UNIVERSITY OF NAIROBI

FACULTY OF ENGINEERING

DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

The Determinants of Pedestrian Safety Risk Factors at Roundabouts along Uhuru Highway in Nairobi, Kenya

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A thesis submitted in partial fulfilment of the requirements for the award of the Degree of Master of Science in Civil Engineering (Transportation Engineering Option) in the Department of Civil Engineering, University of Nairobi

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DECLARATION OF ORIGINALITY

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DEDICATION

To my loving parents Mr. Philip Oyoo and Mrs. Eunice Oyoo, I am forever indebted for your passion for education that has never left me every minute. To my loving wife Shanice Akinyi, your constant prayer and motivation even in the most difficult times has been a key enabler to my success. To my siblings, I am humbled at your resilience and understanding throughout this journey. I truly appreciate the opportunity you have granted me.

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ABSTRACT

Walking is a form of active mobility and one of the most sustainable modes considering its benefits such as improved human physical health, low carbon emissions hence clean environment, affordability, inclusivity and low cost of infrastructure. This study focussed on determining pedestrian safety risk factors at crossings located near three roundabouts and two midblock sections along Uhuru Highway in Nairobi. A case study in conjunction with other relevant mixed methods were applied to assess pedestrian safety risk factors at crossings located within at least 50m from the roundabouts or 50m away for midblock sections. In response to the study objectives, manual classified traffic, oral roadside interviews, questionnaires, direct observation of pedestrian crossing behaviour and linear measurement on all road geometrics. Crash data (2016-2021) for the Nairobi region and analysed using Microsoft Excel 2013 with a specific focus on pedestrian crashes along Uhuru Highway. In total, fourteen pedestrian crossings including twelve located on three roundabouts and two at midblock sections assessed in this study. Pedestrian safety risk factors such as demographics, road infrastructure and environment, pedestrian crossing behaviour and pedestrian crossing warrants were calculated using a formula adopted from a previous study. About 56% of all pedestrian-vehicle collisions occurred at midblock sections (50m away) compared to 44% which occurred within 50m from roundabouts. About 61% of pedestrian related crashes occurred on the road at midblock sections while 39% occurred at junctions along Uhuru Highway. About 65% of all road traffic collisions involving pedestrians occurred at day time compared to 35% occurring at night. On average, 67% of male pedestrians crossed the road weekly compared to 33% who crossed on weekend days. In terms of age, 34% male pedestrians aged 20-29 were involved in fatal collisions, 25% aged 31-40 in serious injuries collisions and 38% male pedestrians whose ages were unknown were at highest risk of slight injuries collisions. Comparatively, 42% female pedestrians aged 31-40 were involved in fatal collisions, 41% aged 41-50 involved in serious injuries collisions and 33% aged 31-40 were at highest risk of slight injuries collisions. In conclusion, pedestrians are safer at crossings near roundabouts (within 50m) compared to midblock sections (50m away). Pedestrians are at highest risk of fatal and injuries collisions at midblock sections compared to near the roundabouts. This study recommends that pedestrian safety needs improvement through implementing interventions such as adequate road infrastructure design, installing traffic signs and markings, improve visibility through installing adequate lighting to eliminate or reduce the risk of pedestrian-vehicle collisions at roundabouts along Uhuru Highway.

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ABBREVIATIONS

Abbreviation	Meaning
AASHTO	Association of State Highways and Transportation Officials
CBD	Central Business District
GDP	Gross Domestic Product
HSA (R3)	Haile Selassie Avenue roundabout
HSA (R31)	Haile Selassie Avenue roundabout 1st Pedestrian Crossing-To CBD
HSA (R32)	Haile Selassie Avenue roundabout 2nd Pedestrian Crossing-To Waiyaki Way
HSA (R33)	Haile Selassie Avenue roundabout 3rd Pedestrian Crossing-To Mombasa Road
HSA (R34)	Haile Selassie Avenue roundabout 4th Pedestrian Crossing-To Upper Hill
KAR (R2)	Kenyatta Avenue roundabout
KAR (R21)	Kenyatta Avenue roundabout 1st Pedestrian Crossing-To CBD
KAR (R22)	Kenyatta Avenue roundabout 2nd Pedestrian Crossing-To Waiyaki Way
KAR (R23)	Kenyatta Avenue roundabout 3rd Pedestrian Crossing-To Mombasa Road
KAR (R24)	Kenyatta Avenue roundabout 4th Pedestrian Crossing-To Community
NTSA	National Transport and Safety Authority
OECD	Organization for Economic Co-operation and Development
SDG	Sustainable Development Goals
TRL	Transport Research Laboratory
UN	United Nations
UWR (R1)	University Way roundabout
UWR (R11)	University Way Roundabout 1st Pedestrian Crossing-To University Way
UWR (R12)	University Way Roundabout 2nd Pedestrian Crossing-To Waiyaki Way
UWR (R13)	University Way Roundabout 3rd Pedestrian Crossing-To Mombasa Road
UWR (R14)	University Way Roundabout 4th Pedestrian Crossing-To State House Road
WHO	World Health Organization

Chapter 1

1. INTRODUCTION

1.1 Background of the Study

About 1.35 million people die from road traffic accidents and another 20 to 50 million people sustain injuries related to road traffic collisions annually (WHO, 2013). However, it is estimated that about 90% of these road traffic crashes still occur in Low- and Middle-income Countries (LMICs) where there is low per capita motorization level. According to Kenya's economic survey report of 2023 (https://www.knbs.or.ke/economic-survey-2023/), in 2022, about 21,757 people were killed or injured in road traffic crashes which consists of 4,690 people killed, 9,935 people seriously injured and another 7,132 people sustained slight injuries based on the National Police accident records. Furthermore, the economic survey report indicated that pedestrians constituted about 17% of all people killed or injured in road traffic crashes in Kenya while about 1,682 pedestrians were killed (35%), 1,690 were seriously injured (17%) and 380 were slightly injured (5.3%) in road traffic collisions in 2022.

Despite these statistics, it is still believed that there is underreporting of road traffic collisions in Kenya which poses a great risk in identifying and implementing proactive countermeasures on specific road user categories such as pedestrians as outlined in the road safety policies and action plans, (NTSA, 2021). Pedestrians are considered the most vulnerable in road traffic compared to other road users and thus require urgent interventions to reduce the risk of more fatalities and injuries. The safe systems approach to road safety has been adopted in the Global plan as decade of action for road safety with a specific target to reduce road traffic deaths and injuries by almost 50% margin between 2021 and 2030 (WHO, 2013). This second decade of action was endorsed based on the premise that the previous decade of action (2011-2020) did not achieve the targets set by the United Nations (UN) for each member state. However, through the five pillars of road safety; safer road users, safer vehicles, safer roads, effective post-crash response and road safety management, it is envisaged that these road safety targets are still achievable.

Kenya's population is currently estimated at about 47,564,296 people and Nairobi is the highest populated county with an estimated population of 4,397,073 people (9.2%) based on the latest census report of 2019 (https://www.knbs.or.ke/2019-kenya-population-and-housing-census-results/). Pedestrian crashes are highly prevalent in most parts of Nairobi city especially when crossing major arterial roads such as Uhuru highway, Outering Road, Waiyaki Way, Mombasa Road and Thika Highway in Nairobi. These roads are characterized with higher vehicular traffic volumes and pedestrians crossing the road at grade in most sections. This study focussed on assessing pedestrian safety risk factors at crossings near roundabouts along Uhuru Highway in Nairobi City. It carries traffic consisting of public service vehicles (PSVs), medium goods vehicles (MGV), private cars, motorcyclists, bicyclists and pedestrian crossing the road at grade from Central Business District (CBD) into the adjacent land utilities such as schools, colleges, churches, recreational parks, offices and other respective workplaces. Most pedestrian crashes occur because of conflicts with motorists when crossing the road near roundabouts along Uhuru highway. Since pedestrians are at highest risk of road traffic deaths and injuries, it is imperative to understand their safety risk factors especially in the most dangerous traffic environment such as when crossing such a multilane arterial road in Nairobi.

Roundabouts are traffic control features which are popular on urban roads and are often used as an engineering solution to junctions connecting four or three roads meeting at the same grade (Jain et al., 2014). In urban areas like Nairobi, it is common to find out that each leg of the roundabout has marked pedestrian crossings often accompanied with traffic signs, signal devices and police officers guiding pedestrians to safe crossing. Traffic engineering design for roundabouts involves determining the width and length of the carriageway depending on the traffic flow patterns. Different vehicle and pedestrian movements are exhibited at the roundabouts and some can lead to pedestrian-vehicle conflicts and consequently crashes. These crashes are either fatal or lead to injury amongst pedestrians hence require further investigation for accurate countermeasures. Many pedestrians cross Uhuru Highway at midblock and at crossings near roundabouts for varied trip purposes most of which are controlled by adjacent land use practices along this arterial road.

This study focuses on assessment of pedestrian safety risk factors while crossing the road near roundabouts with emphasis on pedestrian demographics, crossing behaviour, road infrastructure and environment and pedestrian crossing warrants. A review of road traffic accident causation factors indicated that road users are the leading cause of all road traffic crashes at about 57% to 65% of crashes, road environment resulting to about 2.5% to 3% of all crashes while vehicle factors are attributed to about 2% to 2.5% of all road crashes in single causation, (Yang et al., 2013). In multiple causation, a combination of two factors; road users and the road environment are the leading multiple cause of road crashes at about 24% to 27% of all crashes compared to road users and vehicles causing about 4% to 6% of road crashes (Yang et al., 2013). In Kenya, human factors has largely been attributed as the major cause of road crashes (Ogendi et al., 2013). Pedestrians are no exception to this finding since different crossing behaviour are observed especially on urban roads within Nairobi.

In Kenya, pedestrians alone constituted about 38% of road traffic fatalities with most of them occurring in Nairobi either at points of conflicts near at grade junctions or mid-block sections along newly built roads, (NTSA, 2021). Other categories affected by road traffic crashes include motorcyclists (27%), passengers (23%), and drivers (10%) and pedal cyclists (2%) (NTSA, 2021). Pedestrians remain exposed to road traffic collisions at roundabouts and the key safety risk factors include road infrastructure and traffic environment, demographic factors, land-use practices near roundabouts, road crossing behaviour, driver yielding behaviour to a stop line, traffic control measures, signal operation and efficiency, lighting near roundabouts and different traffic composition and its characteristics at roundabouts (Tulu et al., 2015). Moreover, this study has explored specific challenges and conditions likely to increase exposure and risk to pedestrian-vehicle collisions at level crossings near roundabouts.

Previously, several factors were identified as pedestrian safety risk factors in developing countries such as Kenya and Ethiopia. These factors included; inadequate visibility, illegal crossing, alcohol intoxication while driving and walking, pedestrian fatigue, walking along the roadway, socio-economic factors, poor transport and land use planning, population growth, lack of road safety education, high annual growth of motorization, proportion of two or three wheelers in traffic and poor enforcement of traffic laws and regulations, (Tulu et al., 2015). This study aims at contributing to prevention and eliminating risk of pedestrian fatalities and injuries while crossing near roundabouts. It has achieved this through establishing the level of safety of pedestrians while crossing an urban arterial road especially near roundabouts and at midblock sections along Uhuru Highway in Nairobi, Kenya.

1.2 Study Location

The study site is located along Uhuru Highway in Nairobi City, in Kenya which is classified as urban arterial road carrying traffic from Western and Eastern parts of the city. Twelve (12) pedestrian crossings near roundabouts were identified for risk assessment such as University Way Roundabout (UWR - R1) - (UWR - R11, R12, R13, and R14), Kenyatta Avenue Roundabout (KAR - R2) - (KAR - R21, R22, R23 and R24) and Haile Selassie Avenue

Roundabout (HAS - R3) - (HAS - R31, R32, R33 and R34) as shown in the maps listed as Figure 1-1 below. The study site also captured two pedestrian level crossings located at midblock sections long Uhuru Highway as Midblock (M1) located between University Way roundabout (R1) and Kenyatta Avenue roundabout (R2) and Midblock (M2) located between Kenyatta Avenue and Haile Selassie Avenue (R3).

The study site only considered sections of Uhuru Highway where it does not intersect with the recently constructed Nairobi Expressway. Several parcels of land adjacent to Uhuru highway such as Central Park, St. Paul's Church, University of Nairobi Main campus and students hostels, Green Park terminus, Railway Golf course, Office buildings and Parliament buildings, amongst others which are key pedestrian traffic attraction zones. Figures 1-2, 1-3, 1-4, 1-5, 1-6, and 1-7 below illustrate three roundabouts along Uhuru highway before and after construction of the Nairobi Expressway. Uhuru highway is a dual carriageway consisting of three lanes on each carriageway and a median separation island as well as non-motorized transport routes combining cycle track and pedestrian walkways. Currently no traffic signal devices exist at the roundabouts, existing road markings are missing or faded no adequate signage, no speed calming measures in place and police officers occasionally guide traffic especially at peak hours.

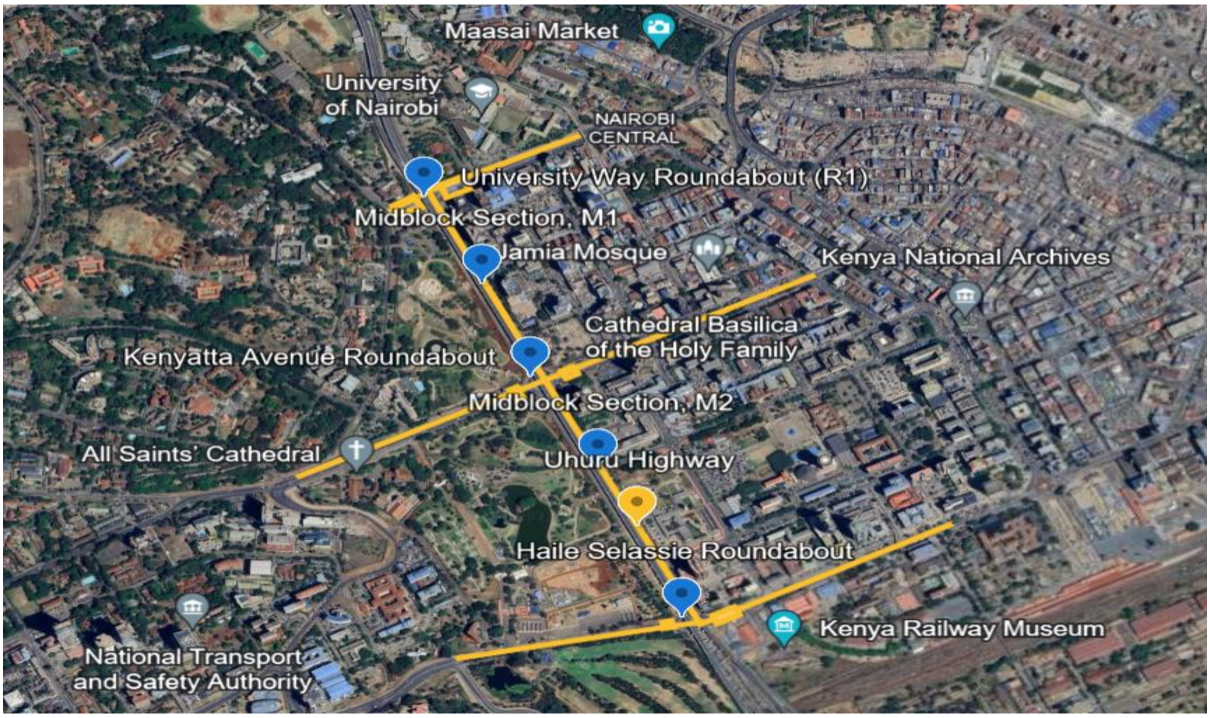

Figure 1-1: Roundabouts along Uhuru Highway in Nairobi, Kenya, Source: http://www.googlemap.com, Retrieved on 13th October, 2023

Figure 1-2: University Roundabout (R1) before construction of the Nairobi Expressway, Source: http://www.googlemap.com, Retrieved on 13th November, 2020

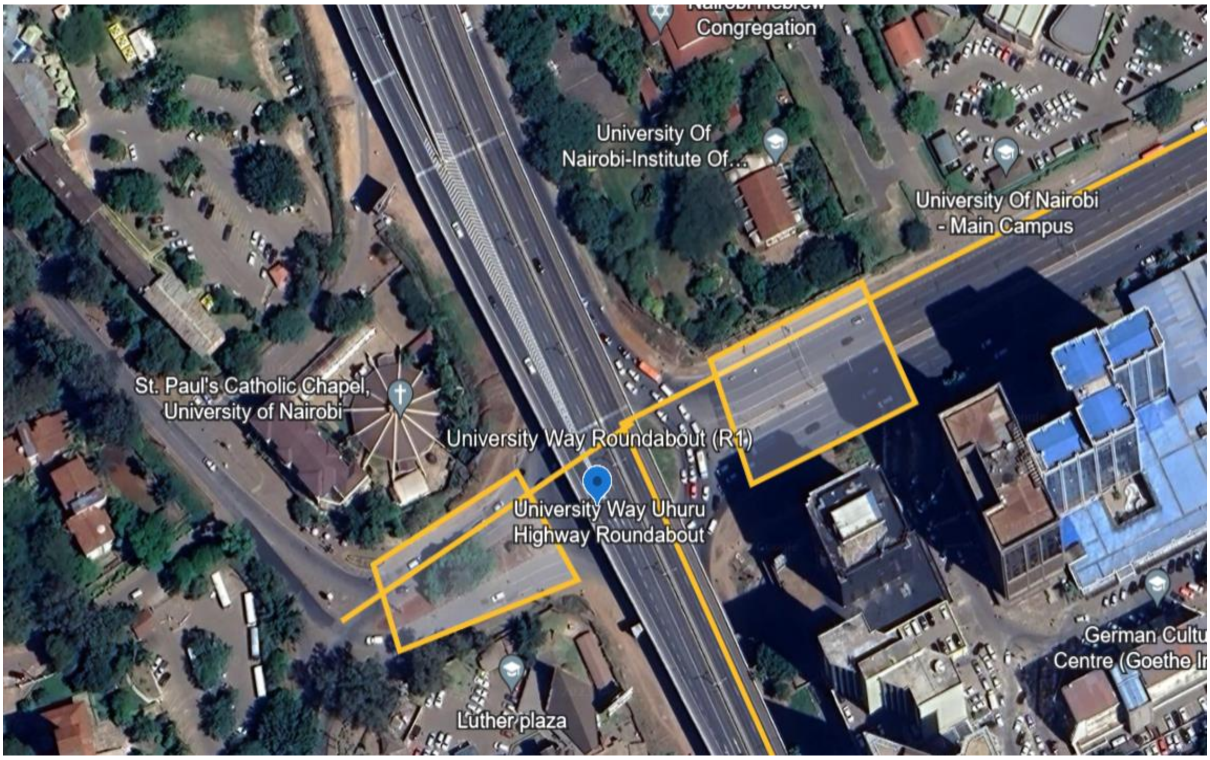

Figure 1-3: University way roundabout (R1) after construction of the Nairobi Expressway, Source: http://www.googlemap.com, Retrieved on 13th October, 2023

Figure 1-4: Kenyatta avenue roundabout (R2) before construction of the Nairobi Expressway, Source: http://www.googlemap.com, Retrieved on 13th November, 2020

