crossing through zebra crossing of roundabout they believed to give attention.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	274	71.4	71.4	71.4
	No	110	28.6	28.6	100.0
	Total	384	100.0	100.0	

Table 4.17 Is that roundabout design considering pedestrians safety?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	297	77.3	77.3	77.3
	No	87	22.7	22.7	100.0
	Total	384	100.0	100.0	

Table 4.18 Guardrails important in terms of safety when pedestrian walking through sidewalks of roundabout.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	208	54.2	54.2	54.2
	No	176	45.8	45.8	100.0
	Total	384	100.0	100.0	

4.2.3. Statistics results for drivers and pedestrians

Table 4.19 Statistics analysis for drivers

		Drive to reach destinations	Driving behavior change	Typically slow down	Communicate with pedestrian	Had a collision
N	Valid	384	384	384	384	384
	Missing	0	0	0	0	0
Mean		1.69	1.98	1.26	1.41	1.86
Std. Error of Mean		.043	.025	.033	.040	.017
Std. Deviation		.846	.490	.648	.793	.343

Table 4.20 Statistics analysis for pedestrians

		Reach destinations crossing roundabout	Had a collision	Waiting on pedestrian island	Crossing the lane at roundabout	They believed to give attention.	Design considering pedestrians	Guard rails importa nt in
N	Valid	384	384	384	384	384	384	384
	Missing	0	0	0	0	0	0	0
Mean		1.55	1.89	1.18	1.22	1.29	1.23	1.46
Std. Error of Mean		.041	.016	.020	.021	.023	.021	.025
Std. Deviation		.796	.309	.382	.417	.453	.419	.499

Generally, Standard error of mean of this distribution individual sample mean is in relation to the true mean with 95% confident interval and that 5% maximum error of the estimate and standard error of mean is less than maximum error of the estimate. As a result, response of both drivers and pedestrians are reliable and more accurate support to conclude.

4.3. Spot speed analysis and results

Before starting analysis of spot speed data first determining the number of classes was first determine the range for a class size of 8 and then for a class size of 20. Finding the difference between the maximum and minimum speeds in the data and dividing this number first by 8 and then by 20 gives the maximum and minimum ranges in each class.

A convenient range for each class is then selected and the number of classes determined. Typically, the mid value of each class range is taken as the speed value for that class. The data also can be presented in the form of a frequency and cumulative frequency distribution curve (Garber and Hoel,2009).

Therefore, the convenient range used for accurate variety between the spot speeds data for superior analysis with regard to speed by using two alternatives.

Using below equations to calculate median of range of classes

$x=\frac{v_{max}-v_{min}}{8}$ ……………………………………………………………………….Eq.4.1

$y=\frac{v_{max}-v_{min}}{20}$ ……………………………………………………………………….Eq.4.2

$u=\frac{x+y}{2}$ ……………………………………………………………………………...……….Eq.4.3

Where:

v_{max} = maximum speed x= Range per class for eight

v_{min} = minimum speed y= Range per class for twenty

u= Median of range of classes

For example Karl roundabout: $x=\frac{56-35}{8}$=2.63 $y=\frac{56-35}{20}$ =1.05

$$u=\frac{2.63+1.05}{2}=1.84$$

Table 4.21 Range of class for sample

Name	Speed range (km/h)	Difference of speed range	Range per class for eight	Range per class for twenty	Median of range of classes
Karl roundabout	35-56	21	2.63	1.05	1.84
German roundabout	35-71	36	4.50	1.80	3.15
City Tip roundabout	36-73	37	4.63	1.85	3.24
Kore roundabout	35-65	30	3.75	1.50	2.63

Based on the median result different range of class per each roundabout (Karl is 2 Km/h per class, German, City Tip and Kore is 3 km/h per class each).

Determining the 85th percentile speed is show below (Robertson, 1994).

s_D= ((p_D-p_{min})/ (p_{max}-p_{min}))*(s_{max}-s_{min})-s_{min}………………………………………Eq4.4

Where:

s_D= speed at p_D p_D = percentile desired (85th percentile speed)

p_{max} = higher cumulative percent at 85th percentile speed

p_{min}= lower cumulative percent 85th percentile speed

s_{max}= higher speed at 85th percentile speed

s_{min} = lower speed 85th percentile speed

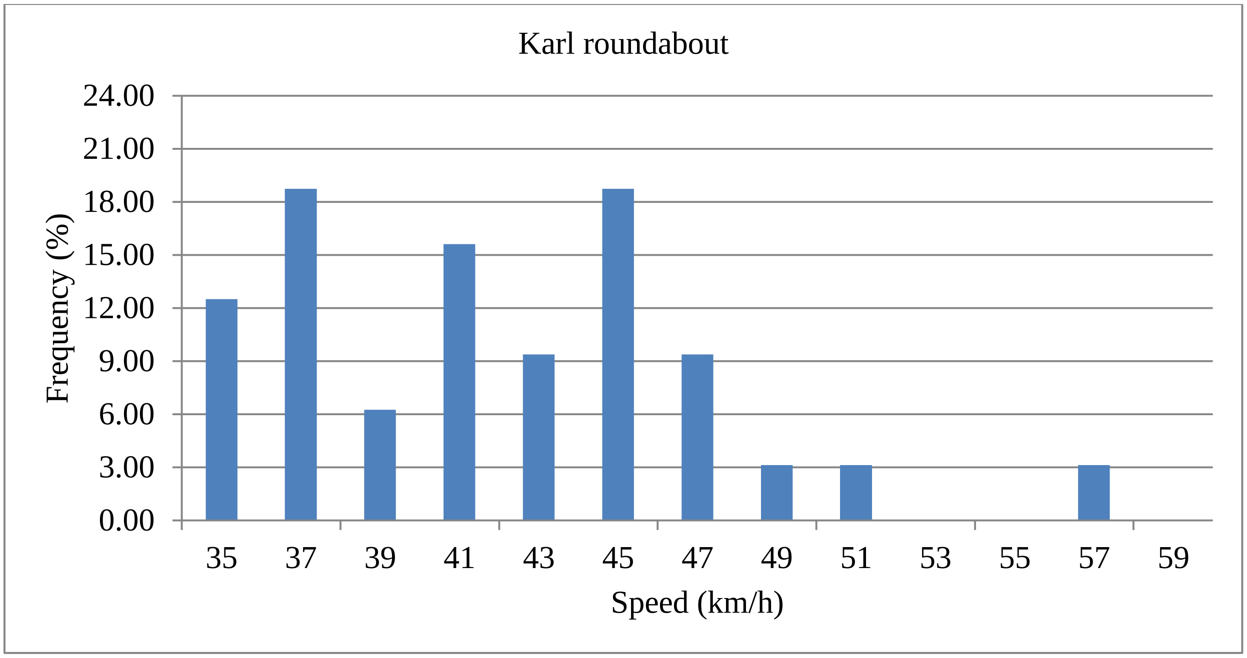
Table 4.22 85th percentile speed for sample

Name	p_D	p_{max}	p_{min}	s_{max}	s_{min}	s_D
Karl roundabout	85	90.63	81.25	47	45	46
German roundabout	85	87.50	84.40	56	53	54
City Tip roundabout	85	93.8	84.40	68	65	65
Kore roundabout	85	87.5	81.30	56	53	55

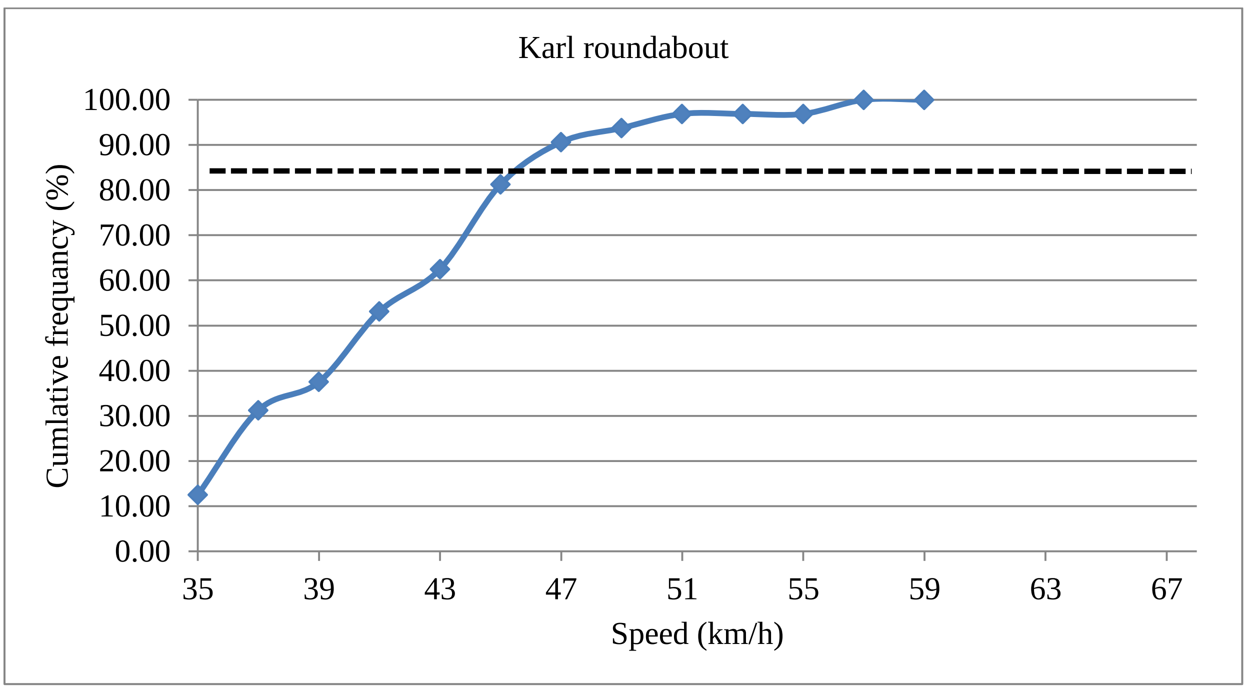
From the analysis: tables', frequency histograms and cumulative frequency distribution graphs are generating for each roundabout. Some of them are revealing below. The rest histograms and curves are can be seen in Appendix B, and the frequency distribution tables they are develop can be seen in Appendix B.

Table 4.23 Distribution table for Karl roundabout spot speed study

Speed class(km/h)(u_i)	Frequency (f_i)	$f_i u_i$	Frequency in-group (%)	Cumulative frequency (%)	$f\ (u_i - \bar{u})^2$
35	4	140	12.50	12.50	225.00
37	6	222	18.75	31.25	181.50
39	2	78	6.25	37.50	24.50
41	5	205	15.63	53.13	11.25
43	3	129	9.38	62.50	0.75
45	6	270	18.75	81.25	37.50
47	3	141	9.38	90.63	60.75
49	1	49	3.13	93.75	42.25
51	1	51	3.13	96.88	72.25
53	0	0	0.00	96.88	0.00
55	0	0	0.00	96.88	0.00
57	1	57	3.13	100.00	210.25
59	0	0	0.00	100.00	0.00
	32	1342	100.00		641.00



A



B

Figure 4.5 Distribution curves. A) Frequency histogram .B) Cumulative frequency curve with 85th level marked by dotted lines.

Speed Management

The speeds at roundabouts are influenced by a variety of factors, including the geometry of the roundabout and the operating speeds of the approaching roadways. Therefore, speed management is often a combination of managing speeds at the roundabout itself and managing speeds on the approaching roadways.

Design speed is the theoretical speed that drivers could achieve through the roundabout, if drivers taking the fastest path through the roundabout regardless to lane line striping. The entry curve radius should be chose such that the 85th percentile approach speed is limited to a maximum of 60km/h (AACRA, 2003). Roundabout design speed is the most important attribute in terms of safety performance, because although the frequency of crashes is most directly tied to volume, collision severity is more directly correlated with speed. Therefore, the design speed of a roundabout needs attention to achieve good safety performance.