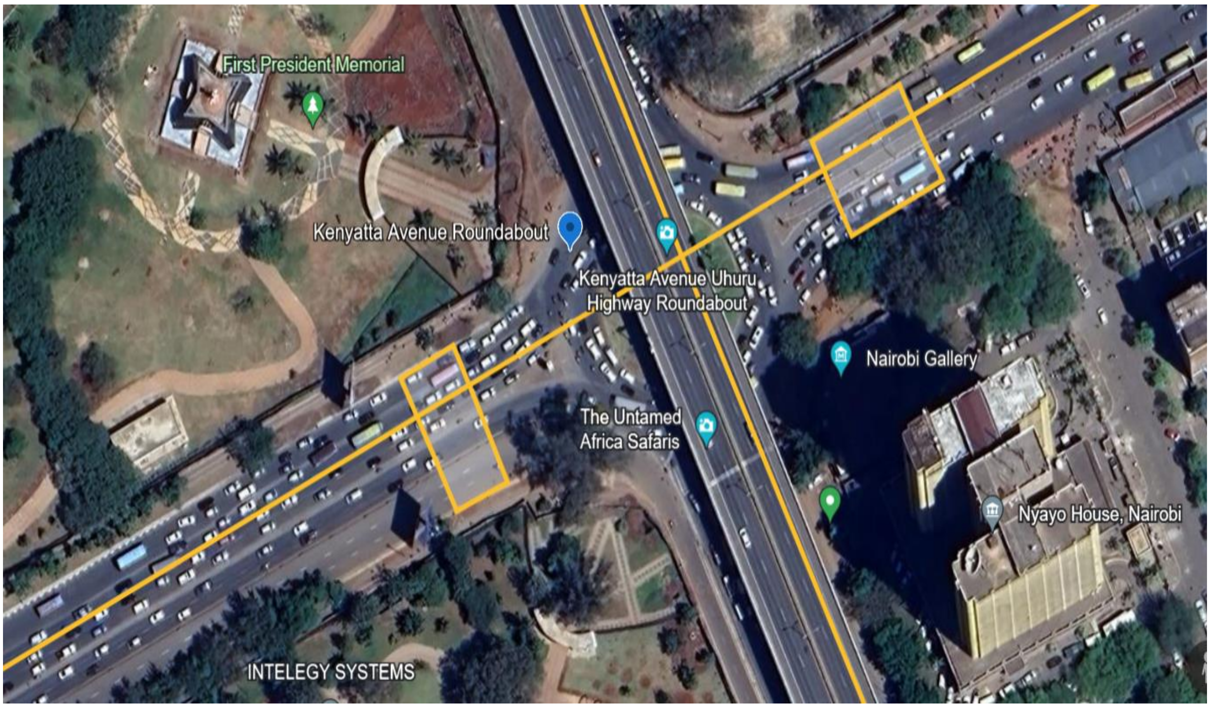

Figure 1-5: Kenyatta avenue roundabout before construction of the Nairobi Expressway, Source: http://www.googlemap.com, Retrieved on 13th October, 2023

Figure 1-6: Haile Selassie avenue roundabout (R3) before construction of the Nairobi Expressway, Source: http://www.googlemap.com, Retrieved on 13th November, 2020

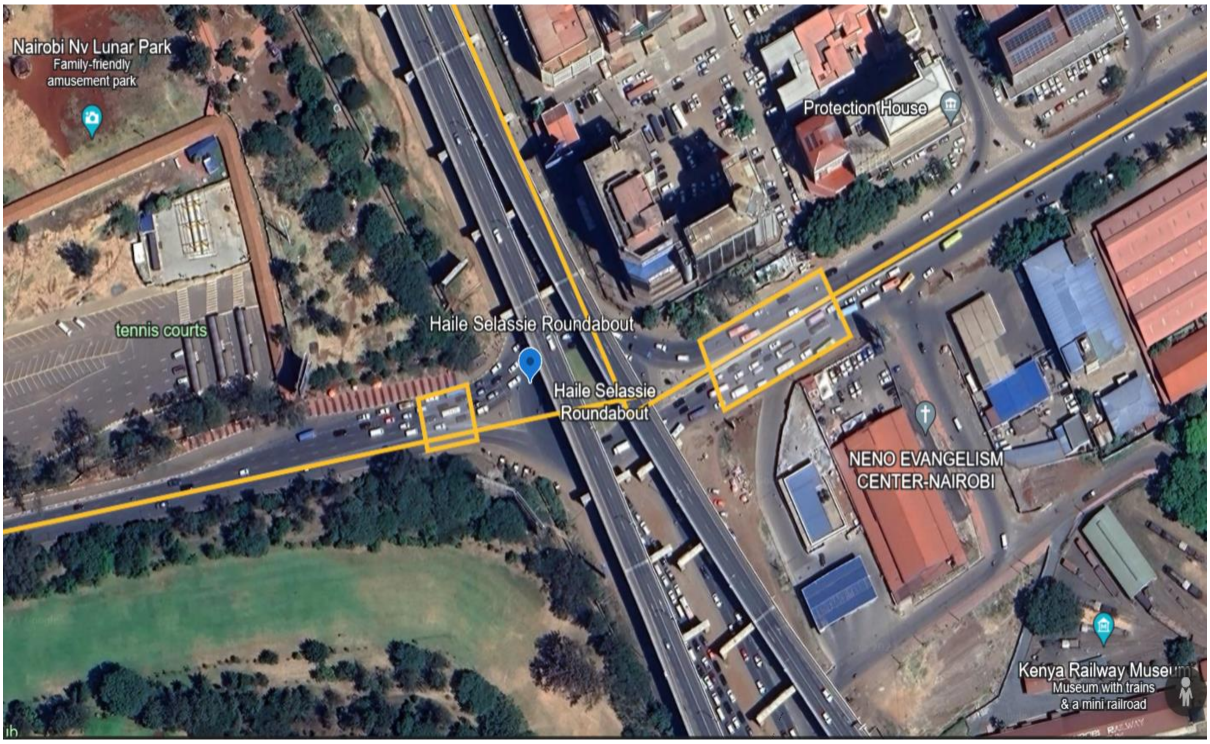

Figure 1-7: Haile Selassie Avenue roundabout after the construction of the Nairobi Expressway, Source: http://www.googlemap.com, Retrieved on 13th October, 2023

1.3 Problem Statement

Globally, road traffic crashes have caused about 1.35 million fatalities and injuries to about 20 to 50 million people each year according to the world global status report (WHO, 2018). In Kenya, the number of road traffic deaths by 1st November 2018 was 2,585, an increase of about 11% from 2,331 in the same period in 2017 (NTSA, 2021). About 21% surge in the number of road users seriously injured in crashes from 3,183 in 2017 to 3,860 in 2018 in the same period (NTSA, 2021). According to the national road traffic accident data, pedestrian fatalities constituted about 38% of total number of road traffic deaths in Nairobi (NTSA, 2021). Figure 1-8 below shows the distribution of pedestrian fatalities in Kenya between 2015 and 2020. In 2019, about 1,390 pedestrians were killed in a road crash despite the outbreak of Corona Virus (Covid-19) pandemic which led to lock downs and low motorization in Kenya and across the globe. This represents the highest statistics

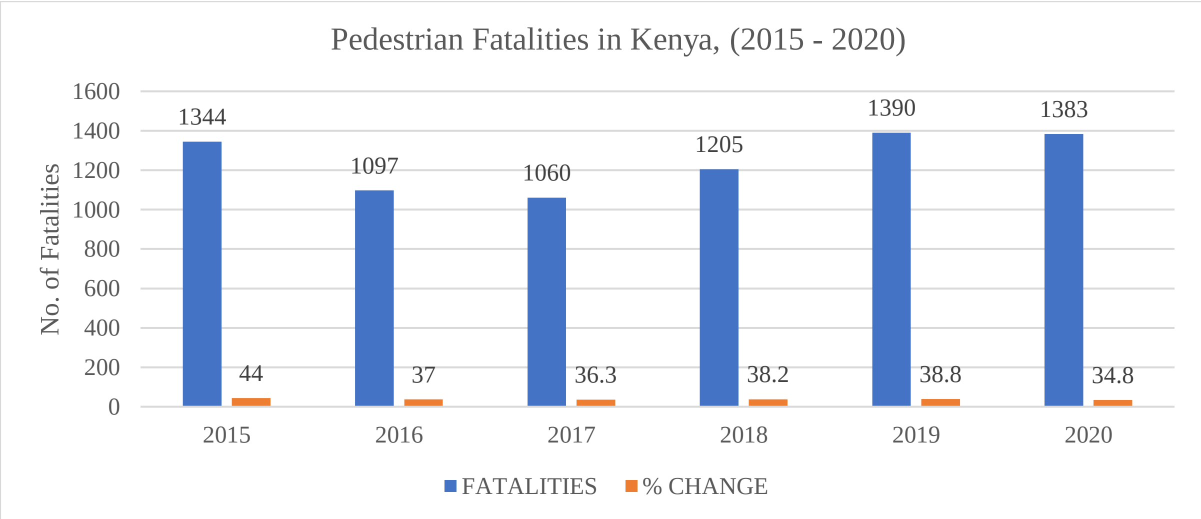

Figure 1-8: Pedestrian Fatalities in Kenya, (2015-2020), (NTSA, 2021)

According to national census data, Nairobi is the most populated city in Kenya with an average population of 4,397,073 on an area of 703.9 Km^2 which translates to a population density of about 6,247 / Km^2 (Kenya National Bureau of Statistics (KNBS) Census Report, 2019). Rapid growth of population and motorization in Kenya is an indicator to an increase in mortality due to road traffic crashes. Owing to inadequate safe infrastructure for walking and cycling in Nairobi, there is a significant exposure to road crashes especially for pedestrians and cyclists. Most pedestrians are killed by vehicular traffic while crossing the road according to statistics. Pedestrians cross the road either at designated crossings near junctions or roundabouts for arterials and at mid-block sections on urban streets.

According to Ogendi et al. (2013), pedestrians comprise the highest proportion of road traffic injury admissions (59.1%) followed by motor-vehicle passengers (24.2%) and motorcyclists (9.7%), Bicyclists and drivers accounted for 5.1% and 1.7% respectively. About 70% of pedestrians were hit while crossing the road, 10.8% while standing by the road and 8.1% while walking along the road. The highest proportion of pedestrian crashes occurred on Saturdays (25.5%) and Sundays (16.7%). Roundabouts in Nairobi are characterized by inadequate markings at crossing areas, non-functional traffic signals, unsafe driver behaviour, and inadequate capacity at peak times, poor lighting and inadequate safety facilities for people living with disability (Ogendi et al., 2013). The safe system approach advocates for determining road safety risk factors amongst the most vulnerable road users such as pedestrians and then designing proactive interventions aimed at eliminating risks or reducing the level of risk. This study focusses on identification of pedestrian safety risk factors using the safe system approach to road safety by assessing pedestrian crossings located near roundabouts along Uhuru Highway in Nairobi which constitutes the highest pedestrian fatalities as shown in Figure 1-9 below.

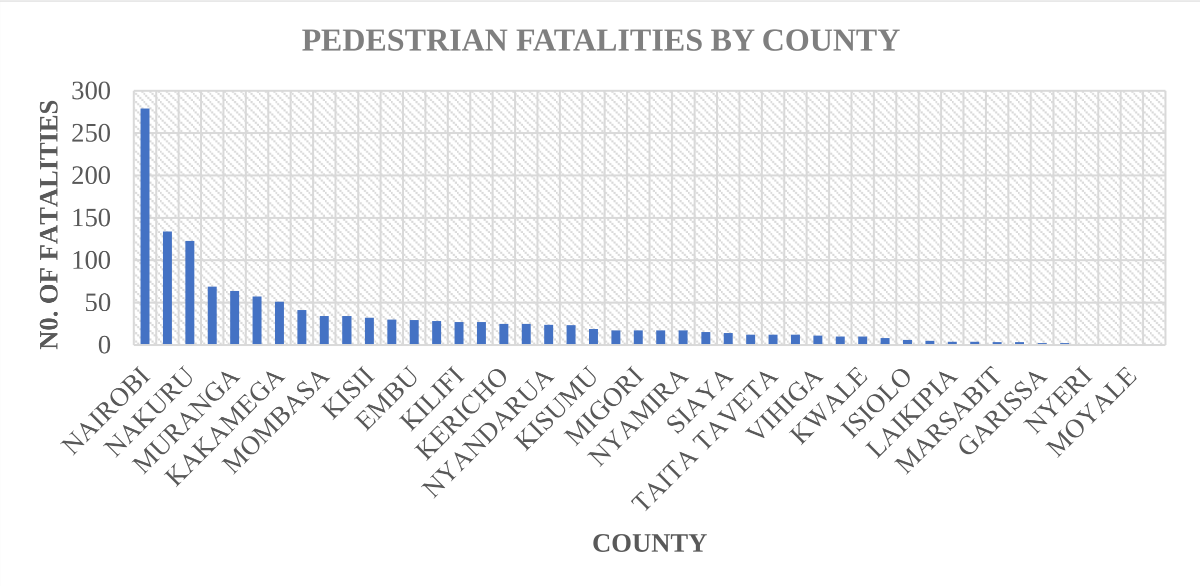

Figure 1-9: Pedestrian Fatalities by County in Kenya (2015-2020), (NTSA, 2021)

According to Majanja and Mbeche (2013), most people still prefer not to use footbridges to cross the road in Nairobi due to a number of reasons such as insecurity, safety at night, vendors encroaching pedestrian spaces, poor maintenance of footbridges, longer distances needed while crossing the road and inappropriate location of the footbridges. The study also suggested that in order to mitigate pedestrian challenges, appropriate countermeasures such as provision of adequate lighting, safe walking facilities and crossing facilities. A subsequent study by Oginga et al., (2017) along Uhuru Highway in Nairobi revealed some challenges faced by pedestrians crossing the road at the tunnel point such as insecurity, congestion, being way from desired line, being filthy and waterlogged, lack of accessibility and connection, and difficulty to use amongst other reasons. These two studies confirmed that many pedestrians are still bound to cross the road at same grade on Uhuru Highway despite interventions to separate pedestrian from motorized traffic through provision of tunnel and footbridge. It is therefore imperative to evaluate pedestrian safety risk factors when crossing Uhuru Highway at grade near roundabouts where many pedestrians cross the road.

1.4 Research Objectives

1.4.1 The Overall Objective

The overall objective of this study is to assess the determinants of pedestrian safety risk factors at crossings near roundabouts along Uhuru Highway in Nairobi.

1.4.2 Specific Objectives

The specific objectives include:

1. To assess the risk of demographic factors in pedestrian safety at level crossings near roundabouts along Uhuru Highway

2. To assess the risk of road infrastructure and its environment on pedestrian safety at level crossings near roundabouts along Uhuru Highway

3. To assess the risk of road user behaviour in pedestrian safety at level crossings near roundabouts along Uhuru Highway

4. To assess the risk of pedestrian crossing warrants in pedestrian safety at level crossings near roundabouts along Uhuru Highway

1.5 Research Questions

The following research questions were formulated to support the specific objectives listed above. These questions are listed as follows:

1. Does gender and age of pedestrians affect safety at crossings near roundabouts along Uhuru Highway?
2. Does road infrastructure and environment affect safety of pedestrians at crossings near roundabouts along Uhuru Highway?
3. Does pedestrian crossing behaviour affect their safety at crossings near roundabouts along Uhuru Highway?
4. Does pedestrian crossing warrants affect safety of pedestrians at crossings near roundabouts?

1.6 Scope and Limitations of the Study

1.6.1 Scope of the Study

The scope of work entailed assessment of various risk factors in pedestrian safety at crosswalks near roundabouts specifically in relation to the demographic factors, road infrastructure design, road environment, road user behaviour and the applicable pedestrian crossing warrants.

1.6.2 Limitations of the Study

Three roundabouts with highest pedestrian activities have been selected for a detailed assessment of the risk factors considering the level of exposure to traffic crashes on pedestrians especially at various times of the day, peak hour traffic and the weather conditions. The case study includes three roundabouts located at junctions between the Uhuru Highway and Haile Selassie Avenue, Kenyatta Avenue and University Way in Nairobi. Moreover, research period was limited to a maximum period of six months in accordance with the regulations on graduate research activities at the University of Nairobi.

1.7 Justification of the Study

Road safety target is amongst the 17 Sustainable Development Goals (SDGs): SDG 3; Good Health and Well Being and SDG 11; Sustainable Cities and Communities. SDG 3.6 target specifies the need to reduce road traffic fatalities and injuries by at least 50% while SDG 11.2 targets improved walkability and safety of the transport systems in cities especially for pedestrians. Walking remains a dominant mode of transport in Nairobi and as the population grows in the city, the demand for safer walking is expected to rise. This thesis offers a guide into assessing pedestrian safety risk factors necessary for designing countermeasures aimed at eliminating or reducing risk to road traffic crashes. The government of Kenya through Ministry of Roads and Transport in collaboration with Nairobi City County aims at improving walkability through investment in sustainable transport infrastructure to improve safe mobility and human health. This is evident through continued partnership with other development agencies such as Japan International Cooperation Agency (JICA) who finance the Nairobi Master Plan and other infrastructure development finance by the World Bank Group, Africa Development Bank amongst others.

The study site; Uhuru Highway, is an arterial road in Nairobi city was selected based on the number of pedestrians crossing the road near roundabouts on daily basis and the number of pedestrian-vehicle collisions leading to fatalities and injuries. The National Transport Safety Authority (NTSA) and National Road Agencies to implement proactive road safety measures targeting pedestrians can use the results of the study findings. These countermeasures proposed in other studies are such as marked pedestrian crossings, installing road signs, traffic control signals, street lighting and creating awareness amongst pedestrians to improve safe crossing behaviour. The results are also important for the Kenya National Highways Authority (KeNHA), Nairobi City County Government (NCCG) and Kenya Urban Roads Authority (KURA) for planning, design and maintenance of non-motorized transport facilities especially pedestrian crossings along Uhuru Highway in Nairobi.

Chapter 2

2. LITERATURE REVIEW

2.1 Introduction

The literature review has captured international and local research outputs with a specific inclination to the title of this thesis. An overview of global issues around road safety and in particular pedestrian safety risk factors at level crossings near roundabouts has been presented herein. This study has also considered local publications and information contained in national documents such as census, economic survey reports, and status reports on road traffic collisions as published by NTSA. In this review, baseline survey has captured findings from local theses on pedestrian safety risk factors as a benchmark. Pedestrian safety risk factors under review have been classified as human factors (demographics and pedestrian crossing behaviour), road infrastructure (geometric and roadway elements), road environment (adjacent land use activities, traffic control devices and lighting conditions), road user behaviour and pedestrian crossing warrants. Other pedestrian safety risk factors considered for review included; vehicle traffic volume, pedestrian volume and crossing speed, time of day, driver yielding behaviour, traffic control devices such as signals, markings, signs as per the Manual on Uniform Traffic Control Devices (MUTCD).

2.2 Outline of Literature Review

The literature review is organized as shown in Figure 2-1 below:

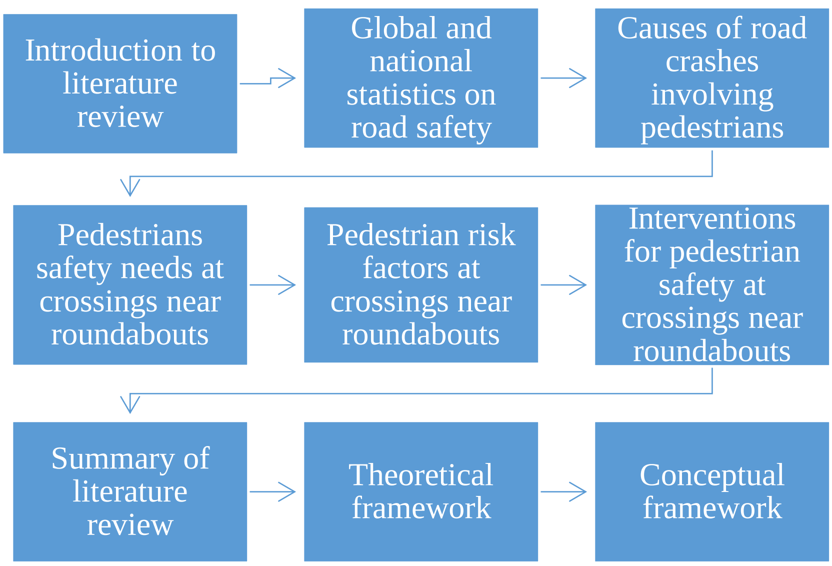

Figure 2-1 Outline of the literature review

2.3 Causes of Pedestrian Crashes

According to the NTSA in Kenya, there are many causes of road traffic accidents in Kenya as shown in Figure 2-2 below. There are several causes of pedestrian crashes in Nairobi such as lack of visibility of pedestrians, poor lighting condition, drunk pedestrians and failure to observe traffic rules by all road users, crossing at non-designated places amongst others. According to Stoker et al. (2015), causes of road traffic accidents are multifactorial in nature and can be categorized into driver factors, vehicle factors and roadway factors. Roundabouts are presumed to be safer than other types of intersections according to studies on evaluation of performance of modern roundabouts. Table 2-1 is a summary of different crash types near roundabouts and a description of crash types.