Table 4.24 Comparison of recommended maximum entry design speeds and entry speed at 85th percentile.

Name of Roundabout	Recommended maximum entry design speed(km/h)(AACRA)	Entry speed at 85th percentile (km/h)
Karl roundabout	60	46
German roundabout	60	54
City Tip roundabout	60	65
Kore roundabout	60	55

Therefore, from the above comparison was getting similar result below recommended maximum entry design speed except City Tip roundabout. Hence, safety performance and enough confirmation of 85th percentile of the observed vehicles travels at and below at roundabout.

4.4 Comparison of each roundabout

In the following, section comparison of each roundabout with regard to field survey and spot speed analysis done to effective roundabout in terms of level of speed calming and pedestrian safety. Karl, German, City Tip and Kore are similar in terms of pedestrian facility are well provided in all approach legs but crosswalk markings (zebra crossing) need improving.

Table 4.25 Comparison of each roundabout

Name	Truck apron(m)	85th speed(km/h)	Central island diameter (m)
Karl roundabout	2.19	45.80	26.00
German roundabout	2.07	53.58	51.00
City Tip roundabout	1.04	65.19	19.00
Kore roundabout	1.22	54.79	38.00

Truck aprons generally provide a lower level of operations, but it is desirable to provide adequate deflection while still accommodating the design vehicle. Then Karl and German roundabouts are fitted with the AACRA standard, as well as adequate truck apron will facilitate safe roundabout operation. Furthermore, Karl roundabout deflection is greater than German roundabout then Karl roundabout is enough truck apron that is will ensure the necessary reduction in speed.

Roundabouts should provide a turning path for the largest vehicles expected to use the facility in significant numbers. Automobile, minibus, medium bus and large bus vehicles are always passing through Karl and Kore roundabouts. However, trucks and truck trailers vehicles are rarely passing through also. However, German and City Tip roundabouts are industry areas then automobile, minibus, medium bus, large bus, trucks and truck trailers vehicles are always passing through. Therefore, City Tip roundabout is effective with regard to speed, which is 65km/h.

Increasing the diameter of a roundabout usually enables provision of better approach geometry that leads to a reduction in vehicle approach speeds. In general, roundabouts in high-speed environments need larger diameters to enable better approach geometry design to reduce the high approach speeds. Therefore, German roundabout is larger diameter, which is desirable to reduce approach speed.

Landscaping design of a roundabout is provided to improve the aesthetics of the area, avoid obscuring form of the roundabout layout to the driver, clearly indicate to the driver that they cannot pass straight through the intersection and discourage pedestrian travel through the central island. German roundabout is well landscaping from the rest-selected roundabouts.

Signing with proper advance warning, directional guidance and regulatory control are required to avoid driver expectancy related problems such as junction assemblies, roundabout ahead ,yield ahead and diagrammatic guide signs should be considered. Therefore, German roundabout is good signing around all directions.

Pavement markings for a roundabout intersection consist of the yield line, hatch markings in the pedestrian crosswalk, raised reflective pavement markings and no painted lines across the exits from roundabouts. As a result, the selected roundabouts are similar in pavement marking which need improving.

Therefore, from the analysis results Karl, German, City Tip and Kore roundabouts are calming effectively with dissimilar speed. However, variation of calming speed basis regards to the above conditions such as deflection, roundabout diameter, landscaping, signing and pavement marking. In terms of these factors, German roundabout is more effective from Karl, City Tip and Kore roundabouts.

5. CONCLUSIONS AND RECOMMANDATIONS

5.1 Conclusions

- ✓ Zebra crossing, movement around the roundabout, design of roundabout, sidewalks and guardrails are provide better safety regarding to pedestrian perception questionnaire

- ✓ Evaluation of geometric conditions such as geometric configuration, geometry of the elements of a roundabout, pavement marking and pavement condition has a negative influence on driver behavior.

- ✓ Generally, enough confirmation of 85% of the observed vehicles travels at and below entering roundabout such as Karl, German, City Tip and Kore with regard to 46km/h, 54km/h, 65km/h and 55km/h respectively below AACRA speed limit is 60km/h except City Tip roundabout. Therefore, drivers have good driving behavior change due to typically slowdown and good communication with other road users with regard to speed .

5.2 Recommendations

Future study into the evaluation of effectiveness of traffic calming at roundabouts may include the following:

- ✓ By giving education and training to pedestrians about their level of knowledge of the rules roundabout uses concerning safety. Therefore, roundabout uses education should be given to all classes of the community. The training and education system should also start at home from his/her parents. A strong commitment is needed towards roundabout uses education in schools. Media campaigns should concentrate on broadcasting knowledge to the public regarding the safe use of roundabouts.

- ✓ Concrete and detailed data will gathering with regard to influencing driver behavior such as vehicle (type of vehicles and vehicle design), road (road geometry, road surface, signing and marking), traffic (traffic volume and speed) and driver (experience, age and general attitude) calibrate new model that will reliable for road users to decrease crashes.

- ✓ Fixing speed limit with regard to general geometric condition when entering drivers into approach of roundabout by collecting through specific enough time, which is enough data for analysis speed limit.