Table 2-1: Types of crashes near roundabouts

Crash types at roundabouts	**Road traffic crash description**
Run-off road	Single vehicle crash in which a vehicle leaves the road and collides with an object such as traffic sign or splitter island
Collision with central island	Single vehicle crash in which a vehicle leaves the circulatory road and collides with the central island
Wrong way	Road user enters the roundabout in the non-permitted direction
Rear end	Second vehicle collides with the rear of the lead vehicle
Loss of control	Collision between two road users due to loss of control
Vulnerable road users	Collision between a vehicle and a vulnerable road user such as pedestrian, bicyclists, motorcyclists or mopeds
Entering - circulating	Collision between two road users in which the entering vehicle fails to yield and collides with the circulating vehicle
Side - swipe	Collisions at double-lane roundabouts caused by lane changing on the circulatory road and by exiting.

Source: Daniels et al., (2013)

2.4 Risk Factors in Pedestrian Safety at Crossings near Roundabouts

Generally, there are pedestrian safety risk factors identified in this study and were categorised into four major groups. They include risk factors related to pedestrian demographics, road infrastructure design and environment, road user behaviour and pedestrian crossing warrants.

Pedestrian crossing behaviour can increase the risk of involvement in road traffic collisions and such can be classified as choice of crossing place, non-compliance with dedicated crossing, varied crossing speeds, failure to observe traffic rules and signal operation and pedestrian alcohol consumption (Gitelman et al., 2012). According to NTSA (2021), there are several causes of road accidents and most crashes are recorded as hit and run which constitutes the highest proportion of all crashes countrywide as shown in Figure 2-2 below. Risk factors related to road infrastructure include road geometric elements while road environment includes roadside activities and land use practices. Demographic factors include pedestrian age and gender as well risk factors for pedestrians with special mobility needs. These risk factors and determinants of pedestrian safety are discussed in detail in this section.

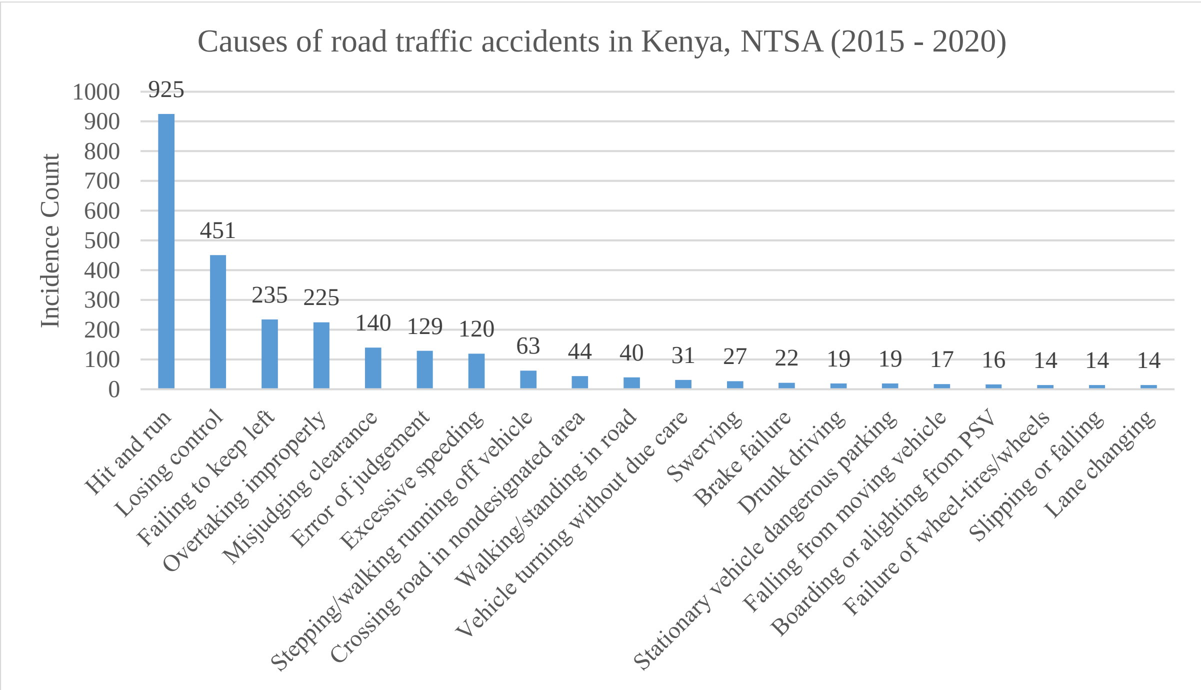

Figure 2-2 Causes of road traffic accidents in Kenya, NTSA, (2021)

2.4.1 Choice of crossing place

The choice of crossing places has an impact on pedestrian safety considering motor vehicle traffic volumes in Nairobi and driver behaviour near signal-controlled junctions and pedestrian crossings. Previous research has shown that risk in crossing the road is much higher away from crossing areas than at level crossings (Hariri Asli, 2022). Other studies show that crossing at signalized junctions is even safer (Mark et al., 2009). Pedestrian safety is of need for consideration as the population grows in the city of Nairobi to provide a more liveable environment for people. These studies also agreed that pedestrians still prefer to cross at grade.

Road safety measures on pedestrian mode improves walking environment and contributes to urban renewal, local economic growth, social cohesion, improved air quality and reduction in harmful effects of noise (Holland & Hill, 2007). According to Farag & Hashim (2017), latent errors and violations by road users can be prevented through the road traffic system by effective measures such as improvement in road safety management, provision of safer road infrastructure and mobility options, safer road users, safer vehicles and adequate post-crash care for victims as demonstrated by through the Swiss error model.

2.4.2 Pedestrian Crossing Location

In any traffic system, the safety of every user is the most integral to justification of their functionality and sustainability. Road traffic crashes involving pedestrians may occur at crossings located on various part of the road geometry including midblock sections, near signalized and unsignalized intersections, and roundabouts. Traffic engineers use pedestrian crossings to enhance safety of people crossing the road at same grade by inducing drivers to yield to them at crosswalk locations(Jain et al., 2014). According to Oginga et al., (2017), about 40% of pedestrians reported that they did not cross Uhuru Highway using the tunnel due to insecurity reasons while 24% pedestrians did not cross the road at the tunnel since it does not fall in their desired line.

Midblock crossings are a common place for pedestrian crashes in urban areas as reported by Wang et al. (2011). Furthermore, Wang et al. (2011) observed that crossing the road at midblock areas is riskier and more deadly compared to intersections. However, this study seeks to verify the amount of risk involved when pedestrian cross the road section near roundabouts. A review of pedestrian safety in a paper titled ‘safe walking’, revealed that most pedestrian-vehicle collisions occur when pedestrians are crossing the road rather than when walking or standing alongside the road (WHO, 2013).

2.4.3 Pedestrian Volume, Speed, Flow and Density

Traffic characteristics such as pedestrian volume, speed, flow and density all have an impact on their safety at level crossings (Zhuang & Wu, 2011). At higher pedestrian volumes, the vehicular traffic is compelled to wait for pedestrians to cross rather than wait at traffic signals. Average walk speed while crossing the road at crossing location affects the signal timing. Other improvements incorporated into pedestrian safety at crosswalks including the push-button device for pedestrians to signal the drivers of imminent action to cross the road.

2.4.4 Marked and Unmarked Crosswalks

Manual on Uniform Traffic Control Devices, (2009), identifies three types of crosswalk markings such as standard parallel lines, ladder or continental stripes and diagonal stripes. A study by Mukherjee & Mitra, (2022), found out that there was no statistically significant difference in pedestrian crash risks for various types of cross walk markings. However, this study highlights that crosswalks may be raised 'speed tables' or used in conjunction to supplemental signing, in-pavement signing, overhead flashers, night-time lighting, and pedestrian refugee island and traffic signalization.

Pedestrian crossings have varying geometric requirements that provide for safety and convenience for pedestrians crossing at grade. In Nairobi, the most common type of crossing is zebra crossing characterised by white marking of thermoplastic paint material on pavement. These markings are provided as street furniture to enhance safety of pedestrians. Most of the zebra crossing on streets of Nairobi are designed to provide crossing at grade near roundabouts and at mid-block sections.

Previous study concluded that pedestrian crashes were higher on unmarked crosswalks compared to marked crosswalks (Sheykhfard et al., 2021). Also, Gibby et al. (1994) analysed crashes at 380 unsignalized highway intersections in California, USA from among 1000 candidate intersections and found out that crash rates per pedestrian vehicle volume were two or three times higher in marked than unmarked crosswalks at those sites. A study by Zegeer et al. (2002) revealed that pedestrian behaviour and motorist behaviour changed once marking was introduced on pre-existing crosswalks such as increased usage of crosswalks by pedestrians and yielding by motorists on approach to marked crosswalks. The overall effect of this improvement was lowering the number of pedestrian crashes.

Zegeer et al. (2002) suggested some of the following recommendations for improving safety of pedestrians at crossings near unsignalized intersections: raised medians, traffic and pedestrian signals, curb extensions or raised pedestrian refuge islands, installing adequate night-time lighting at pedestrian crossings, constructing raised street crossing and designing safer intersection and driveways. Usually, road designers intend that pedestrians will cross the road at provided marked crossings points considered safe. Such crossing points are provided based on standard guidelines published in the Kenyan Road Design Manuals. These provisions are made to enhance safety of pedestrians and other Non-motorized users such as cyclists.

2.4.5 Roundabout Geometrics and Road Design

Roundabouts are considered safer than traditional intersections for motorists, bicyclists and pedestrians due to reduced number of crashes and conflict points between pedestrians and vehicles at roundabouts (Giuffrè et al., 2016) . Due to geometrics of roundabouts, the injuries that may occur in case of a crash are less severe compared to those on intersections to reduced speeds of approach to roundabouts by motorists (Giuffrè et al., 2016). A study conducted by Granà (2011) revealed that lower design speeds of roundabouts contribute to higher safety levels. Geometrically, roundabouts can be identified in three major classes namely mini-roundabouts, single-lane roundabouts and multi-lane roundabouts.

Most of these geometric configurations have varied effect on the safety of pedestrians crossing near roundabouts and these are highlighted from previous studies as number of traffic lanes on each leg of the roundabout, size of the roundabout and size of pedestrian refuge island. According to Stone et al. (2002) roundabouts are designed to provide safety for all road users, improve operational efficiency to motorized traffic and adequate comfort to turning drivers. The design aims to improve traffic flow at the junction by reducing waiting time, reduce delays to a minimum and to maximize throughput with reduced traffic conflicts.

The roundabouts analysed in this study are of four-leg type and the geometric parameters determining the practical capacity of a roundabout includes average width and length of weaving section (Wang et al., 2013). The number of lanes on the weaving length and the entry and exit legs have a great effect on types and number of crashes at roundabouts. For pedestrians, the crossing is often located across the exit and entry legs with a central median or refuge separation between two carriageways for traffic in opposite direction. Aziz et al., (2010) analysed pedestrian vehicles crashes in New York, USA and found out that roadway features such as number of lanes, road surface condition and lighting have a significant contribution to severity of injuries to pedestrians when crashes occur.

To improve traffic flow, some designers incorporate yield lanes on approach to entry into the mini roundabout to enhance capacity and improve overall safety to the roundabout (Al-madani, 2012). In case of higher pedestrian volumes, signal controls and larger crosswalks widths may be included to improve safety of pedestrians. Roundabouts are not recommended for areas where traffic flows would present difficulty for pedestrians to navigate the intersection or vehicle delay. Moreover, roundabouts are not meant for high-speed roads due to the expected mix of traffic in both urban and sub-urban areas. A significant increase in Average Annual Daily Traffic (AADT), pedestrian volumes, number of approaching lanes and number of circulating lanes would cause significant increase in the number of pedestrian-vehicle crashes hence increasing pedestrian safety risk to collisions (Granà, 2011). Traditionally, pedestrian safety at roundabouts is improved compared to other intersections due to reduced speeds, minimal conflict between pedestrians and vehicles (Hariri Asli, 2022).

2.4.6 Pedestrian Crossing Behaviour

The behaviour of pedestrians when crossing the road depends on various factors such as traffic conditions, location of signalized or unsignalized intersection and phasing of traffic signals (Ni et al., 2017). Some of these behaviours have been studied in different measures and variables including gender, age group, way of crossing, pedestrian waiting time before crossing, pedestrian volumes, pedestrian crossing pattern including single, couple or group. Zhuang & Wu, (2011) concluded that careless and illegal pedestrian crossing behaviour (not using the pedestrian crossing facilities) contributed significantly to all casualties on pedestrian-vehicle crashes. According to Toran Pour et al., (2018), significant factors affecting pedestrian compliance behaviour are gender and group size of pedestrians. Toran Pour et al., (2018) in their study revealed that the probability of violations decreased by pedestrian group size and that women and middle-aged individuals were found to be more likely to violate traffic rules. Waiting time is another characteristic of pedestrians that has a great impact on their safety. Studies have reported that male pedestrians expect a shorter and reasonable waiting time compared to females, while the elderly persons and children who are generally willing to take reasonably longer waiting time (Zafri et al., 2019).

For signal-controlled crossings, Tiwari et al. (2007), concluded that as signal time increases, pedestrians get more impatient and violate the traffic signal thus increasing the risk of involvement in crashes. According to Jain et al. (2014), male pedestrians were found to perform much riskier behaviour when crossing the road and that the safety of pedestrians at a crossing is also related to their perception to priority rules at intersections.

Pedestrian crossing in groups of three or more often feel safer and more comfortable on crossings near roundabouts. This proposition has been confirmed in previous studies including one by Ni et al. (2017) that pedestrian perception of safety and comfort is higher since when they cross in groups motorists tend to yield more on the approach to level crossings near roundabouts. Additionally, this study by Ni et al. (2017) confirmed that this comfort and perception of safety by pedestrians in groups is connected to traffic conflicts, crossing facilities and delays in traffic stream. Distefano et al. (2021) further concluded that there is a gap in relating the indicators or safety to pedestrian crossing behaviour at roundabouts.

2.4.7 Traffic Volume, Speed, Flow and Density

Intersections have a higher concentration of vehicle-pedestrian crashes and according to a study by Lee & Abdel-Aty (2005), the number of pedestrian-vehicle crashes increased with the amount of traffic volume at that intersection. Motorized traffic has a great impact on safety of pedestrians at crossings near roundabouts and this is evident by the behaviour of pedestrians when crossing large roundabouts with higher traffic volume like the one located along Uhuru Highway in Nairobi. Owing to rapid increase in motorization, powered two-wheelers have significantly increased in number thus hindering safety of pedestrians at crosswalks due to their violation of signal operation.

Roundabout capacity design involves determining the parameters such as width of weaving section, average width of entries to weaving section and length of the weaving section (Al-madani, 2012). Entry widths are critical to pedestrian safety and therefore they need to be proportional to the amount of pedestrian volume accessing the roundabout. To meet the geometrical standards of a roundabout, the highway engineer needs to select appropriate layouts with parameters defined based on traffic volume, speed, flow and density.

2.4.8 Driver Behaviour (Yielding)

Driver yielding is a key determinant of how pedestrians behave at a crossing near roundabout or midblock section since the human body is highly vulnerable to injuries in case of a crash. Tulu (2015) conducted a study on why pedestrian crashes are so different in developing countries and concluded that the crossing behaviour of pedestrians in Addis Ababa, Ethiopia is rarely in compliance with pedestrian regulations though drivers contribute to this by not yielding at pedestrian crossing. This study however, indicated that despite widespread illegal behaviour by pedestrians at crossings, there is little information about relative contribution to this behaviour by the level of knowledge of traffic rules, relative opportunities to cross legally (Tulu, 2015).

However, driver behaviour varies according to the type of regulations at the intersection, junction or roundabout. These could include violations for signal-controlled intersections or junctions such as going through an orange or red light and start when pedestrians are still crossing. A previous study by Pulugurtha et al. (2007) revealed that there was a significant increase in the number of drivers yielding to pedestrians at crosswalk location hence reducing the risk to crashes.

However, motorcyclists rarely yield to pedestrians near crossings located at midblock sections, intersections and near roundabouts. In recent years, the use of motorcycle for public transport has increased tremendously and thus triggering an increase in number of pedestrian-motorcycle crashes hence posing a great risk to pedestrian safety. Motorcyclists have been on the leading trend by recording the highest number of violations to traffic rules and regulations at intersections, roundabouts and midblock section in Nairobi.

2.4.9 Demographic Factors (Gender and Age)

Gender has the most significant effect on pedestrian's perception on safety at crosswalks with the male pedestrians being more impatient in traffic activities than female pedestrians (Toran Pour et al., 2018). Overall, studies have revealed that different age groups have different walking needs; like younger pedestrians being more willing to tolerate pedestrian congestion unlike older pedestrians needing more walking space to have the same perception of comfort and safety. A recent study in Kenya showed that pedestrian demographic factors significantly influences implementation of road safety rules. It further mentioned that pedestrian age is a critical factor which should be considered in planning and design of road infrastructure safety interventions (Otieno et al., 2016). Age also playing a key role in determining crash involvement for pedestrians crossing the road near roundabouts. Considering demographics in Nairobi, people aged 20 - 29 years old are the majority followed by people aged 0 - 9 years old. People in these age groups are likely to participate more in walking since it comprises schools children, college students and people seeking employment or working informally.

2.4.10 Pedestrian Refuge/Island

The design of pedestrian facilities around roundabouts also includes provision of safe refuge/ island area between lanes especially where the pedestrian crossing distance is longer. Pedestrian refuge is a vital infrastructure on the roadway to improve pedestrian safety at crossings near roundabouts. Previous study by Zegeer et al. (2002), revealed that there are benefits to pedestrian safety when pedestrian refuge islands are provided with crossings considering statistically lower number of crashes at such locations. Availability of island also improves safety of pedestrians hence leading to a significant number of users.

According to Huang & Cynecki (2001), the number of pedestrians using a pedestrian crossing increased significantly considering provision of the refuge on median. Due to increase in population and the number of road users on foot near institutions, the risk to involvement in crashes or conflicts with vehicular traffic is higher at pedestrian crossings.

2.4.11 Visibility at Roundabouts

Most roundabouts in Nairobi consist of a central island dedicated for beautification and installing other amenities that aid in traffic control such as traffic signal devices, traffic lighting, city clock, monuments and other decorations. However, some of these amenities on the traffic island could significantly reduce visibility of other road users like pedestrians. Specifically, obstructions have a net effect of reducing visibility of pedestrians at night as confirmed from previous studies. Safer roundabouts require proper illumination at night for motorists to see pedestrians crossing the road or waiting for signal operation and police guidance. According to NTSA, there significant proportion of reported pedestrian-vehicle collisions which occur between 5pm and 10pm as shown in Figure 2-3 below.

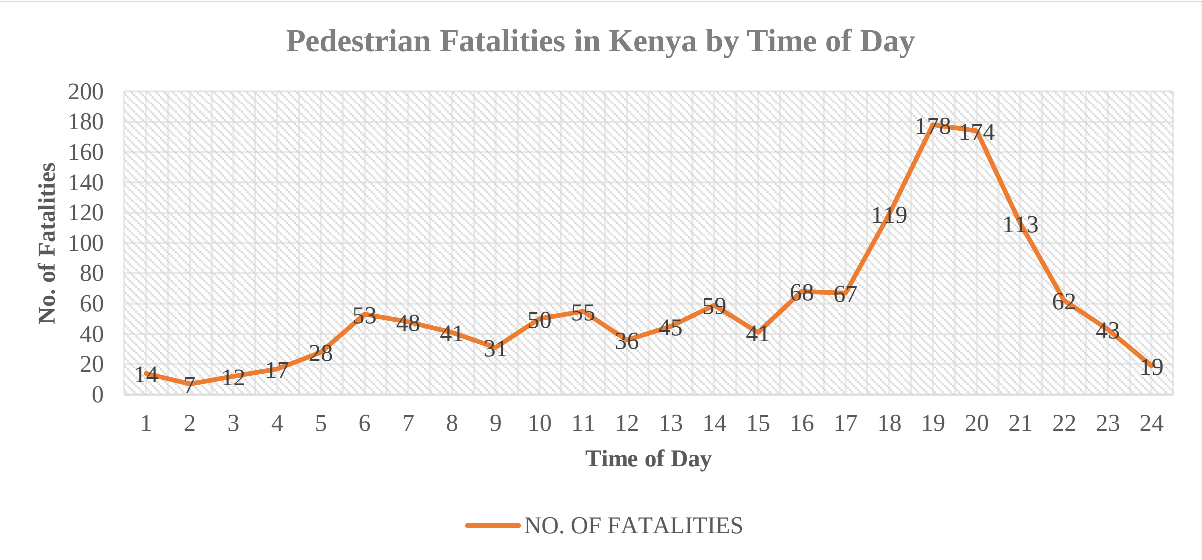

Figure 2-3: Pedestrian Fatalities in Kenya by Time of Day (NTSA, 2021)

According to a report by World Health Organization on "*Make Walking Safe*", around the world, most pedestrian crashes do occur when lighting conditions are low during dusk, at dawn and at night (WHO, 2013). This report gives an overview of pedestrian safety around the world and it indicated that key amongst risks to pedestrian crashes were driver behaviour, pedestrian behaviour, road design, land-use planning near crossing locations, vehicle design and trauma care. Figure 2-3 below indicates the pattern of road crashes in Nairobi with time of day. Most crashes are visibly occurring between 6.00 pm to 9.00 pm indicating that night conditions are a major contributor to crashes (NTSA, 2021). Installation of lighting infrastructure aids visibility and pedestrians need to wear reflective clothing to reduce the risk to crashes at level crossings.

Traffic islands have the effect of obstructing motorists entering the roundabout from seeing pedestrians crossing the road. To improve this visibility, previous studies have demonstrated the net effect of enhancing roadway lighting at roundabouts. Pedestrian crash risk is higher at night than daytime since drivers' ability to recognize pedestrians at night is degraded such that pedestrian fatalities may rise seven times higher than daytime (Wood et al., 2012). Figure 2-4 shows a comparative analysis of collisions involving pedestrians in Nairobi between January to October in the years 2018 and 2019. This statistical analysis shows that still majority of crashes involving pedestrians occur between 6pm and 10pm in Nairobi. Therefore, visibility is a key safety risk factor and should be explored in relation to crossing the road near roundabouts.

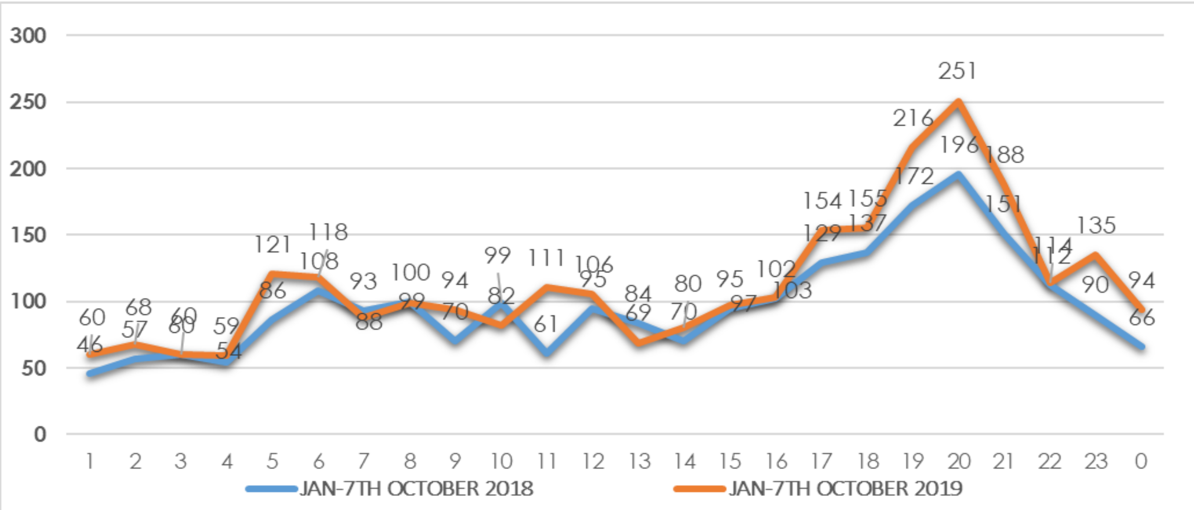

Figure 2-4 Contribution to fatalities associated with time, NTSA, (2021)

2.4.12 Traffic Control Devices

Traffic control devices are important in reducing road fatalities. For instance zebra marking on the road ways reduces drivers speed (Wood et al., 2012). A review of literature on safety of vulnerable road users by OECD (1998) reported that different kinds of behaviour by pedestrians results into different kinds of accident risks such as drinking, not using retro-reflective devices, crossing the road in breach of traffic rules and signal information, not using pedestrian crossings, not respecting pedestrian signals, among others. The report also highlighted that the highest risk to pedestrian crashes would occur when on pedestrian crossings especially if traffic lights are ignored and when the pedestrians do not use the crossing provided (OECD, 1998).

2.4.13 Pedestrian Crossing Warrants

Globally, there are four types of crossing facilities such as physical aids, marked crossings, signalized crossings and grade separated crossings (Rastogi et al., 2013). These facilities are further outlined in Figure 2-5 below. In Kenya, physical aids include kerb extensions and pedestrian refuge located near roundabouts for dual carriageway roads. Zebra crossing is the most common type of marking provided near roundabouts. Along Uhuru Highway, there is a pedestrian tunnel used by some students and staff to cross the road despite the challenges such as insecurity, water logging and poor lighting. No other grade-separated crossings exist currently along Uhuru Highway such as a footbridge. The Kenya National Highways Authority (KeNHA) is currently evaluating the need for a grade separated crossing facility along Uhuru Highway especially near Haile Selassie Roundabout. This pedestrian crossing facility is intended to improve safety of pedestrians and other vulnerable road users crossing from Green Park terminus to Central Business District (CBD).

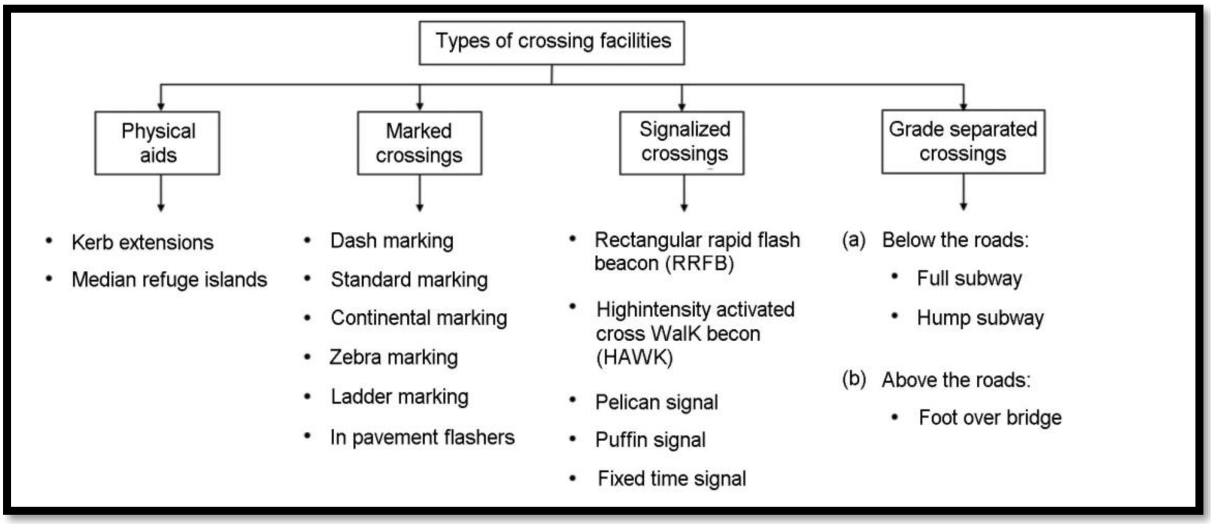

Figure 2-5: Types of crossing facilities (Rastogi et al., 2013)

Due to emerging technology, the Kenya Urban Roads Authority (KURA) has installed push buttons along Harambee Avenue in Nairobi City to improve safety of pedestrians but none near roundabouts along Uhuru Highway. Currently, there are no traffic signal control devices exist currently at these crossings, markings are faded due to lack of maintenance, no adequate signage for motorists and pedestrians. Pedestrian crossing warrants guides engineers and planners in selecting appropriate location and type of crossing facility for pedestrians.

2.5 Comparing Pedestrian Safety Issues at Roundabouts and Intersections

Pedestrian safety issues near roundabout encompass several things as in Table 2-2 below.

Table 2-2: Comparison of pedestrian safety issues at roundabouts and intersections

Pedestrian Safety Issue	Roundabouts	Intersections
Pedestrian crash data	Little	Much
Speed	Lower	Higher
Traffic calming	Enhancing	Inhibiting
Pedestrian Refuge Island	Yes	No
Pedestrian vehicle conflict	8	16
Right of way	Vehicle	Pedestrian
Driver-Pedestrian Familiarity	Little	Much
Judging Gaps (Sighted)	Easy (low speed)	Hard
Judging Gaps (sight disability)	Difficult (continuous traffic)	Easy (Discontinuous Traffic)
Auditory cues (sight disability)	Difficult (continuous traffic)	Easy (Discontinuous Traffic)

Source: (Stone et al., 2002)

2.6 Conclusion to Literature Review

In conclusion, pedestrian safety risk pedestrian safety at level crossings near roundabouts has been reviewed in relation to road infrastructure, road environment, road user behaviour, pedestrian demographics and pedestrian crossing warrants. Several factors reviewed from global to national perspective for ease of comparison of results obtained in this study. Road user behaviour is attributed to majority of pedestrian-vehicle crashes and especially when pedestrians are crossing the road near junctions. According to Distefano et al. (2021), behaviour of pedestrians is strongly influence by human factors such as age and gender rather than location of crosswalks on each leg of roundabouts. Elderly pedestrians are more cautious and since they still perceive crossing the road as more dangerous activity.

Three analytical frameworks can be used in preventing pedestrian crashes such as public health approach, the Haddon's matrix and the Safe Systems Approach. The Haddon's matrix is used to identify risk factors in road crashes at the pre-crash phase. The safe systems approach is instrumental in designing countermeasures to road crashes involving pedestrians at different locations. Implementing countermeasures is a vital component of road safety management and it relies on accurate identification of risk factors, magnitude of risk and the risk mitigation strategies and costs. According to Mukherjee & Mitra (2022), most studies on pedestrian safety at intersections have focussed on vehicle factors and crash data which seems more updated in western countries as opposed to developing countries. It is therefore appropriate for this study to focus on every component of the safe system in regards to pedestrian safety risk factors at crossings near roundabouts.

2.7 Literature review summary and research gap

Several knowledge gaps have been identified which has formed the basis for this study. Detailed assessment of pedestrian safety risk factors is vital in understanding the causes of pedestrian-vehicle crashes at crossings near roundabouts. As established in this literature review, pedestrian demographic factors, road infrastructure and environment, pedestrian crossing behaviour and pedestrian crossing warrants have a strong effect on safety of pedestrians when crossing the road near roundabouts. Pedestrian-vehicle collisions are significantly increasing in Nairobi which implies an increase in exposure to safety risk factors. These factors may include; poor visibility, lack of adequate signage, markings and traffic control signals, speeding motorists, high pedestrian and vehicle flows, poor choice of crossing place, lack of safe crossing facility and obstruction by piers supporting the Nairobi Expressway as shown in Plate 2-1 below.

Plate 2-1: The Nairobi Expressway along Uhuru Highway in Nairobi City, Kenya. Source: Author, 2022

Comprehensive and integrated multimodal transport planning recommends a sustainable transport solution for improving safety of all road users especially pedestrians in Nairobi. The increase in number of motorcyclists in the city has affected safety of other road users especially pedestrians and bicyclists along Uhuru Highway. This has been evident by the number of motorcyclists violating traffic rules at roundabouts especially by speeding while pedestrians are crossing. The literature review has not established adequate findings on the behaviour of motorists at roundabouts locally in Kenya hence the need to examine this scenario. Table 2-3 illustrates some of the literature gaps identified during the review which formed the basis for this study.

Table 2-3: Summary Literature Gaps

S/No.	**Author, (Year)**	**Findings**	**Gaps in Literature**
2.1	(Granà, 2011)	Roundabouts are considered safer to pedestrian due to reduced vehicle speed, minimized pedestrian-vehicle conflicts, For safety conscious planning, sharing the road space between motorists and pedestrians can significantly improve safety	No relationship was established between pedestrian safety and demographic factors (age and gender) The study did not estimate the risk in pedestrian safety while crossing near roundabouts or at road segments
2.2	(Basile et al., 2017)	It separated signalized and non-signalized crossing. It applied Analytic Hierarchy Process (AHP) method focussing on Spatial and Temporal Design, Day time and Night time visibility, and accessibility as key safety risk factors when crossing the road	Study did not include road infrastructure design and environment as a safety risk factor for pedestrians at crossings Study did not capture effect of age and gender on pedestrian safety at crossings near roundabouts

S/No.	Author, (Year)	Findings	Gaps in Literature
2.3	(Mukherjee & Mitra, 2022)	The study focussed on modelling factors affecting pedestrian safety including impact of built environment, traffic parameters, land use and spatial factors, and pedestrian level attributes. It recommended countermeasures aimed at reducing pedestrian crossing difficulty	Study did not examine pedestrian crossing behaviour as a safety risk factor when crossing the road. Study focussed on pedestrian crossings in general but did not specify effect of crossings near roundabouts
2.4	(Distefano et al., 2021)	Applied CHAID (Chi-Square Automatic Interaction Detector Analysis) decision analysis tree to measure effect of pedestrian crossing pattern near roundabouts. It applied path analysis method to analysis relationship between independent and dependent variables	Study did not capture crossing behaviour at midblock sections. It did not capture effect of pedestrian demographic factors at crossings.
2.5	(Fylan & Stradling, 2014)	It focussed on evaluating behaviour of young pedestrians at crossings by applying Behaviour Change Technique method.	Did not capture impact of road design, environment and traffic parameters on safety of young pedestrians at crossings near roundabouts
2.6	(Zegeer et al., 2002)	Compared safety level of different types of crossing in different cities in the USA including impact of raised and unraised marked crossing.	Did not relate impact of marked and unmarked crossing and pedestrian crossing behaviour. Study did not estimate the risk level for pedestrians on marked or unmarked crossing

S/No.	Author, (Year)	Findings	Gaps in Literature
2.7	(Ogendi et al., 2013)	Applied prospective study design by using 3 months data obtained for Nairobi City at Kenyatta National Hospital. Based on hospital data, it classified types of injuries sustained by pedestrians involved collisions	Did not focus on infrastructure, environment and traffic engineering parameters affecting safety of pedestrians at crossings
2.8	(Polders et al., 2013)	Applied crash data analysis and collision diagrams to establish eight major crash types at roundabouts in a case study in Flanders, Belgium. Study found out 80% of collisions occurred on entry land and in circulatory island. Most serious injury crashes involved vulnerable road users such as cyclists and mopeds	Study did not establish percentage of crashes involving pedestrians at crossings near roundabouts. It did not establish crash patterns for pedestrians at crossings near roundabouts.
2.9	(Tulu et al., 2015)	Study explored effects of geometric, traffic parameters and spatial factors	Study did not measure pedestrian crossing behaviour and safety effects of pedestrians

Source: Author, 2022

2.8 Conceptual Framework of the Study

The conceptual framework for this study is embedded in the selection of parameters/variables to be measured. The study aims at determining pedestrian safety risk factors through analysis of previous frameworks on causes of road traffic collisions. These are borrowed from the three main factors; human factors (pedestrian demographics, pedestrian crossing behaviour and other road user behaviour), road infrastructure and environment factors, vehicle factors and the interrelationships that exist amongst these factors. The study evaluates pedestrian safety risk factors in respect to demographics (age and gender), pedestrian crossing behaviour (way of crossing), road infrastructure and environment (geometric elements, vehicle and pedestrian traffic characteristics and adjacent land use activities) and pedestrian crossing warrants (markings, signs and signals, in-pavement lighting). The study also seeks to estimate pedestrian safety risk at each crossing location based on a formula used in a separate study.

Risk is often defined as the overall product of a number of factors often measurable as key variables in the study. The magnitude of this overall risk is a determinant of level of safety for pedestrians while crossing the road. Equation 1 was adapted from previous findings on methodology for assessing pedestrian safety risk factor by (Basile O. et al., 2017). It postulates that the overall safety risk factor (W) can be calculated as a summation of the products of all factors affecting pedestrian safety at crossings near roundabout. This equation stipulates that pedestrian safety is dependent on a number of variables, which are components of the four major categories of pedestrian safety risk factors; pedestrian demographics, road infrastructure and environment, pedestrian crossing behaviour and pedestrian crossing warrants which have been identified in this study.

$W = \prod_{i=1}^{n} m_i \dots\dots\dots\dots\dots\dots..Equation$ 1, Source: (Basile O. et al., 2017)

Where;

‘W’ is the overall risk per pedestrian crossing located near roundabouts

‘m’ is *i* number of pedestrian safety risk factors identified and classified in the four major categories as shown in the conceptual framework in Figure 2-6 below.

This study has adopted this formulae to calculate the overall pedestrian safety risk factor for all 14 crossings located near three roundabouts along Uhuru Highway. The study has relied on a number of mixed methods used to estimated quantitative values of road traffic safety elements applicable to pedestrians crossing near roundabouts Uhuru Highway in Nairobi.

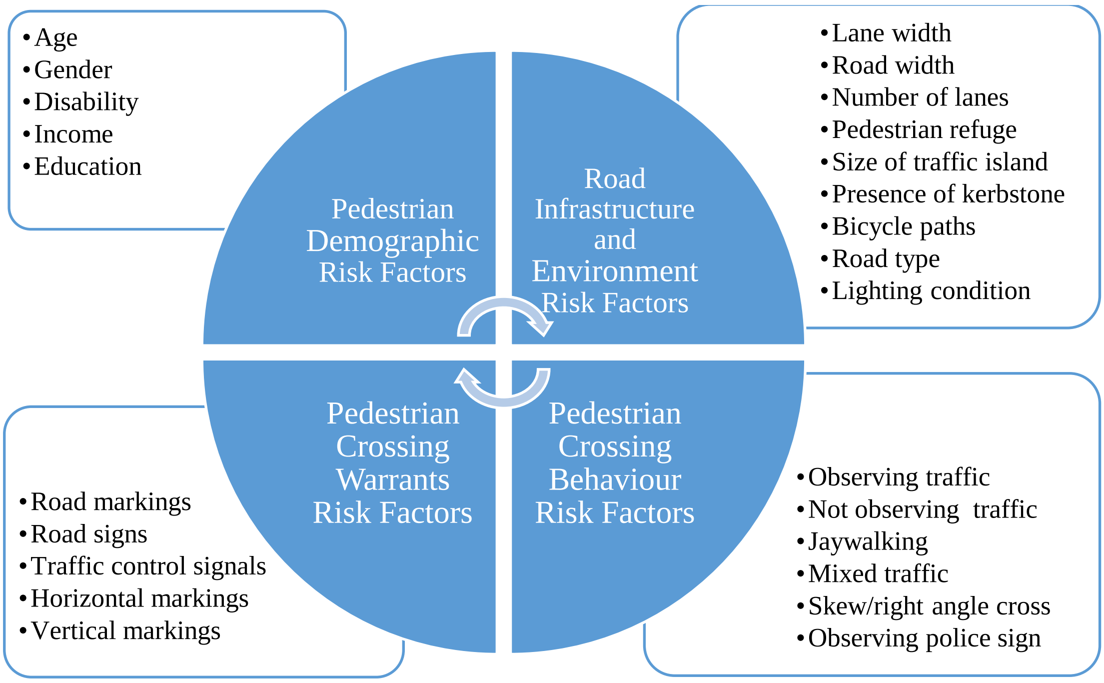

Figure 2-6: Conceptual Framework, Author, (2022)

Chapter 3

3. METHODOLOGY

3.1 Study Design

The study was conducted to accurately assess and determine pedestrian safety risk factors at crossings near three roundabouts along Uhuru Highway in Nairobi City, Kenya. Several mixed methods were adopted in the study including oral roadside interviews, questionnaire, classified motorized and non-motorized traffic counts, linear measurement of all geometric elements of roundabouts, directly observing pedestrian crossing behaviour, assessing visibility of pedestrians at crossings during the day and night. An inventory on land use practices along the road corridor was performed to assess the level of pedestrian activities around the study location. Various traffic flow parameters were calculated based on the results obtained from primary data collection including vehicle volume, pedestrian volume, pedestrian waiting time, pedestrian crossing time and average walk speed across the level crossings near roundabouts.