6. REFERENCES

1. AACRA Manual 2003, *Geometric Design Manual section 14-Roundabout*, Addis Ababa.
2. Addis Ababa Police Commission 2014, *Criminal Director Directorate,* Addis Ababa.
3. Belkıs DÖNMEZ 2012, *Modifying Traffic Calming Elements for the Cultural and Spatial Constraints of the Turkish Urban Streets: İzmir-Güzelyali Case Study,* Turkish.
4. Bruce W.Robinson, Lee Rodegerdts, Wade Scarborough, Wayne Kitteison 1999, *Roundabouts: An Information Guide*. FHWA-RD-00-067, Us Department of Transportation.
5. Bureau of Design and Environment Manual 2013, *Intersections.*
6. Cecilia Friis and Lina Svensson 2013, *Pedestrian Micro simulation a comparative study between the software programs Vissim and Viswalk,* Chalmers University of Technology Göteborg Sweden.
7. Erik Lawrence Seiberlich 2001, *A Formulation to Evaluate Capacity and Delay of Multilane Roundabouts in the United States for Implementation into a Travel Forecasting Model,* University of Wisconsin-Milwaukee.
8. Erik Lawrence Seiberlich 2001,.*A Formulation to Evaluate Capacity and Delay of Multilane Roundabouts in the United States for Implementation into a Travel Forecasting Model Travel Forecasting Model,* University of Wisconsin-Milwaukee.
9. Finbarr Crowley, Anne MacDermott1996, *Evaluation of Traffic Calming Schemes Constructed on National Roads1993-1996*, Ireland.
10. International Journal of Traffic and Transportation Engineering 2012,.*Evaluating the Effectiveness of Traffic Calming Devices: Using Simulation to Overcome Analytical Models Assumptions.*
11. Jeffrey Bagdade, Bhagwant N. Persaud, Kiel McIntosh, Joyce Yassin, Craig A. Lyon, Cynthia Redinger, Jason Whitten and Wesley A. Butch 2011, *Evaluating the Performance and Safety Effectiveness of Roundabouts,* Opus International Consultants Inc.
12. Laser Technology Manual 2013.
13. Marius de Langen, Theo Rwebangira, Enoch Kitandu, Stephen Mburu, 2003, *The Role of Traffic Calming Facilities*, Urban road design in Africa.
14. Mark Lenters, P. E., Eng., Nancy Button, MBA, PhD, P. Eng. Tom Knostman, P.E., Loveland, 2010,*Improving Pedestrian Performance and Driver Response at Unsignalized Roundabout Crosswalks*, Canada.

15. Mobushar A. Pannu, P.Eng. 1999, *Traffic Calming Within Metropolitan Toronto*, University of Toronto.
16. Neil E. Absil, 2008, *Driver Behavior Model for the Multi-Agent Real-Time Simulation*, Netherlands.
17. Nicholas J. Garber Lester A. Hoel 2009, *Traffic and Highway Engineering*, Fourth Edition, University of Virginia.
18. Rana Salah-ud-Din Mujahid 2012, *Dual-Lane Roundabouts Geometric Design for Optimum Design Consistency and Operation*, Ryerson University.
19. Randel R.Jaeger 1999, *Traffic Calming-Speed Humps Effect on Emergency response Times*, Des Plaines.
20. Reuben Ray Collins 2008, *Evaluation of a Roundabout at a Five-Way Intersection: An Alternatives Analysis Using Micro simulation*, University of Minnesota.
21. Richard A. Retting, MS, Bhagwant N. Persaud, PhD, Per E. Garder, PhD, and Dominique Lord, MASc 2001. *Crash and Injury Reduction Following Installation of Roundabouts in the United States*, American Journal of Public Health, Vol. 91, No. 4.
22. Robertson, H. D. 1994. Spot Speed Studies. *In Manual of Transportation Engineering Studies.*
23. Thaweesak Taekratok 1998,*Modern Roundabouts for Oregon*, Oregon Department of Transportation Research Unit 200 Hawthorne SE, Suite B-240 Salem, Oregon 97310.
24. Wong, S. C, M.ASCE; N. N. Sze; Becky P. Y. Loo; Alice S. Y. Chow; Hong K. Lo, M.ASCE; and Hung, W. T 2012,.*Performance Evaluations of the Spiral-Marking Roundabouts in Hong Kong*, Journal of Transportation Engineering .

APPENDIX A: Roundabout safety questionnaire English and Amharic

Experience of Driver

For questions 1 through 3, please fill in the rectangle mark √ that best fits your response to the question.

1. How frequently do you drive to reach destinations while pass through roundabout per day?

   Regularly ☐ Occasionally ☐
   Rarely ☐ Never ☐

2. Does your driving behavior change when you enter to roundabout from a main road?

   Yes ☐ No ☐ Sometimes ☐

   2a. Do you typically slow down?

   Yes ☐ No ☐ Sometimes ☐

   2b. Do you ever communicate with pedestrian, bicyclists, or other drivers in a non-verbal manner (e.g. eye contact, hand gestures) at roundabout?

   Yes ☐ No ☐ Sometimes ☐

3. As a driver, have you ever had a collision with a pedestrian around roundabout?

   Yes ☐ No ☐

General Information of drivers

For questions 4 through 6, please fill in the rectangle √ that best fits your response to the question.

4. What is your gender?

   Male ☐ Female ☐

5. What is your present age?

   18 – 24 ☐ 25 – 34 ☐ 35 – 44 ☐
   45 – 54 ☐ 55+ ☐

6. What is the highest level of education that you have completed?

   Completed high school ☐ Bachelor degree ☐
   Diploma ☐ Master’s degree ☐

Experience for Pedestrian and safety perception

For questions 1 through 7 please fill in the rectangle √ that best fits your response to the question.

1. How frequently do you walk to reach destinations crossing roundabout per day?

Regularly ☐ Occasionally ☐

Rarely ☐ Never ☐

2. As a pedestrian, have you ever had a collision with a car around Roundabout?

Yes ☐ No ☐

3. As a pedestrian, are you feel safe waiting on Pedestrian island at roundabout?

Yes ☐ No ☐

4. As a pedestrian, are you feel safe crossing the lane at roundabout compare with others traffic calming?

Yes ☐ No ☐

5.When pedestrians crossing through zebra crossing of roundabout they believed to give attention.

Yes ☐ No ☐

6. Is that roundabout design considering pedestrians safety?

Yes ☐ No ☐

7. Guard rails important in terms of safety when pedestrian walking through sidewalks of roundabout.

Yes ☐ No ☐

General information of pedestrians

For questions 8 through 10, please fill in the rectangle √ that best fits your response to the question.

8. What is your gender?

Male ☐ Female ☐

9. What is your present age?

18 – 24 ☐ 25 – 34 ☐ 35 – 44 ☐

45 – 54 ☐ 55+ ☐

10. What is the highest level of education that you have completed?

Completed high school ☐ Bachelor degree ☐

Diploma ☐ Master's degree ☐

የአደባባይ ደህንነት መጠይቆች

<u>ከሹፌሮች ልምድ አንፃር</u>

ከተራ ቁጥር 1 እስከ 3 ያሉትን መጠይቆች √ በማድርግ ትክክለኛውን መልስ ስጡ፡፡

1. ወደ መድረሻህ ለማጓጓዝ በቀን ምን ያህል በአደባባይ ተቋርጣለህ/ሽ?

   በመደበኛነት ☐ በተወሰነ ጊዜ ገደብ ☐

   አልፎ አልፎ ☐ በፍፁም ☐

2. ወደ አደባባይ ስትገቢ/ባ የማሽከርከር ፀባይ ለውጥ ይታይብሃል/ሻል ወይ?

   አዎ ☐ አይታይብኝም ☐ አልፎአልፎ ☐

   2ሀ. ቀጥታ ፍጥነትህ ትቀንሳልህ/ሽ?

   አዎ ☐ በፍፁም ☐ አልፎ አልፎ ☐

   2ለ. ለእግረኛና ለሌሎች አሽከርካሪዎች ጋር በምልክት ቋንቋ ትግባባለህ/ሽ?

   አዎ ☐ በፍፁም ☐ አልፎ አልፎ ☐

3. አደባባይ አካባቢ እግረኛ ገጭተህ/ሽ ታውቃለህ/ሽ?

   አዎ ☐ አላውቅም ☐

አጠቃላይ መረጃ ለሹፌሮች

ከጥያቄ 4 እስከ 6 ያሉትን መጠይቆች √ በማድርግ ትክክለኛውን መልስ ስጡ፡፡

4. ፆታ ወንድ ☐ ሴት ☐

5. እድሜ 18-24 ☐ 35-44 ☐

   25-34 ☐ 45-54 ☐ 55+ ☐

6. የትምህርት ደረጃ

   ሁለተኛ ደረጃ ያጠናቀቀ/ች ☐ ዲግሪ ☐

   ዲፕሎማ ☐ ማስተርስ ☐

ከእግረኞች ልምድ አንፃር እና ስለ ደህንነት ያላቸው አስተሳሰብ

ከተራ ቁጥር 1 እስከ 7 ያሉትን መጠይቆች √ በማድርግ ትክክለኛውን መልስ ስጡ፡፡

1. ወደ መድረሻህ ለመሄድ አደባባይ በቀን ምን ያህል ጊዜ ታቋርጣለህ/ሽ?

   በመደበኝነት ☐ በተወሰነ ጊዜ ገደብ ☐

   አልፎ አልፎ ☐ በፍፁም ☐

2. እንደ እግረኛ ከመኪና ጋር ተጋጭተህ ታውቃለህ/ሽ?

   አዎ ☐ አላውቅም ☐

3. እንደ እግረኛ የአደባባይ እግረኞች ማቆያ ስትቆይ/ዪ ድህንነት ይሰማሃል/ሻል?

   አዎ ☐ አይሰማኝም ☐

4. እንደ እግረኛ የአደባባይ የእግረኞች መቋረጫ ከሌለው መስቀለኛ ማቋረጫ ለደህንነቱ የተሻለ ነው ወይ?

   አዎ ☐ አይደለም ☐

5. እንደ እግረኛ አደባባይ የእግረኞች ማቋረጫ ሲሻገሩ ትኩረት መስጠት አለባቸው ብለው ያምናሉ፡፡

   አዎ ☐ አላምንም ☐

6. የአደባባይ ዲዛይን እግረኞች ግንዛቤ ውስጥ ያስገባ ነው ወይ?

   አዎ ☐ አይደለም ☐

7. የአደባባይ የእግረኛ መንገድ መከለያ አጥር ከደህንነት አንፃር አስፈላጊ ነው?