The study also relied on secondary data such as road crash data obtained from the National Police and National Transport Safety Authority (NTSA) for the period 2016-2021. Crash data obtained from Nairobi Central Police Division was considered adequate since it captured crashes which occurred within Nairobi Central Business District including Uhuru Highway. The data obtained was filtered and analysed using Microsoft Excel 2013 with a specific focus on crashes involving pedestrians along Uhuru Highway only. This analysis aimed at answering the specific objectives by assessing pedestrian safety risk factors in relation to pedestrian demographics, road infrastructure and environment, pedestrian crossing behaviour and pedestrian crossing warrants at crossings near roundabouts.

3.2 Research Framework

The independent variables were limited to road infrastructure design, road environment, road user behaviour, pedestrian demographics and pedestrian crossing warrants. Dependent variables included; road geometrics such as geometric layout of the roundabout, lane width, length of pedestrian crossings and pavement surface condition. Environmental factors assessed included; land use characteristics, visibility and lighting condition, vehicle and pedestrian traffic activities along Uhuru Highway. Pedestrian demographic factors assessed were limited to age, gender and other socio-economic factors amongst pedestrians. Traffic flow characteristics assessed included vehicle volumes, pedestrian volumes and walk speed, pedestrian average waiting time and average crossing time. Pedestrian crossing warrants were limited to markings, traffic signs, traffic signals, speed humps and rumble strips. Road user behaviour was assessed with specific focus on pedestrian crossing behaviour, motorist/bicyclist yielding behaviour and traffic control and management at crossings near roundabouts along Uhuru Highway. Figure 3-1 below represents the research framework adopted.

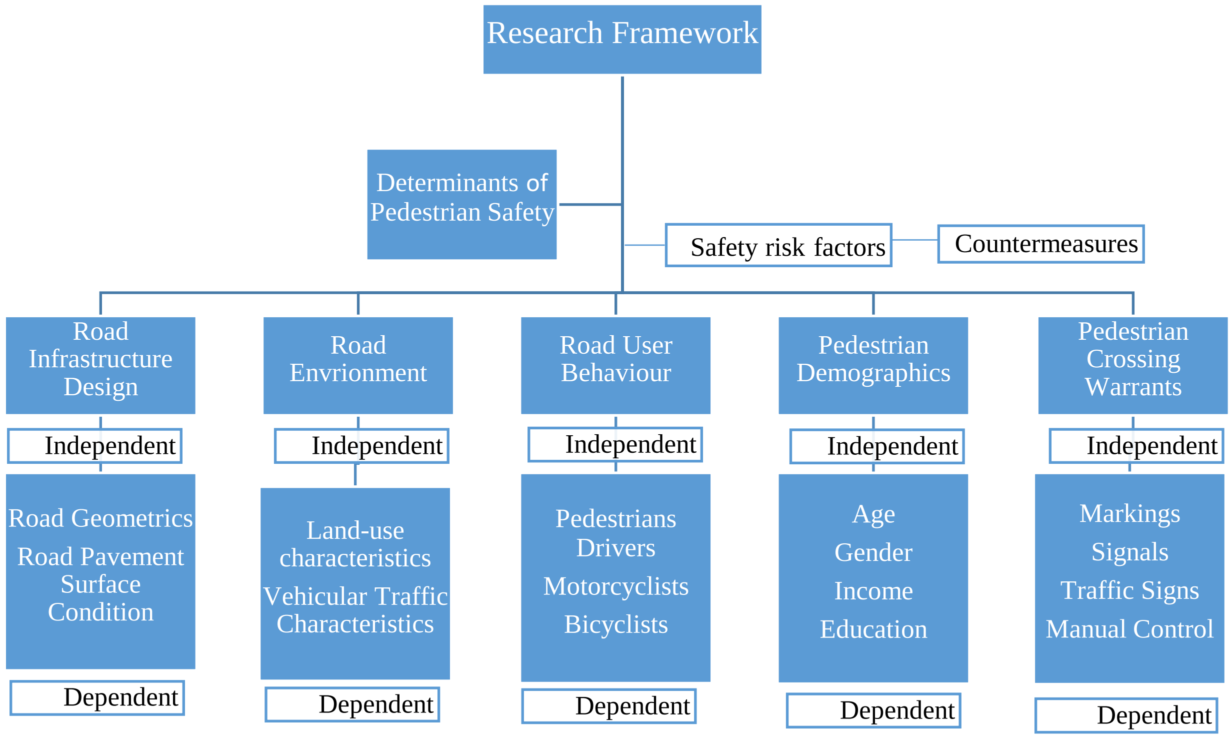

Figure 3-1 Research framework, Author, (2022)

3.3 Data Sources

3.3.1 Primary Data

The primary data used in this study consisted of the following:

a) Road Geometric Features

An inventory and condition survey of the road infrastructure asset at three roundabouts was undertaken to inform on geometric features of the three roundabouts, pavement surface condition and other related roadside furniture provided at roundabouts to guide traffic flow. Actual measurements of roundabout features by use of surveyor's tape measure were conducted on road geometric elements such as lane widths, size of island, width of crossings, separation distance between stop lines and crossings, total number of lanes on each arm of the roundabout, size of the traffic island and areas provided for truck manoeuvres. This exercise was conducted in live traffic on a Sunday when traffic was low without closing the road but rather closing some lanes using traffic cones. Also linear measurement of nearby non-motorized transport infrastructure was conducted to establish the width of the pedestrian walkway parallel to Uhuru Highway in Nairobi as shown in Plate 3-1 below.

Plate 3-1: Road geometric features along Uhuru Highway, Source: Author, (2022)

b) Traffic Control and Pedestrian Crossing Behaviour

Pedestrian gap acceptance at level crossings was not recorded at the roundabouts since there were not traffic control signals except road markings as shown in Plate 3-2 near Kenyatta Avenue roundabout. However, the number of pedestrians crossing in different patterns were recorded such as; holding hands, obeying traffic, observing police hand signal, observing oncoming vehicle, not observing, crossing in groups or as individuals, crossing at right angle to roadway or at skew angle to the roadway. Pedestrians were observed 12 hours a day for three days on weekdays (24^{th}, 25^{th} and 26^{th} August 2022) and one weekend day (27^{th} August 2022).

Plate 3-2: Road Marking at Pedestrian Crossing along Uhuru Highway, Source: Author, (2022)

c) Land Use Practices

Land inventory was conducted along the Uhuru Highway to establish different land use activities such as recreational parks, higher learning institutions (colleges and universities), primary and secondary schools, bus terminus and stations, office buildings, commercial buildings, industrial zones, religious centres, agricultural area, sports and leisure parks near these roundabouts. One of the major pedestrian traffic generating activities consisted for Central Park (leisure and recreation), Community Area and Central Business District (work activities) and Green Park terminus located near Haile Selassie roundabout. Most pedestrians accessing the terminus cross at Midblock section near Parliament buildings as shown in Plat 3-3 below. The land use practices are a major pedestrian safety risk factor since they contribute to higher pedestrian volumes, longer waiting time and exposure to crashes. This study has calculated risk factors based on land use activities adjacent to the roundabouts.

Plate 3-3: Pedestrian walkway along Uhuru Highway, Source: Author, (2022)

d) Traffic Volume

Risk and exposure to crashes at crossings can only be estimated correctly once actual traffic volume counts for all road user categories such as pedestrians, bicyclists, motorcyclists and motor-vehicles has been conducted. Through manual traffic counts at level crossings near roundabouts and midblock sections, the study determined the average daily traffic (ADT) and secondary data obtained on average annual daily traffic (AADT) was used to calculate risk and exposure to risk at roundabouts.

e) Traffic Speed

Vehicle spot speeds were not assessed due to higher cost of hiring a radar speedometer. However, vehicle mean speeds were measured between two roundabouts by estimating the total time taken to move between two roundabouts using handheld stopwatch and the distance travelled. Vehicle mean speed was to assess the risk of crash outcome on pedestrians especially on approach to the level crossing areas near roundabouts and at midblock sections.

f) Pedestrian Visibility and Safety Hazards

Visibility of pedestrian at level crossings near roundabouts was assessed through camera images taken at each crossing for both day and night conditions. Areas of poor visibility were highlighted especially for pedestrians crossing near roundabouts along Uhuru Highway. The number of pedestrians wearing reflective clothing at the roundabouts was recorded compared to number of pedestrians who were not wearing reflective clothing. At night, visibility was assessed through camera recording of pedestrians crossing the roundabout at different locations. Currently, a new road has been constructed adjacent to Uhuru highway to link Green park terminus and Kenyatta Avenue but it lacks adequate pedestrian safety facilities and the geometry consists or an open drain which may only be visible at day time as shown in Plate 3-4 below.

Plate 3-4: Open Drains along Uhuru Highway, Source: Author, (2022)

Construction of the Nairobi Expressway is also a safety hazard to pedestrians since some piers are located on the pedestrian walkway along Uhuru Highway which often hinders walkability and can cause diversion of pedestrian traffic into the roadway as shown in Plate 3-5 below.

Plate 3-5: Obstruction to Pedestrians Walking along Uhuru Highway, Source: Author, (2022)

g) Pedestrian Demographics (Gender and Age)

Pedestrian age and gender were assessed and recorded in data sheets through direct observation by enumerators through classified non-motorized traffic counts. A video recording of pedestrians was taken to confirm visual records and the effect of demographics on crossing behaviour near roundabouts. A camera was set up at each roundabouts for recording road traffic activities at crossings near roundabouts for three days in a week and one day during the weekend to estimate pedestrian and vehicle traffic levels at peak and off-peak conditions. A questionnaire was also administered through a representative sample collected for the purpose of interviewing a number of pedestrians at each crossing. The following formula was applied:

Sample Number (n) = N/(1+Ne2) …………. Equation 3.1

Where:

n=sample size

N= Pedestrian peak population at crossings (Averagely 542)

e= margin of error

In this case the margin of error of 5% was used which gives results with 95% confidence interval. Hence n = 230.148 taken as 231 pedestrians.

h) Pedestrian Counts

Pedestrian counts were conducted through classified non-motorized traffic counts to establish pedestrian volumes at all crossings near roundabouts along Uhuru Highway. Through the use of stop watch, pedestrian average waiting time and crossing time was recording at the same time during volume counts. This data obtained was analysed using Microsoft Excel 2013 to determine pedestrian peak hour volume at each crossing under study. Using linear measurements recorded for average lane width and width of pedestrian refuge during road geometrics data collection, an average pedestrian walk speed across level crossings near roundabouts was determined.

i) Road Environment

Road environment factors including road infrastructure asset condition such as, pavement surface condition, roadside drainage, non-motorized transport infrastructure conditions, traffic flow conditions were also assessed. Traffic flow conditions around Uhuru Highway has recently changed due to the ongoing upgrade of central park, and Green Park terminus near Haile Selassie roundabout. Also, upon completion of Nairobi Expressway, KeNHA has upgraded pavement surface condition on Uhuru Highway with new road markings to improve traffic safety and walkability as shown on Plate 3-6 below.

Plate 3-6: Ongoing Construction Activities near Uhuru Highway, Source: Author, (2022)

3.3.2 Secondary Data

a) Police accident records

National police accident records were obtained from nearby Nairobi Central Police station which comprised of all collisions data for the period 2016-2021 as recorded by the police. Data screening was conducted and analysis carried out with specific focus on pedestrian related collisions. This data comprised of all road crashes in general in Nairobi CBD with specific crash descriptions such as; fatal collisions, serious injuries collisions, slight injuries collisions, property damage only collisions and people involved. The data also comprised of accident cause codes, accident location (junction or section), age and gender of persons involved in crash, traffic police base, date, time, location of accident, road name, direction of travel, junction traffic control type, initial impact type, lighting condition and geographical co-ordinates of crash location.

b) National road crash data

The national road crash data was obtained from the NTSA (2016-2021) was critical for further analysis with specific attention to crashes involving pedestrians along Uhuru Highway. The data obtained indicated the total number of collisions recorded for each road user category by year of crash occurrence, place, time, persons involved, cause of crash amongst others.

c) Injury severity and casualty data

Injury severity and casualty data from the Ministry of Health and the National Civil Registration Department for Nairobi County was not availed by respective agencies at the time of data collection and therefore were not used in result analysis. Other relevant data analysed included the national statistics from Economic Survey Report 2021 and Census Report 2019 which were availed by the Kenya National Bureau of Statistics. Moreover, the Kenyan Road Design Manuals (RDM) obtained from the Ministry of Transport, Infrastructure, and Housing and Urban Development were used in determining roundabout geometrics determining safety requirements.

3.3.3 Data Collection Techniques

Data collection techniques used in this research depended on the specific objectives which were used to determine the specific variables selected for the study. Mixed methods have been adopted based on study limitations such as availability of finance, equipment and personnel for data collection and the time allocated for research. The level of measurement for each variable under consideration for data collection was designed to suit the specific objectives of the study. Risk factors were later compounded by adopting risk criteria dependent on a number of factors in four categories; human factors, road geometrics, road environment, pedestrian crossing warrants, traffic conditions and history of accidents at the selected study site.

3.3.4 Illustration of data needs, materials and methods applied

The study adopted several mixed methods based on specific objective, data needs as illustrated in Table 3-1 below:

Table 3-1: Research questions, methods and data needs

Objective 1: To assess the risk of demographic factors in pedestrian safety at level crossings near roundabouts along Uhuru Highway in Nairobi

Research Question	**Research Method**	**Data Needs**
Does gender affect pedestrian safety at cross walks near roundabouts?	Direct Observation	Gender of pedestrians
Does age affect pedestrian safety at cross walks near roundabouts?	Oral Interview and Direct Observation	Age of pedestrians
Does level of education affect pedestrian safety at crossings near roundabouts?	Oral Interview	Traffic Safety Knowledge (Signs, Signals, Marking)
Objective 2: To assess the risk of road environment and infrastructure in pedestrian safety at crossings near roundabouts along Uhuru Highway in Nairobi		
Does geometry of roundabouts affect safety of pedestrians at cross walks?	Road Asset and Condition Survey	Geometric Measurements of the Roundabout
Does width and length of crossings affect pedestrian safety near roundabouts?	Road Asset and Condition Survey	Length and width of crosswalks
Do traffic volume, speed and density affect safety of pedestrians near roundabouts?	Manual Traffic Counts and Speed Survey (Spot and Mean Speeds)	Vehicle and pedestrian volume, speed and density
Does median/pedestrian refuge affect safety of pedestrians?	Road Asset Condition Survey and Oral Interview	Geometric measurement of refuge islands, adequacy of refuge

Research Question	Research Method	Data Needs
Does land use affect pedestrian safety at crossings near roundabouts? Is there a risk in mixed land use characteristics?	Direct Observation and Oral Interview	Land use types along study sites, Pedestrian volume generated per day
Objective 3: To assess the risk of road user behaviour in pedestrian safety near roundabouts along Uhuru Highway in Nairobi		
Do pedestrians obey traffic control signals at level crossing near roundabouts?	Direct observation	Number of pedestrians violating or complying to traffic signal phases
Do pedestrians observe traffic signs at level crossings near roundabouts?	Direct Observation	Number of pedestrians violating or complying to traffic signs
Does crossing behaviour (single/grouped, skew/straight) pedestrian affect safety at crossings near roundabouts?	Direct Observation	Percentage of pedestrians crossing as single/group individuals, at skew/right angle to crosswalk
Do motorists and bicyclists yield adequately at pedestrian crossings near roundabouts?	Direct Observation	Percentage of motorists yielding at crosswalks, average space between vehicles and pedestrians
Objective 4: To assess the risk of pedestrian crossing warrants in pedestrian safety at level crossings near roundabouts		
Do traffic signals provide adequate time gap for pedestrians of all needs?	Direct observation	Signal time per phase (Green, Amber, Red and Pedestrian Crossing)

Research Question	Research Method	Data Needs
Do pavement markings provide adequate space and visibility for pedestrians at crosswalks near roundabouts?	Direct observation	Availability of markings Types of markings Visibility of makings
Do level crossings provide additional pedestrian traffic control mechanisms at crosswalks near roundabouts?	Direct observation	Types of pedestrian control mechanisms used at roundabouts

Source: Author, (2022)

3.4 Pedestrian Safety Risk Factor Calculation

In this study, pedestrian safety risk factor (W) was calculated for all fourteen (14) crossings near roundabouts along Uhuru Highway in Nairobi, Kenya. After extensive review of different methods and formulae applied in calculating pedestrian safety risk factor, a more conservative method was adopted based on a number of risk factors assessed and measured as variables in the study. Risk levels is measured on an arbitrary scale depending on the value of risk score (W) calculated as per Equation 1 below.

$$W = \prod_{i=1}^{n} m_i \ldots\ldots\ldots\ldots\ldots\ldots.. Equation\ 1$$

Where, (W) is the risk factor calculated as a product of other related factors (m) affecting pedestrian safety at crossings near roundabouts. These factors include; road width, number of traffic lanes, presence of kerbs, bicycle path, streetlight, angle of crossing, bus stop, neighbouring crossing, horizontal road markings, pedestrian visibility due to vertical markings, pedestrian visibility due to parked vehicles, road sign visibility, speed limit, presence of special pedestrian targets, raised pedestrian crossing, road humps, coloured horizontal markings, safety island or median, narrowing on the road, additional road, additional lighting, barriers, other factors such as behavioural factors decreasing safety, actual speeds of vehicles prior to crossings and previous accident history at the study location in the previous 3 years, The results obtained were used to determine risk levels; dangerous crossing, high risk crossing, moderate risk and safer crossing as shown in Table 3-2 below.

Table 3-2: Risk levels at pedestrian crossings

Risk score, W	W>=15	10<W,<=15	5<W<=10	W<=5
Risk level,	1	2	3	4
Risk description	Dangerous Crossing	High risk	Moderate risk	Safe crossing

Source: Author, 2022

3.5 Summary of Methodology

In summary, several mixed methods applied to collect primary data and secondary data needed to calculate pedestrian safety risk factors for all crossings near roundabout and midblock sections. Sample data collection forms, questionnaires and data collected for analysis have been included in this thesis report as annexes. Data collected was filtered and screened before performing analysis using Microsoft Excel 2013 between 5^{th} and 9^{th} September 2022. Each study objective applied different specific methods and materials as obtained the desired results as highlighted in this chapter.

Chapter 4

4. RESULTS AND DISCUSSION

4.1 General

The data obtained comprised of primary data collected through classified traffic counts, geometric measurement of roundabout parameters, pedestrian behaviour through direct observation, pedestrian crossing warrants, pedestrian demographics through direct observation and oral interviews. Vehicle yielding behaviour was also observed at the roundabouts at different peak periods during the day. Secondary data comprised of National Road Traffic Accident Data obtained from the Nairobi Central Police Division. This crash data included all collisions recorded for the period between 2016 and 2021.

The data collection was guided by the objectives of the study and a guiding tool attached herein as an Annex 1. Primary data was obtained using data forms and also processed by entering into Microsoft Excel 2013 before subsequent analysis using the same software. Secondary data was obtained in Microsoft Excel file format and analysis was performed using the same software. The results obtained have been presented in the form of charts, tables and graphs which are summarized and presented in this report. The results presented for discussion are in the form of charts which are in the order of the objectives of the study.

4.2 Pedestrian Demographics

The study focussed on evaluation of pedestrian peak hour volumes and its composition by gender and age through direct observation, classified manual pedestrian traffic counts and roadside interviews conducted at the study site. Based on analysis on primary data, the average percentage pedestrians crossing near roundabouts by gender was determined as an average of pedestrian volume by gender per roundabout. The results obtained indicate that about 67% of male pedestrians cross the roundabouts on week days compared to 33% on weekend days. Comparatively, 76% of female pedestrians cross near the roundabouts on week days while 24% of female pedestrians cross on weekend days.

Weekend volumes indicated lower number of pedestrians owing to reduced number of activities like commuting to work and school. In regards to age, the number of pedestrians that crossed Uhuru Highway near roundabouts comprised 16% (0-19), 21 % (20-29), 32% (30-39), 19% (40-49), 9% (50-59) and 5% 60 years and above. During weekends, the average daily number of pedestrians crossing near roundabouts by age along Uhuru Highway is represented as follows; 14% (0-19), 36% (20-19), 18% (30-39), 13% (40-49), 10% (50-59) and 9% above 60. These results indicate that majority of pedestrians who cross the road near roundabouts on weekdays are people of aged 30-39, compared to weekends when majority of pedestrians crossing the road near roundabouts are people aged 20-29.