   አዎ ☐ አይደለም ☐

አጠቃላይ መረጃ ለእግረኞች

ከጥያቄ 8 እስከ 10 ያሉትን መጠይቆች √ በማድርግ ትክክለኛውን መልስ ስጡ፡፡

8. ፆታ ወንድ ☐ ሴት ☐

   ☐

9. እድሜ 18-24 ☐ 35-44 ☐

   25-34 ☐ 45-54 ☐ 55+ ☐

10. የትምህርት ደረጃ

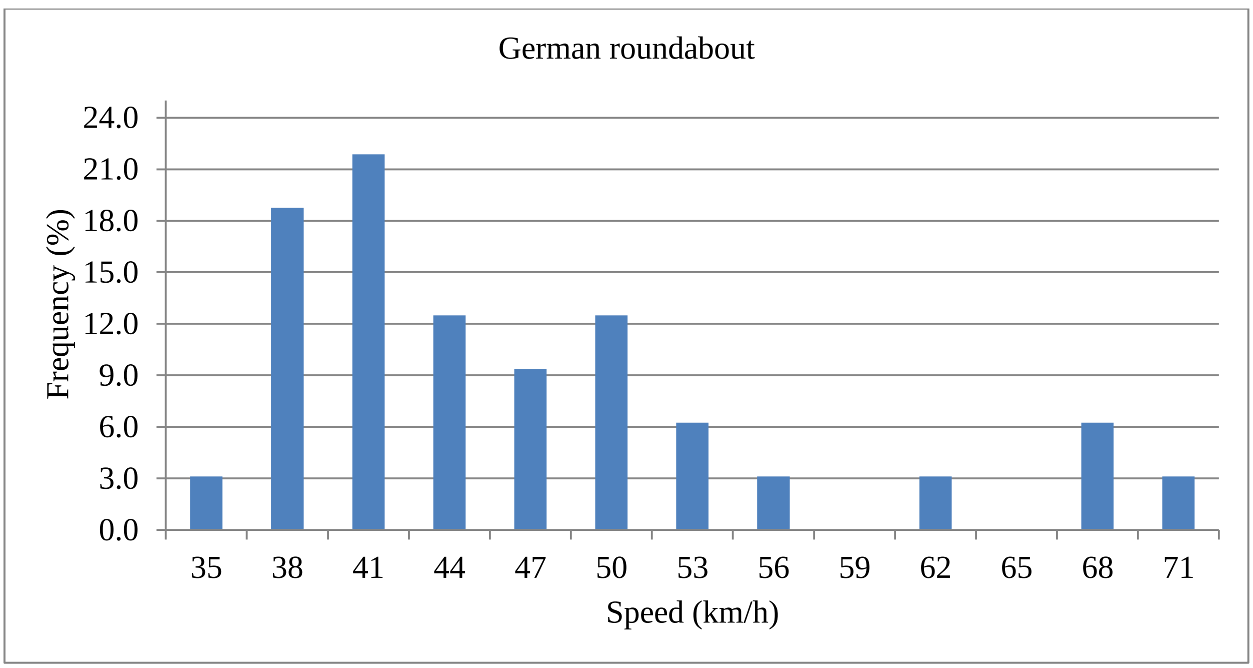
    ሁለተኛ ደረጃ ያጠናቀቀ/ች ☐ ዲግሪ ☐

    ዲፕሎማ ☐ ማስተርስ ☐

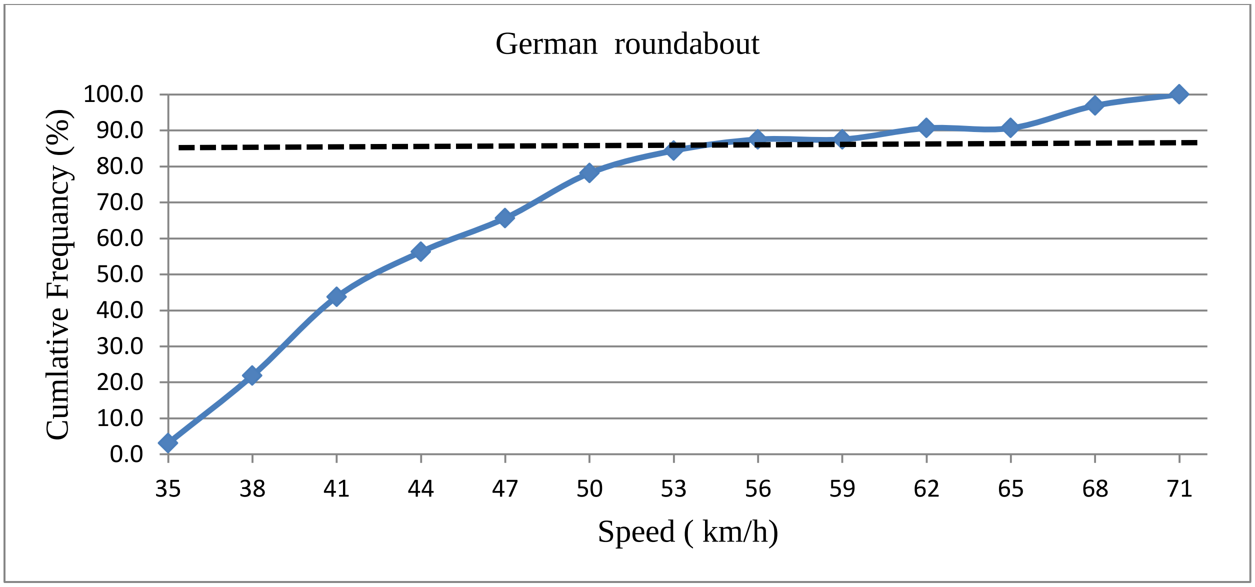
APPENDIX B: Spot speed study

Table B-1 Distribution table for German roundabout spot speed study

Speed class(km/h)(u_i)	Frequency (f_i)	$f_i u_i$	Frequency in-group (%)	Cumulative frequency (%)	$f\ (u_i - \bar{u})^2$
35	1	35	3.1	3.1	93.8961
38	6	228	18.8	21.9	268.5366
41	7	287	21.9	43.8	95.3127
44	4	176	12.5	56.3	1.9044
47	3	141	9.4	65.6	16.0083
50	4	200	12.5	78.1	112.7844
53	2	106	6.3	84.4	138.1122
56	1	56	3.1	87.5	127.9161
59	0	0	0.0	87.5	0
62	1	62	3.1	90.6	299.6361
65	0	0	0.0	90.6	0
68	2	136	6.3	96.9	1086.7122
71	1	71	3.1	100.0	692.2161
	32	1498	100.0		2933.0352



A

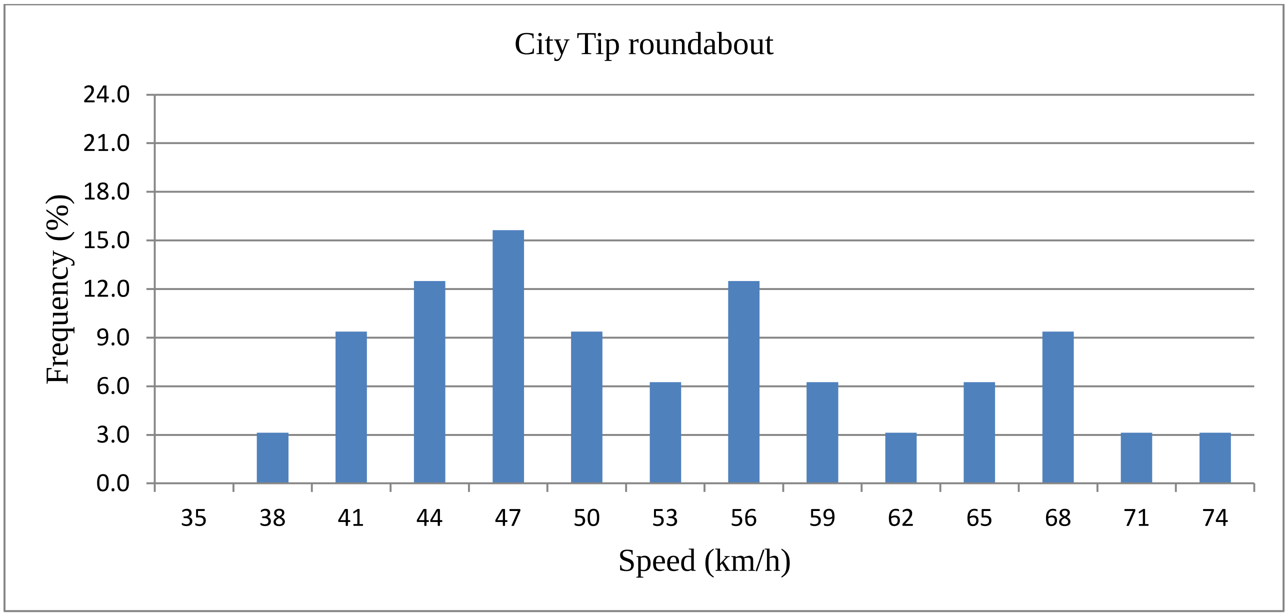


B

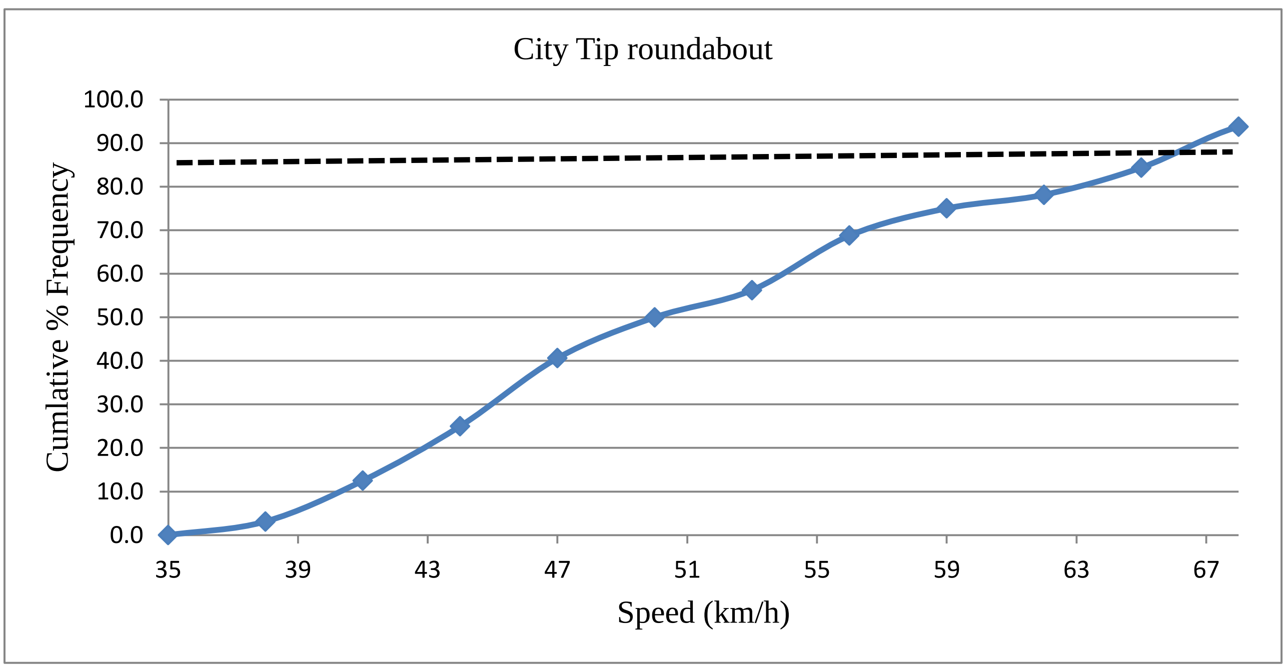
Figure B-1 Distribution curves. A) Frequency histogram .B) Cumulative frequency curve with 85th level marked by dotted lines.

Table B-2 Distribution table for City Tip roundabout spot speed study

Speed class(km/h)(u_i)	Frequency (f_i)	$f_i u_i$	Frequency in-group (%)	Cumulative frequency (%)	$f\ (u_i - \bar{u})^2$
35	0	0	0.0	0.0	0
38	1	38	3.1	3.1	126.5625
41	3	123	9.4	12.5	204.1875
44	4	176	12.5	25.0	110.25
47	5	235	15.6	40.6	25.3125
50	3	150	9.4	50.0	1.6875
53	2	106	6.3	56.3	28.125
56	4	224	12.5	68.8	182.25
59	2	118	6.3	75.0	190.125
62	1	62	3.1	78.1	162.5625
65	2	130	6.3	84.4	496.125
68	3	204	9.4	93.8	1054.6875
71	1	71	3.1	96.9	473.0625
74	1	74	3.1	100.0	612.5625
	32	1711	100.0		3667.5