Based on a roadside interviews conducted at the three roundabouts and two midblock crossings along Uhuru Highway, about 74% of pedestrians responded that their trip purpose was recreational activities which shows that weekend trips are popular with leisure trips compared to 87% of pedestrians crossing Uhuru Highway on weekdays for work based trips. On average, about 8,657 pedestrians crossed the road daily at midblock/section areas on weekdays, which comprises 5,612 male pedestrians (64%), and 3,045 female pedestrians (36%). Comparatively, pedestrians cross the road at midblock/section areas on weekend days which comprises of 3,486 male pedestrians (67%) and 1691 female pedestrians (33%) per day. In terms of hourly volume, on weekdays about 721 pedestrians cross near roundabouts per hour compared to weekend hourly volume estimated at 290 pedestrians per hour.

These results indicate that male pedestrians are more exposed to crashes on weekdays compared to females. Since more crashes occur at midblock/section areas and male/female pedestrians represent the highest proportion of pedestrians crossing at these locations, therefore male pedestrians are more exposed to crashes at crossings near roundabouts. Based on secondary data analysis on pedestrian crash data, 74 male pedestrians (86%) were involved in fatal collisions compared to 12 female pedestrians (14%) while 302 male pedestrians (69%) were involved in serious injury collisions compared to 150 female pedestrians (31%) along Uhuru Highway. About 45 male pedestrians (65%) were involved in slight injury collisions compared to 24 female pedestrians (35%). Further analysis on road crash data by gender revealed that male pedestrians involved in serious injuries collisions constituted 69% compared to 31% female pedestrians who were involved in serious injuries collisions along Uhuru Highway as shown in Figure 4-1 below.

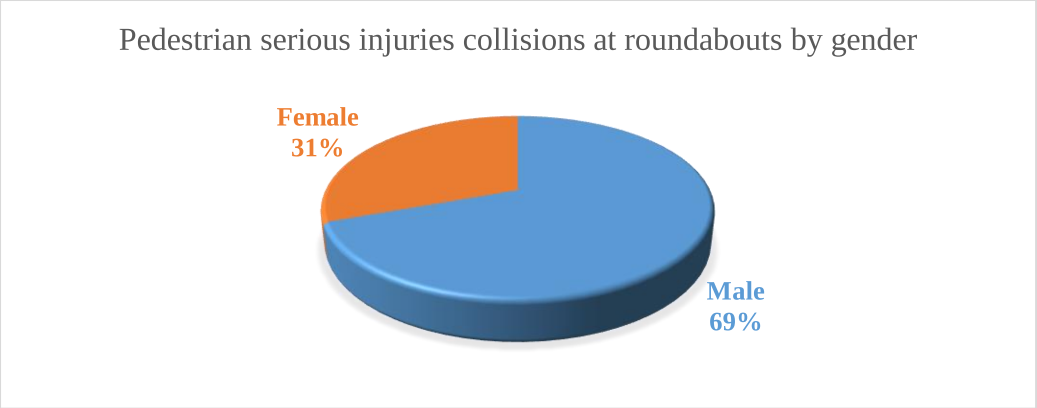

Figure 4-1: Pedestrian serious injuries at roundabouts by gender

Analysis on serious injuries collisions involving male pedestrians revealed that 56% of serious injuries collisions involving male pedestrians occurred at sections/mid-block areas compared to 44% occurring at roundabouts along Uhuru Highway as shown in Figure 4-2 below. This further suggests that male pedestrians are more likely to be involved in road traffic collisions while crossing Uhuru Highway at midblock/section areas than at crossings near roundabouts.

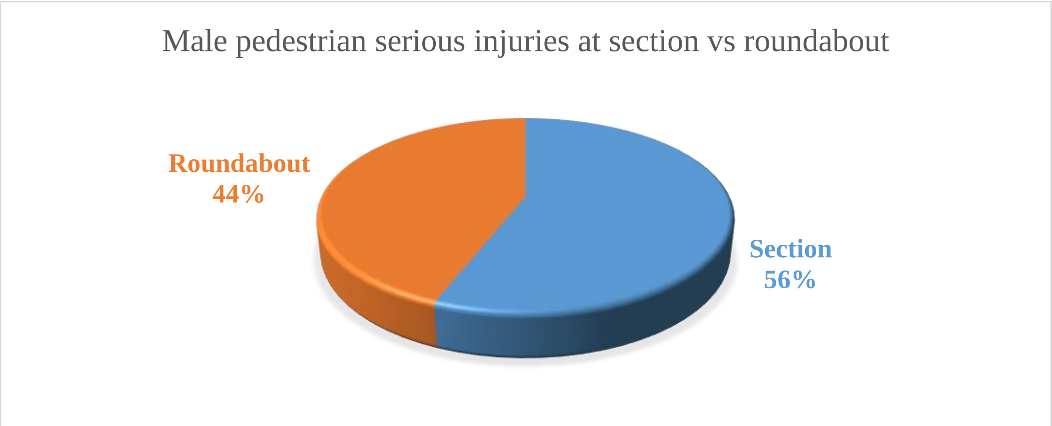

Figure 4-2: Male Pedestrian serious injuries at midblock/sections vs roundabouts

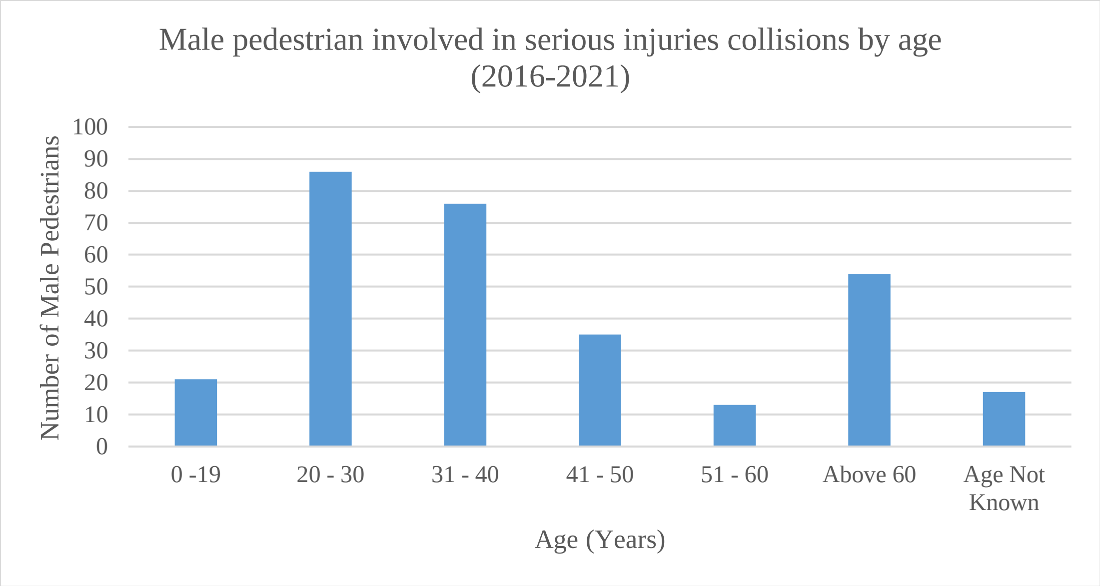

Figure 4-3: Male pedestrians involved in serious injuries collisions by Age (2016-2021)

An analysis on serious injuries collisions involving female pedestrians revealed that 82% of serious injuries collisions involving female pedestrians occurred at midblock/sections areas compared to 18% collisions which occurred at roundabouts along Uhuru Highway as shown in Figure 4-4 and Figure 4-5 below. The result shows that female pedestrians are at higher risk of being involved in serious injuries collisions at midblock/section areas that near roundabouts.

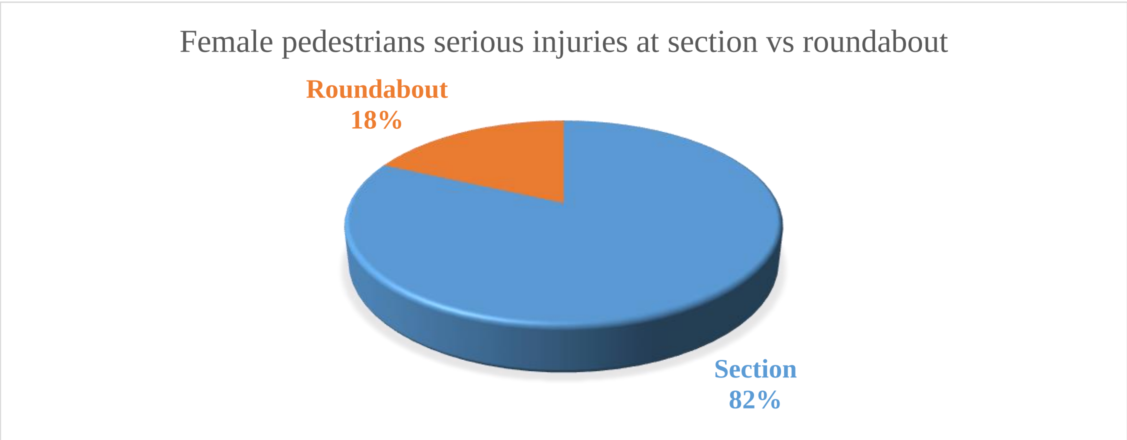

Figure 4-4: Female pedestrian serious injuries at section vs roundabouts

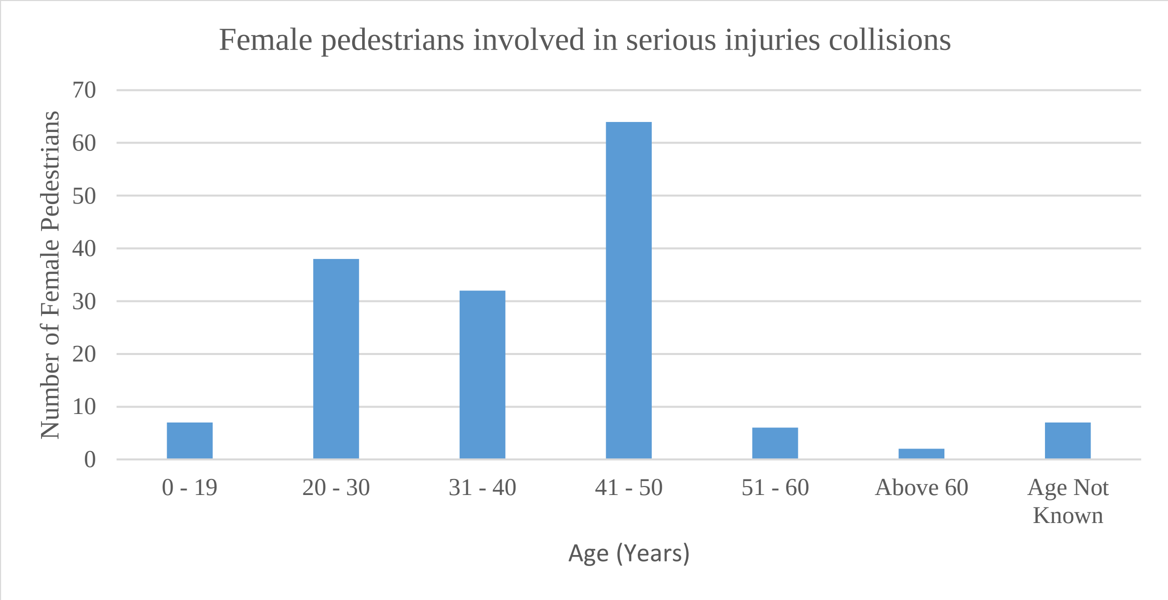

Figure 4-5: Female pedestrians involved in serious injuries collisions by age (2016-2021)

Analysis conducted on male pedestrians involved in fatal collisions by age showed that 34% of male pedestrians were aged 20-30, 26% were aged 31-40, 5% were aged above 60, 11% were aged 41-50, 4% were aged 0-19, 16% for persons whose ages were unknown and 4 % were persons aged 51-60 years old as shown in Figure 4-6 and Figure 4-7 below. The result indicates that male pedestrians aged 20-30 years old are at a highest risk of fatal collisions while crossing near roundabouts along Uhuru Highway followed by male pedestrians aged 31-40 years old. Male pedestrians aged above 60 years old indicated the lowest proportion of males involved in fatal collisions and this can be due to the low number of pedestrians crossing the road in this age group.

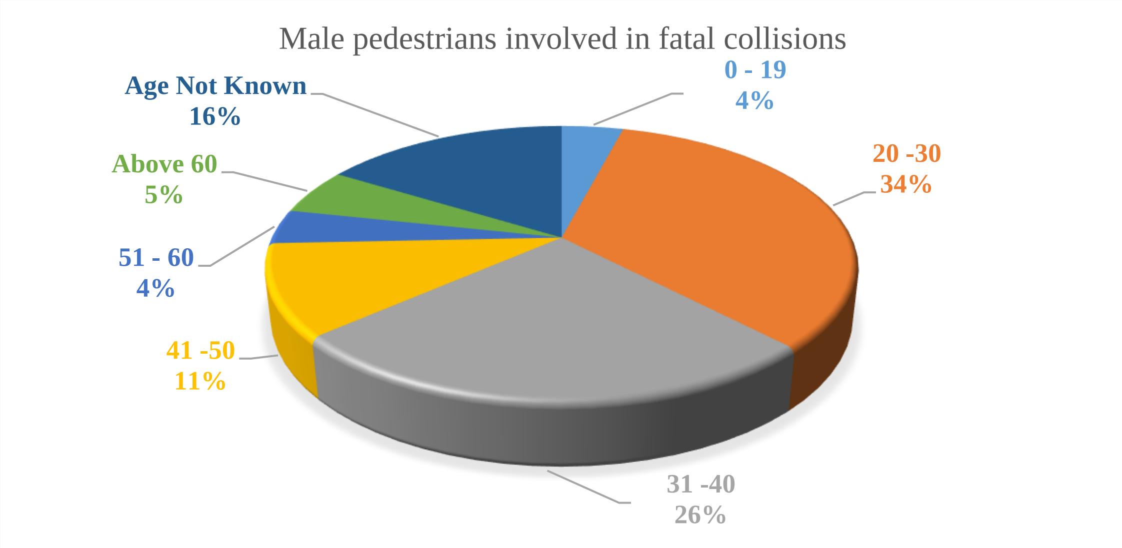

Figure 4-6: Male pedestrian fatal collisions by age

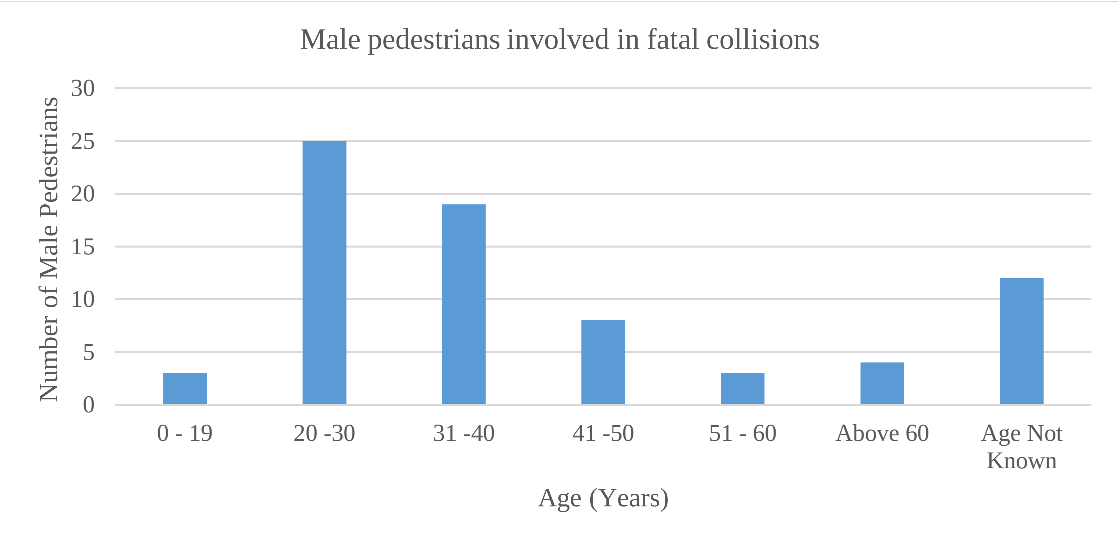

Figure 4-7: Male pedestrians involved in fatal collisions by age (2016-2021)

A significant number of male pedestrians involved in fatal collisions (16%) were persons whose age could not be determined due to incomplete records. This result indicates that there is need to enhance accurate accident data collection and reporting by the police and other stakeholders such as hospitals and emergency rescue units.

Female Pedestrians Involved in Fatal Collisions

Analysis conducted on female pedestrians involved in fatal collisions by age showed that 8% of persons involved were aged 20-30, 42% were persons aged 31-40, 0% persons aged above

60 years, 0% persons aged 41-50 years, 8% were persons age 0-19 years, 8% were persons whose ages were not known and 34% for persons aged 51-60 years old as shown in Figure 4-8 and Figure 4-9 below.

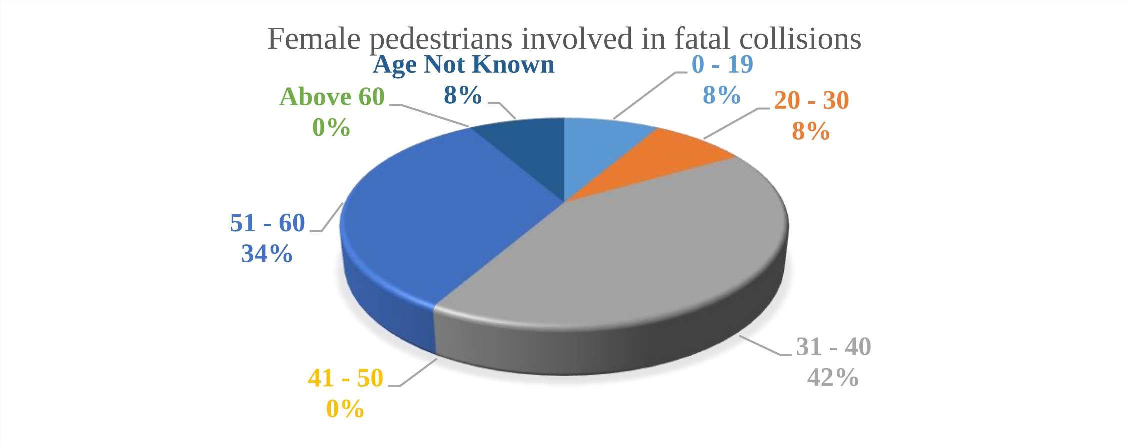

Figure 4-8: Female pedestrians involved in fatal collisions by age

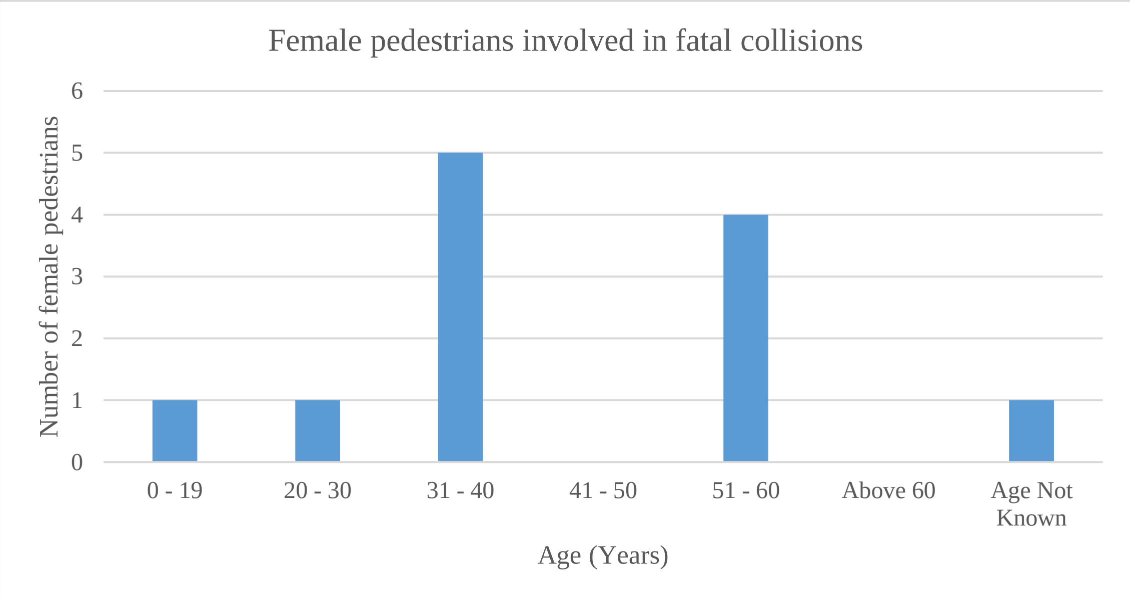

Figure 4-9: Female pedestrians involved in fatal collisions

Analysis on male pedestrians involved in serious collisions by age showed that 28% of all persons involved were aged 20-30, 25% were aged 31-40, 18% were aged above 60 years, 12% were aged 41-50 years, 7% were aged 0-19 years, 6% were persons whose ages were unknown and 4% were persons aged 51-60 years old as shown in Figure 4-10 and Figure 4-11 below. This result shows that male pedestrians aged 31-40 years old are at highest risk of serious injuries when involved in collisions. Male pedestrians aged 51-60 years old were at lowest risk of being involved in road traffic collisions along Uhuru Highway.