A

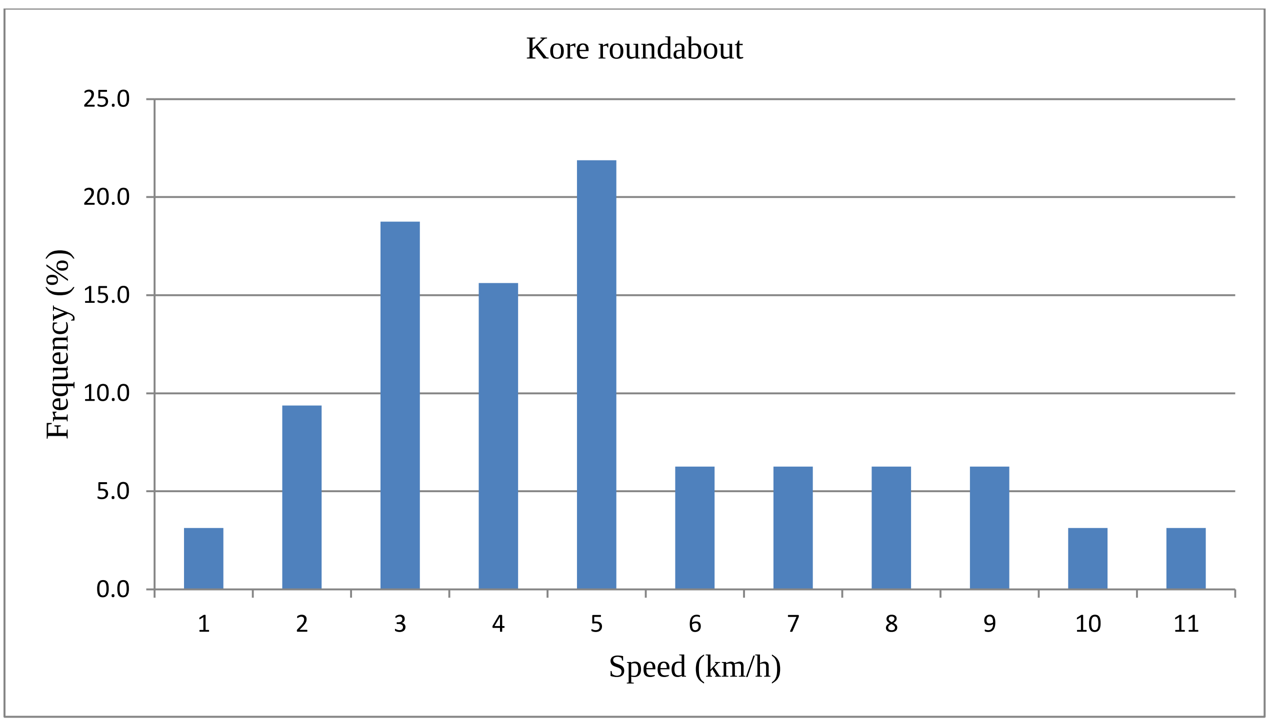


B

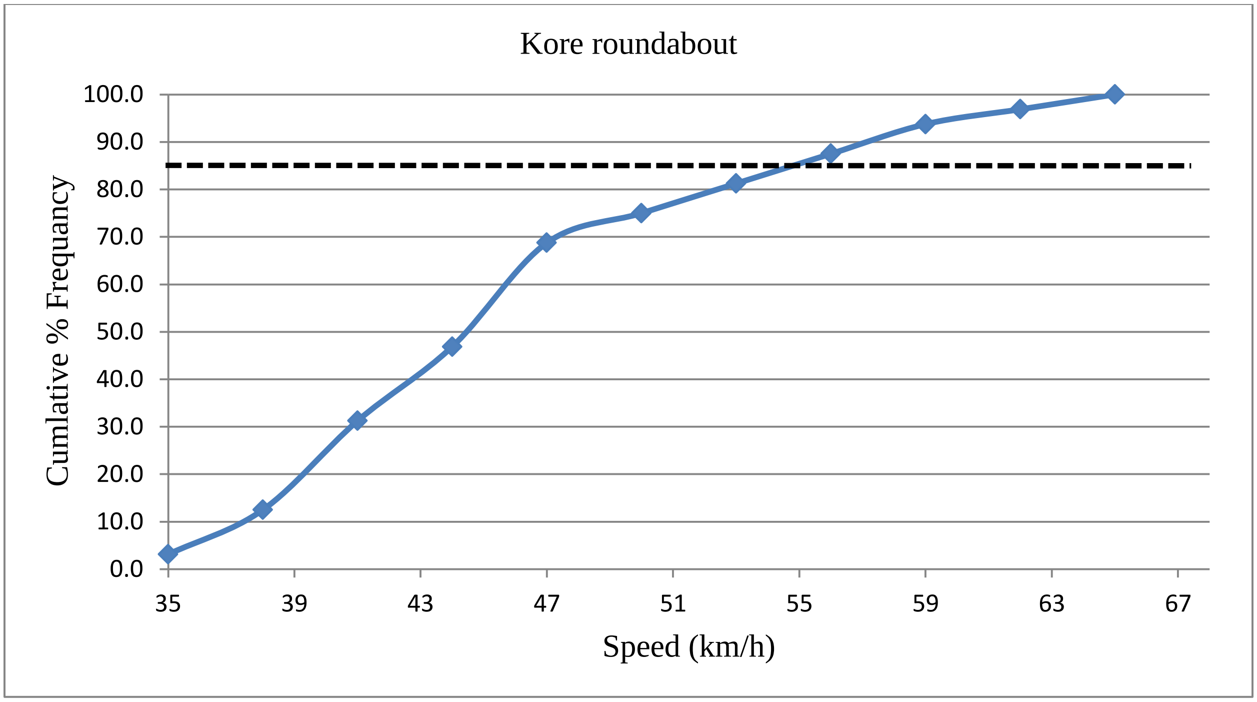
Figure B-2 Distribution curves. A) Frequency histogram B) Cumulative frequency curve with 85th level marked by dotted lines.

Table B-3 Distribution table for Kore roundabout spot speed study

Speed class(km/h)(u_i)	Frequency (f_i)	$f_i u_i$	Frequency in-group (%)	Cumulative frequency (%)	$f\ (u_i - \bar{u})^2$
35	1	35	3.1	3.1	118.37
38	3	114	9.4	12.5	186.28
41	6	246	18.8	31.3	142.89
44	5	220	15.6	46.9	17.67
47	7	329	21.9	68.8	8.78
50	2	100	6.3	75.0	33.95
53	2	106	6.3	81.3	101.39
56	2	112	6.3	87.5	204.83
59	2	118	6.3	93.8	344.27
62	1	62	3.1	96.9	259.85
65	1	65	3.1	100.0	365.57
Total	32	1507	100.0		1783.86



A



B

Figure B-3 Distribution curves. A) Frequency histogram .B) Cumulative frequency curve with 85th level marked by dotted lines.