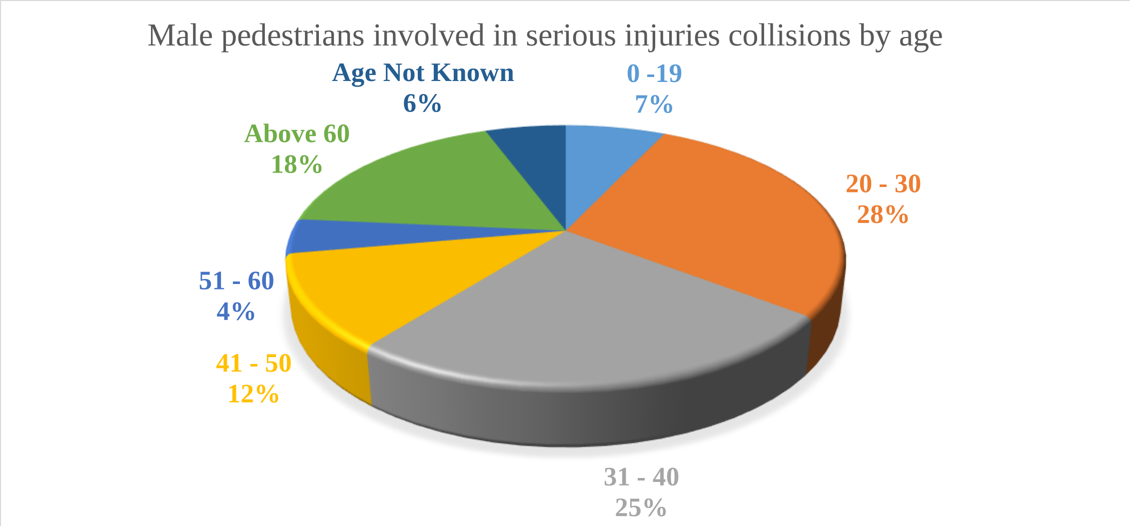

Figure 4-10: Male pedestrians involved in serious injuries collisions by age

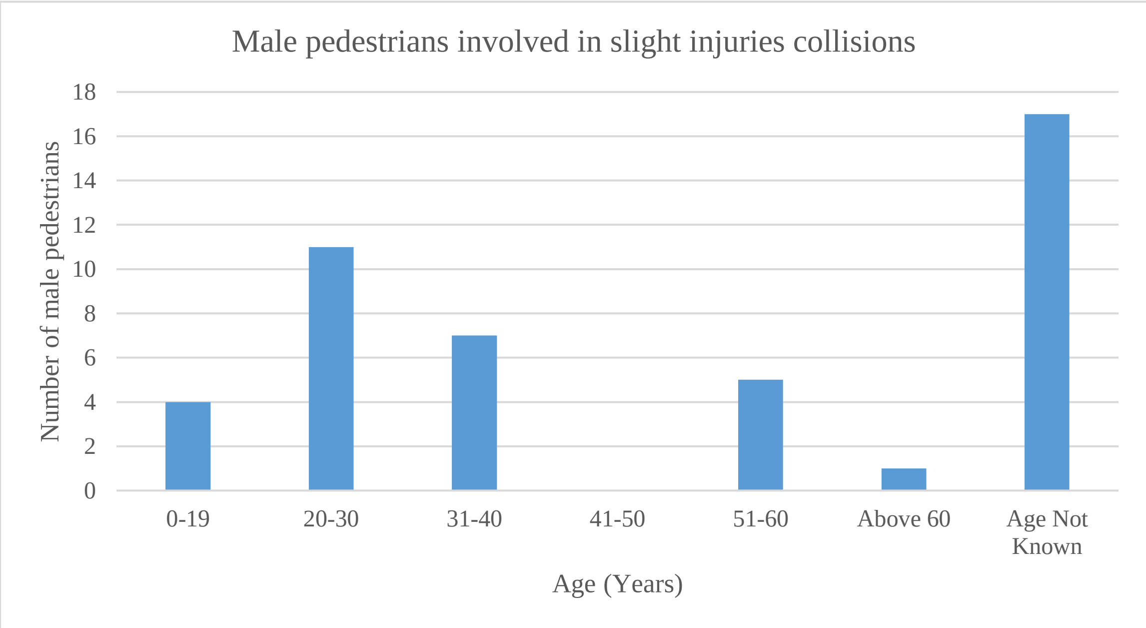

Figure 4-11: Male pedestrians involved in slight injuries collisions

Analysis on female pedestrians involved in serious collisions by age showed that 24% were persons aged 20-30, 21% were persons aged 31-40, 1% were persons aged above 60 years, 41% were persons aged 41-50 years, 5% were persons aged between 0-19 years old, 4% were persons whose ages were unknown and 4% were persons aged 51-60 years old as shown in Figure 4-12 and Figure 4-13 below. This result shows that female pedestrians aged 41-50 years old are at highest risk of serious injuries collision while those aged above 60 years old are at lowest risk.

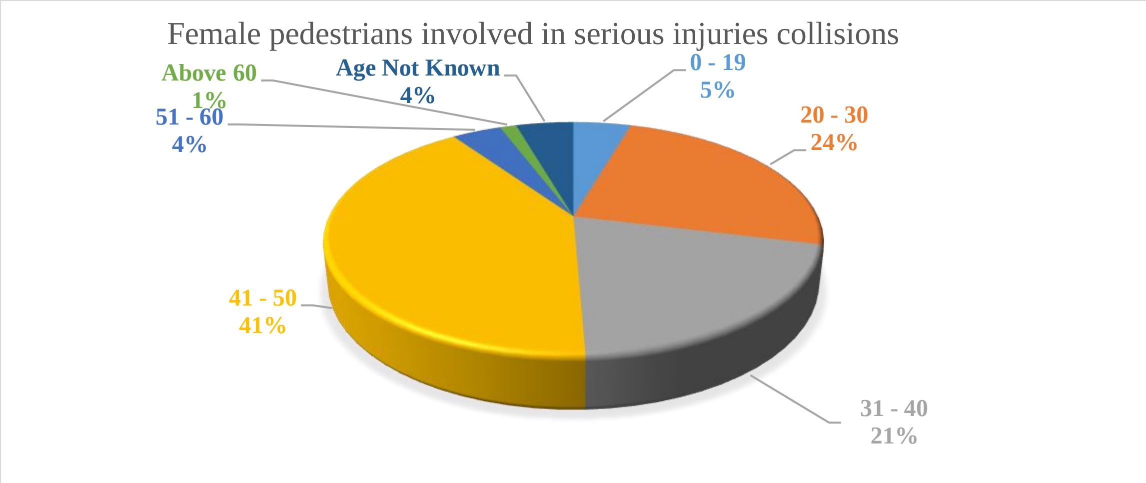

Figure 4-12: Female pedestrians involved in serious injuries collisions by age

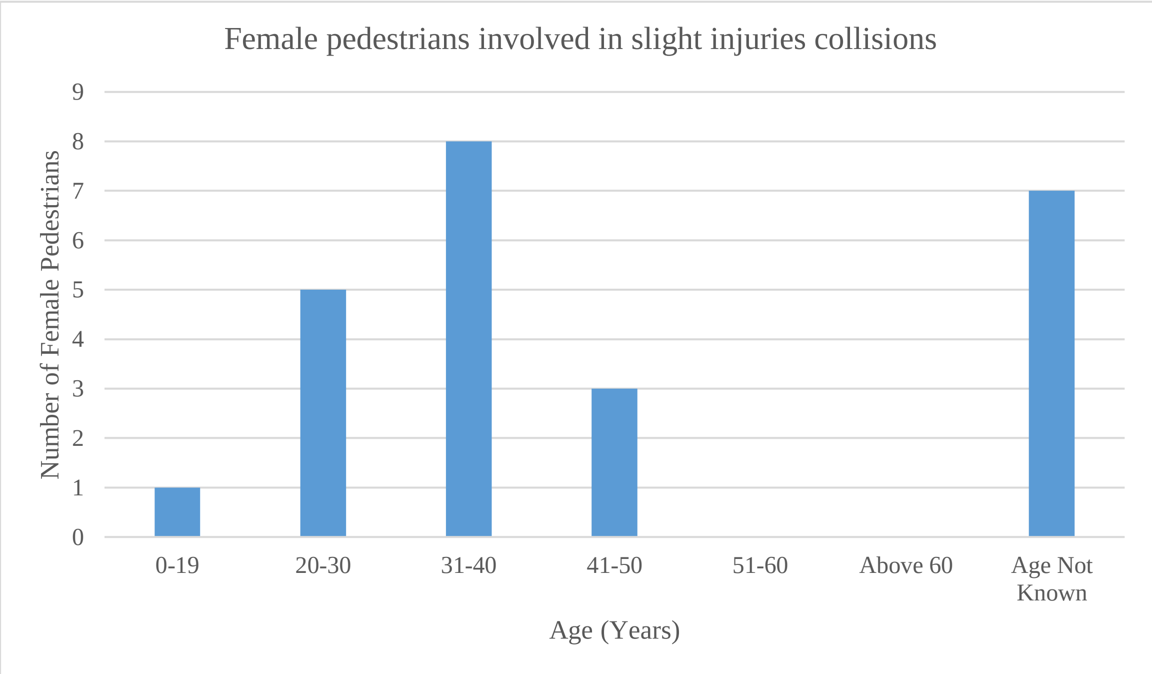

Figure 4-13: Female pedestrians involved in slight injuries collisions

Analysis on male pedestrians involved in slight injuries collisions by age showed that 24% were persons aged 20-30, 16% were persons aged 31- 40, 2% were persons aged above 60 years, 0% were persons aged 41-50 years, 9% persons age 0-19 years, 38% were persons whose ages were not known and 11% for persons aged 51-60 years old as shown in Figure 4-14 below. This result shows that majority of male pedestrians involved in slight injuries collision were persons whose ages were unknown due to incomplete records in the data obtained from the national police. Male pedestrians aged 20-30 years old were also at higher risk of slight injuries collisions along Uhuru Highway.

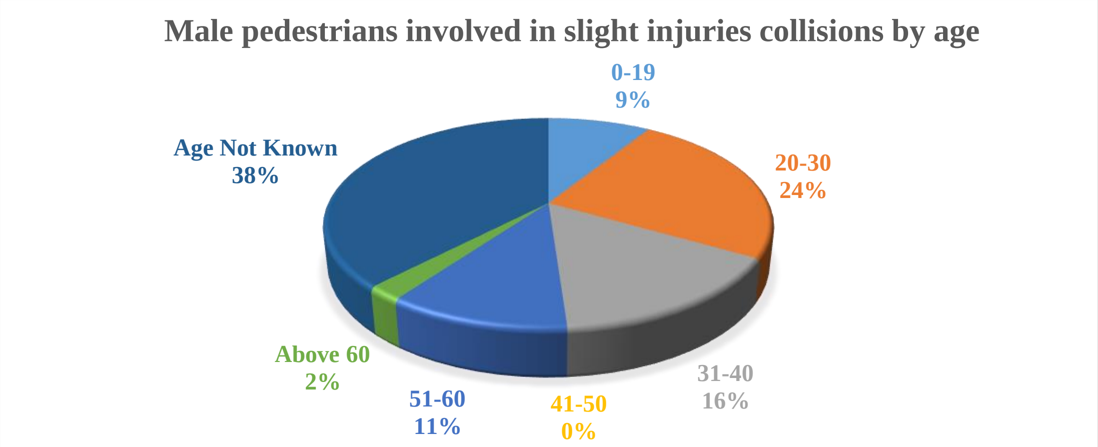

Figure 4-14: Male pedestrians involved in slight injuries collisions by age

Analysis on female pedestrians involved in slight injuries collisions by age showed that 21% were persons aged 20-30, 33% were persons aged 31-40, 0% were persons aged above 60 years, 13% were persons aged 41-50 years, 4% were persons age 0-19 years, 29% were persons whose ages were unknown and 0% for persons aged 51 - 60 years old as shown in Figure 4-15 below. The result shows that female pedestrians aged 31-40 were at highest risk of being involved in slight injuries collisions compared to persons aged 0-19 years old. There were female pedestrians involved in slight injury collisions between the ages 51-60 and above 60 years old. The proportion of female pedestrians whose ages are unknown indicates incomplete accident records which would otherwise be useful in analysis.

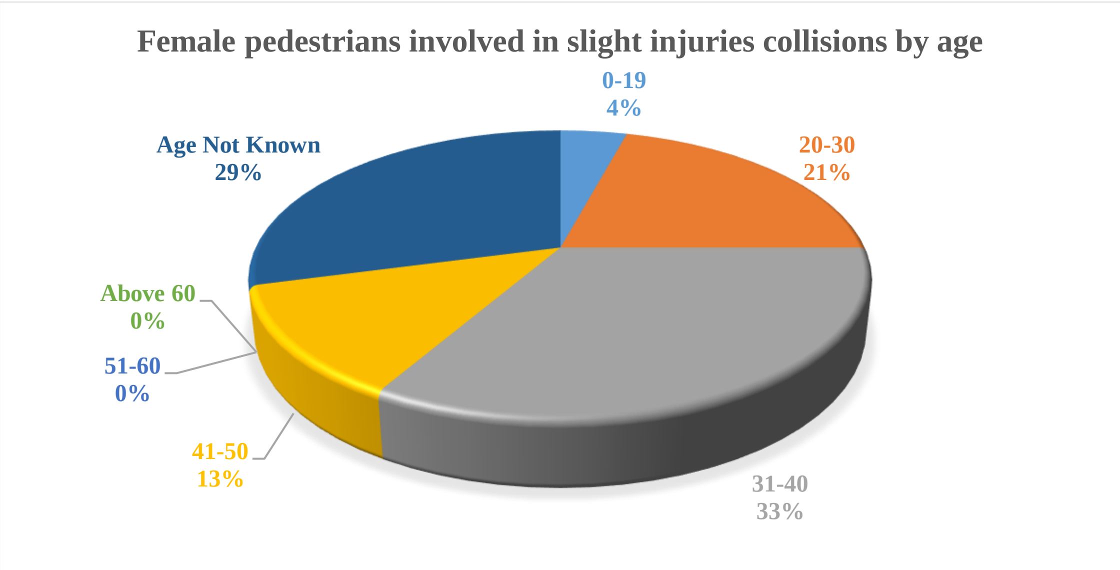

Figure 4-15: Female pedestrians involved in slight injuries collisions by age

4.3 Road Infrastructure Design and Environment

Secondary data obtained consisted of road accident data comprising road traffic collisions recorded within Nairobi area. The data obtained was sorted and filtered for analysis with a specific focus on road traffic collisions involving pedestrians along Uhuru Highway in line with the objectives of this study. In total, 93 collisions were analysed for the period 2016-2021 with emphasis on risk factors in pedestrian safety such as road infrastructure design and environment shown in Plate 4-1 and Plate 4-1 below. These risk factors assessed include; spatial distribution of road crashes along Uhuru Highway such as number of collisions at roundabouts or at road segment areas otherwise referred to here as midblock/section areas. Other factors for analysis considered include road geometric design, pavement surface condition and road safety infrastructure facilities such as kerbs, pedestrian refuge island.

Plate 4-1: Pedestrian Walkway along Uhuru Highway. Source: Author, (2022)

Plate 4-2: Marked Pedestrian Crossing at Midblock Section on Uhuru Highway. Source: Author, (2022)

Crash Distribution by Road Segment Type

In general, the results obtained from road crash data analysis shows that 57 collisions occurred at sections/midblock (61%) areas along Uhuru Highway compared 36 collisions which occurred at junctions/near roundabouts (39%) as illustrated in Figure 4-16 below. This shows that pedestrians are more exposed to crashes at sections/midblock areas compared to junction/roundabouts along Uhuru Highway.

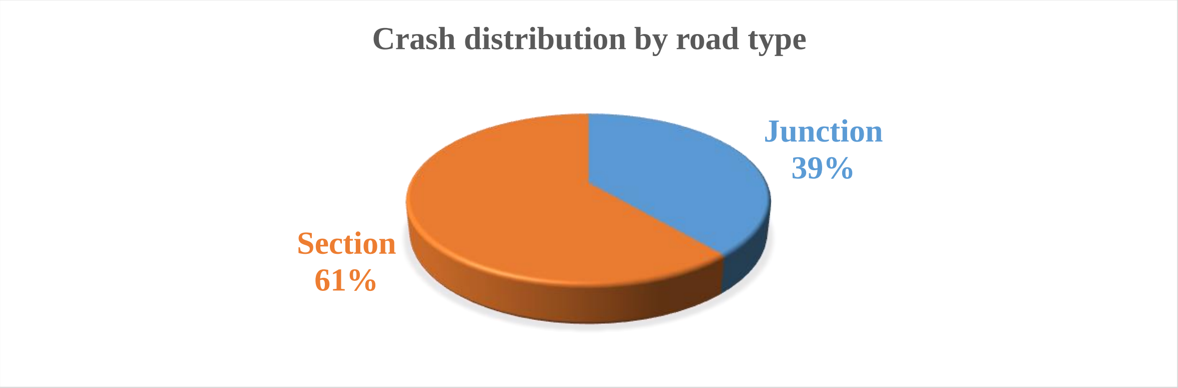

Figure 4-16: Pedestrian crash distribution by road section types

Based on road crash data analysis on secondary data obtained from Nairobi central police station for the period 2016-2021, there were 45 pedestrian injuries collisions (48%) compared to 48 non-pedestrian injuries collisions (52%) along Uhuru Highway in Nairobi as shown in Figure 4-17 below. The proportion of pedestrians involved in non-injuries collisions indicate that pedestrians are still exposed to road crashes hence requires adequate protection from vehicle crashes through legislation, traffic law enforcement and efficient traffic control and management. Considering the fact that most collisions involving pedestrians are greatly underreported in Nairobi and their causes are still unknown, it is prudent to establish a mechanism to eliminate risk factors in pedestrian crashes before they occur.

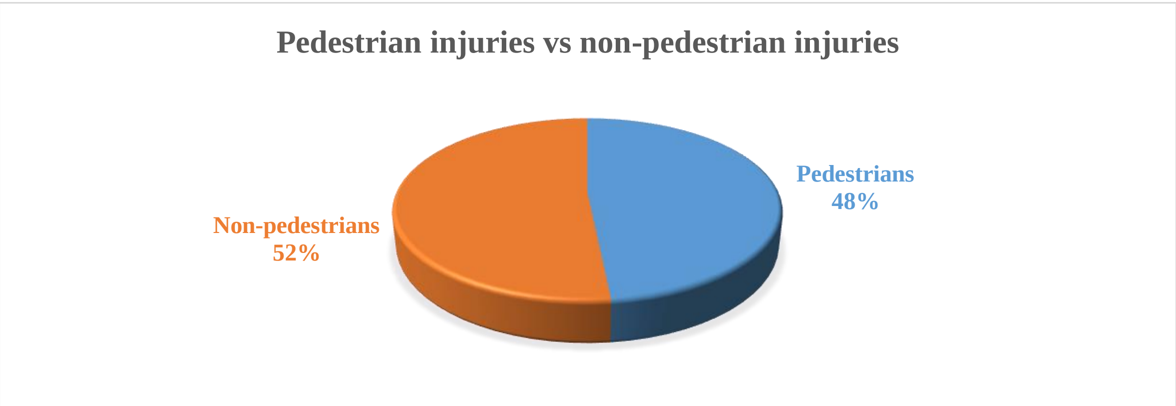

Figure 4-17: Pedestrian injuries vs non-pedestrian injuries

At the roundabouts, 57 crashes involving pedestrians occurred at midblock/sections (61%), 15 collisions occurred at Roundabout 1 (University Way Roundabout) (16%), 9 collisions occurred at Roundabout 2 (Kenyatta Avenue Roundabout) (10%) and 12 collisions occurred at Roundabout 3 (Haile Selassie Roundabout) (13%) along Uhuru Highway as shown in Figure 4-18 below. In total, 36 of all collisions involving pedestrians (39%) occurred at the three roundabouts along Uhuru Highway which shows that pedestrians are safer at crossings near roundabouts compared to midblock/section areas. Pedestrians are more exposed to risk of being involved in road traffic collisions while crossing Uhuru Highway at Roundabout 1 (University Way Roundabout) but are slightly safer while crossing the road at crossings near Roundabout 2 (Kenyatta Avenue Roundabout).

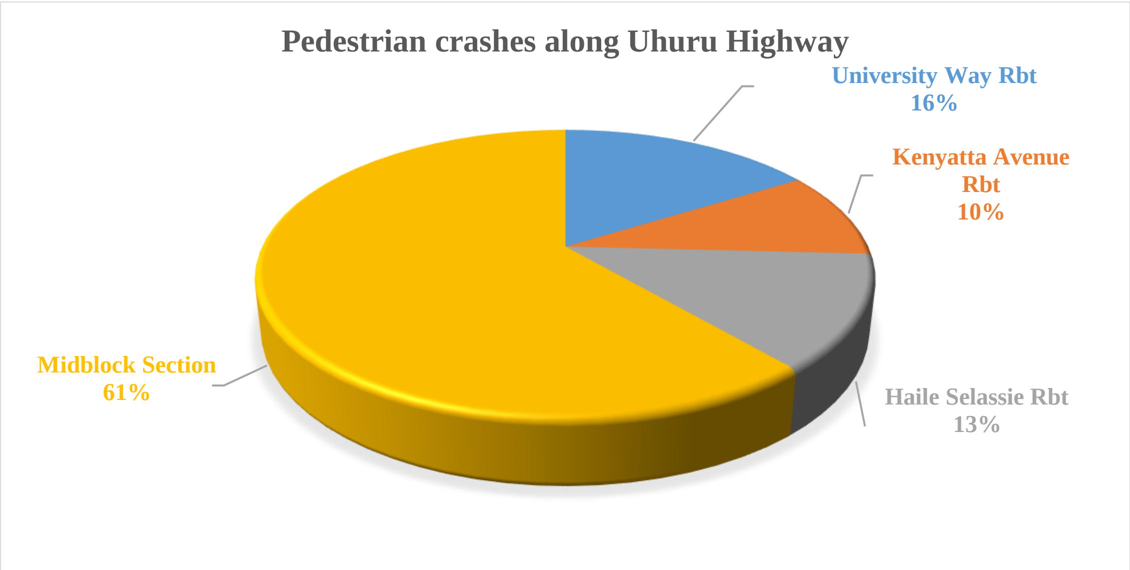

Figure 4-18: Pedestrian crashes along Uhuru Highway

Analysis on road crash data specific to Uhuru Highway revealed that 76% of road traffic collisions involving pedestrians occurred at sections/midblock areas while 24% occurred at roundabouts as shown in Figure 4-19 below. This shows that pedestrians were at higher risk of collisions while crossing the road at midblock/section areas compared to near roundabouts along Uhuru Highway. At midblock/section areas pedestrian volumes are low and vehicle speeds are higher hence higher risk of collisions. The highest pedestrian traffic was observed at midblock section (M2) located between Kenyatta Avenue roundabouts (R2) and Haile Selassie roundabout R3. It is a desired crossing point since it connects Central Park, Community Area and Nairobi Green Park terminus to the CBD. Vehicle yielding behaviour was observed as shown in Plate 4-3 just before the pedestrian crossing point and can determine the risk of fatalities and injuries to pedestrians crossing the road along Uhuru Highway.

Plate 4-3: Pedestrian crossing points, Source: Author, 2023

The construction of reinforced concrete piers supporting the Nairobi Expressway has increased the risk of collision at midblock/section areas due to reduced visibility of pedestrian crossing the road.

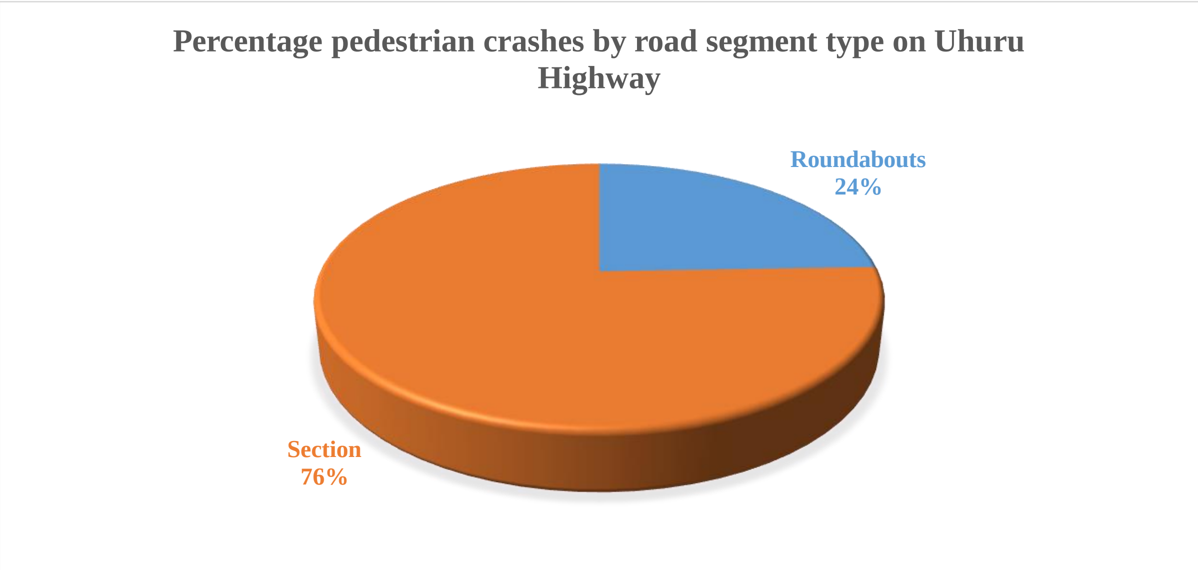

Figure 4-19: Percentage pedestrian crashes by road segment type on Uhuru Highway

Analysis on spatial crash distribution of road traffic crashes involving pedestrians revealed that 9% of all crashes involving pedestrians occurred on Uhuru Highway while 91% occurred in other areas in the Nairobi as shown in Figure 4-20 below. This result compares the magnitude of crashes at the selected study site in comparison to other roads within Nairobi City.

Uhuru Highway is classified as a major arterial road located along a major national highway classified as A8 (Malaba-Eldoret-Nakuru-Nairobi-Voi-Mombasa). Currently, the Nairobi Expressway has been commissioned and it has impacted slightly on the traffic volume along this arterial road.

The construction of Southern Bypass road has also impacted significantly by reducing the volume of traffic passing through Nairobi city from the eastern to western side and vice versa. Traffic composition therefore indicates a lower percentage comprising heavy goods vehicles and articulated truck which are banned from accessing the city through Uhuru Highway. However, private cars are still representing the highest of vehicles in the traffic system followed by public service vehicles.

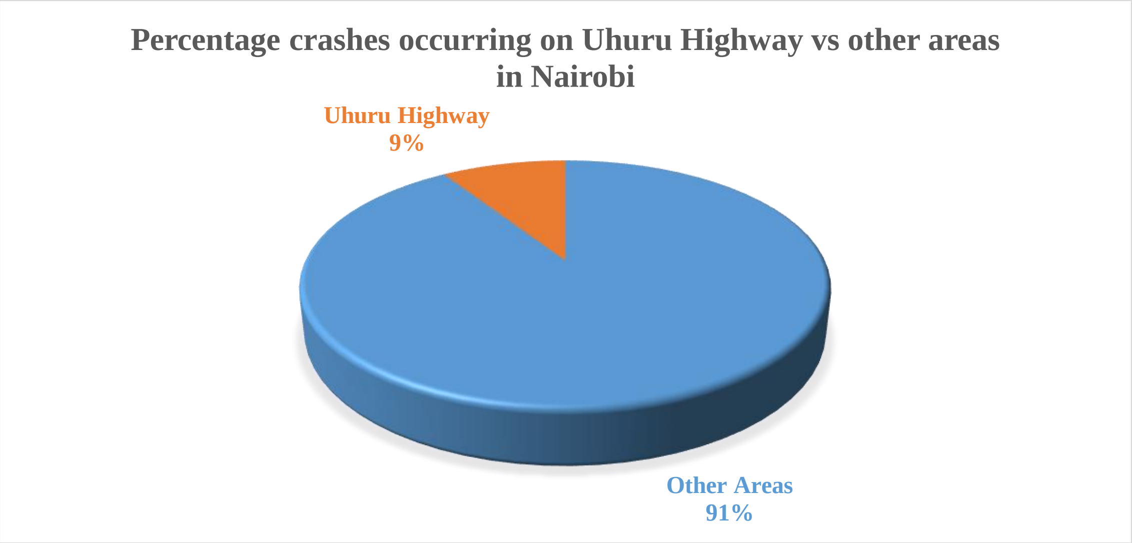

Figure 4-20: Pedestrian crashes occurring on Uhuru Highway vs other areas in Nairobi

Analysis on road crash distribution by time of day revealed that 65% of crashes involving pedestrians occurred during the day while 35% occurred during the night along Uhuru Highway as shown in Figure 4-21 below. Visibility is a key risk factor in pedestrian safety and the results obtained indicate that pedestrians are more likely to be involved in collisions at night due to poor visibility compared to day time when visibility is improved. Most pedestrians observed while crossing near roundabouts along Uhuru Highway did not have reflective clothing which shows that pedestrians are at highest of risk of being involved in road traffic collisions while crossing especially at night. At present, there are no streetlights installed along Uhuru Highway and most pedestrians crossing the road are at risk of being hit by motorists. However, majority rely on night time glare by motorists which is inadequate to guarantee safety of pedestrians while crossing the road.

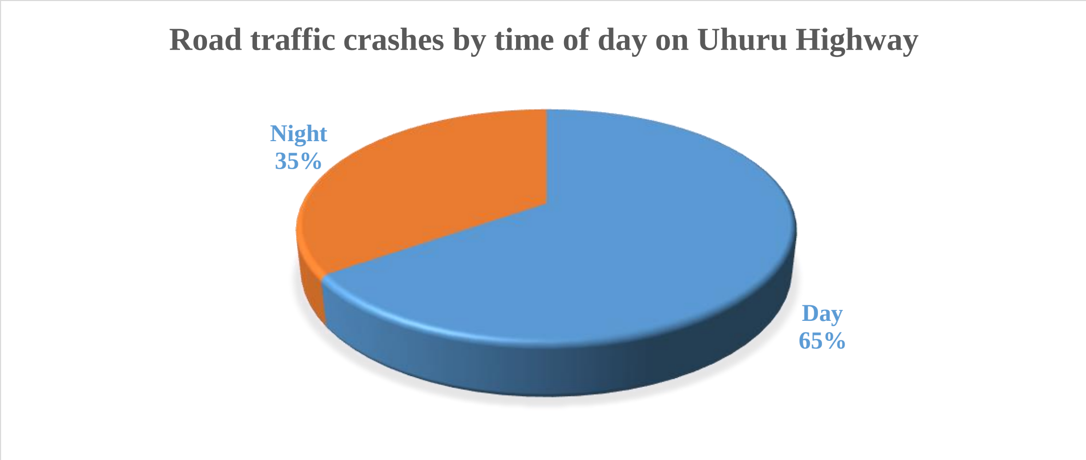

Figure 4-21: Road crashes by time of day along Uhuru Highway

4.4 Pedestrian Road Crossing Behaviour

An assessment of pedestrian crossing behaviour revealed that 22% of pedestrians crossed the roundabout while observing oncoming traffic, 21% crossed at right angle, 14% as a group, 12 % as single individuals, 9% crossed in mixed traffic, 6% crossed while talking to each other, 5% crossed with police hand signal, 5% crossed at skew angle, 4% cross while not observing oncoming traffic, 2% crossed while holding hands and 0% crossed while talking on phone. Pedestrian crossing behaviour while crossing Uhuru Highway at different locations was recorded through direct observation. The result obtained for roundabout for Roundabout 1-University Way is shown in Figure 4-22 below.

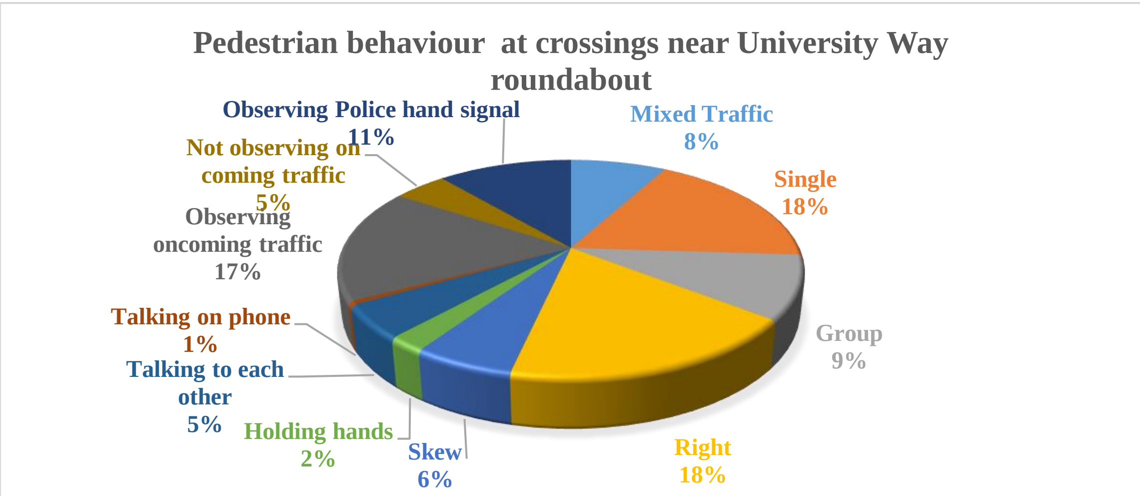

Figure 4-22: Pedesrtian behaviour at crossings near University Way roundabout

Pedestrian crossing behaviour at Kenyatta Avenue roundabout is shown in Figure 4-23 below.

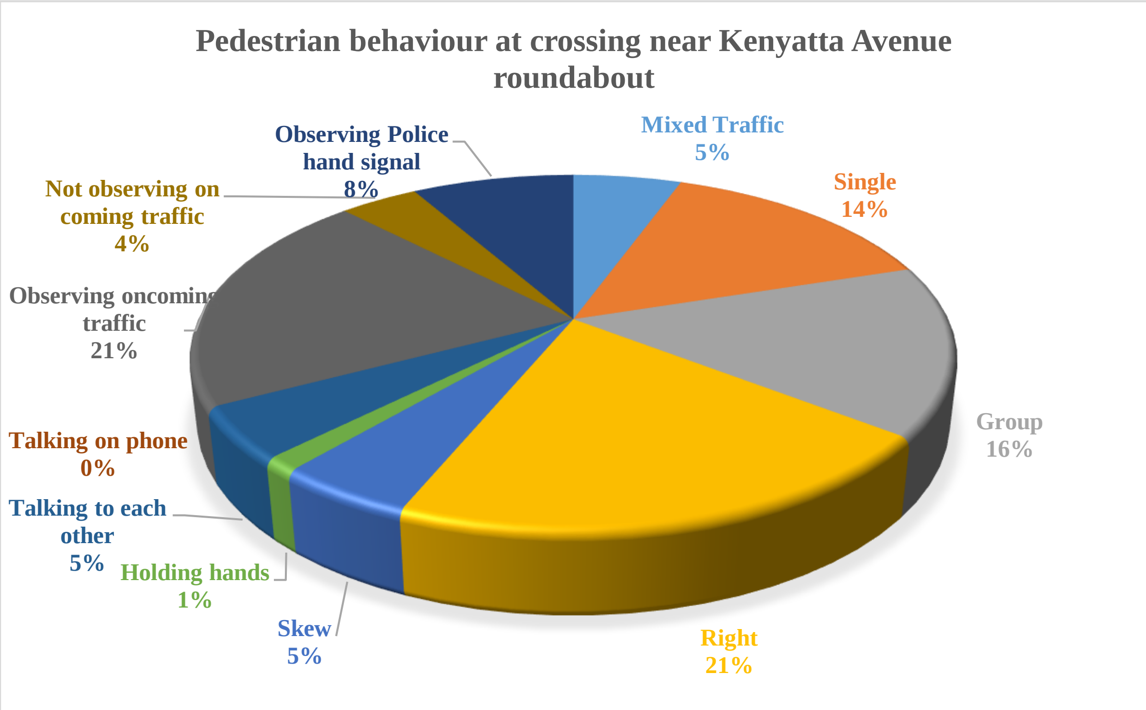

Figure 4-23: Pedestrian behaviour at crossings near Kenyatta Avenue roundabout

Pedestrian crossing behaviour at crossings near Haile Selassie venue roundabout has also been analyzed and presented at shown in Figure 4-24 below.

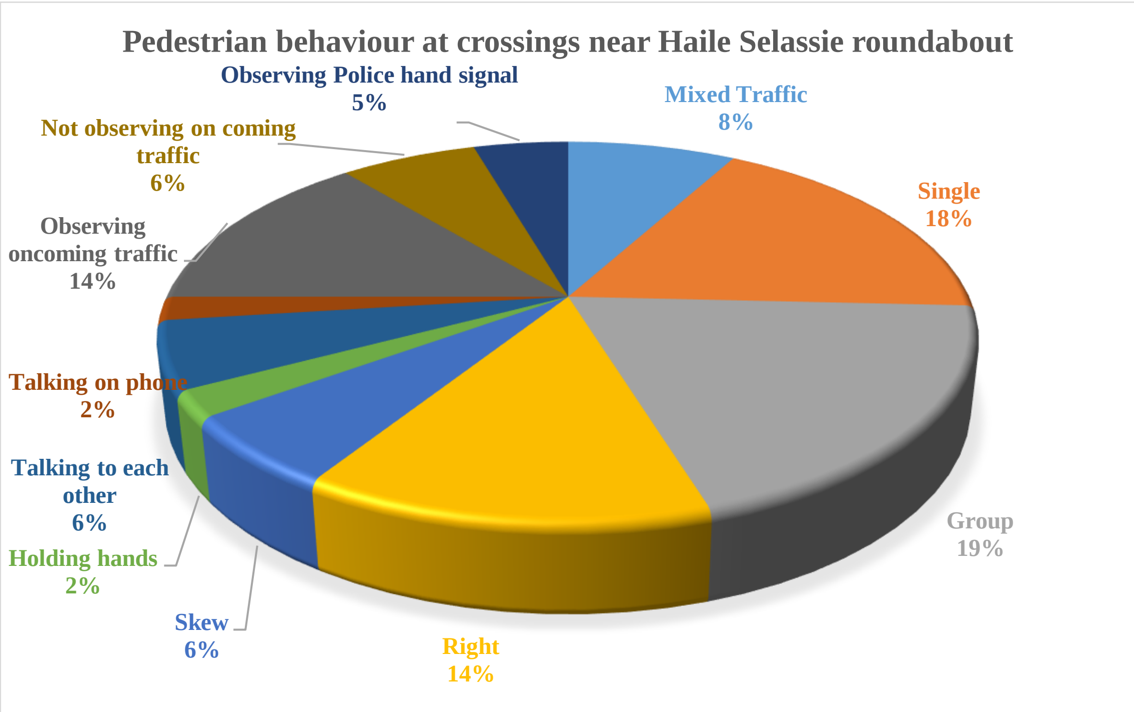

Figure 4-24: Pedestrian crossing behaviour near Haile Selassie roundabouts

The behaviour of pedestrians while crossing near the three roundabouts along Uhuru Highway were observed and the average behaviour was calculated based on certain characteristics. At the three roundabouts, 7% of pedestrians crossed the road in mixed traffic, 17% as single individuals, 15% as a group of individuals, 17% crossed at right angle to road alignment, 6% at skew angle to road alignment, 2% crossed while holding hands, 5% while talking to each other, 1% while talking on phone, 17% crossed while observing oncoming traffic, 5% crossed while not observing oncoming traffic and 8% crossed while observing police hand signal as shown in Figure 4-25 below.

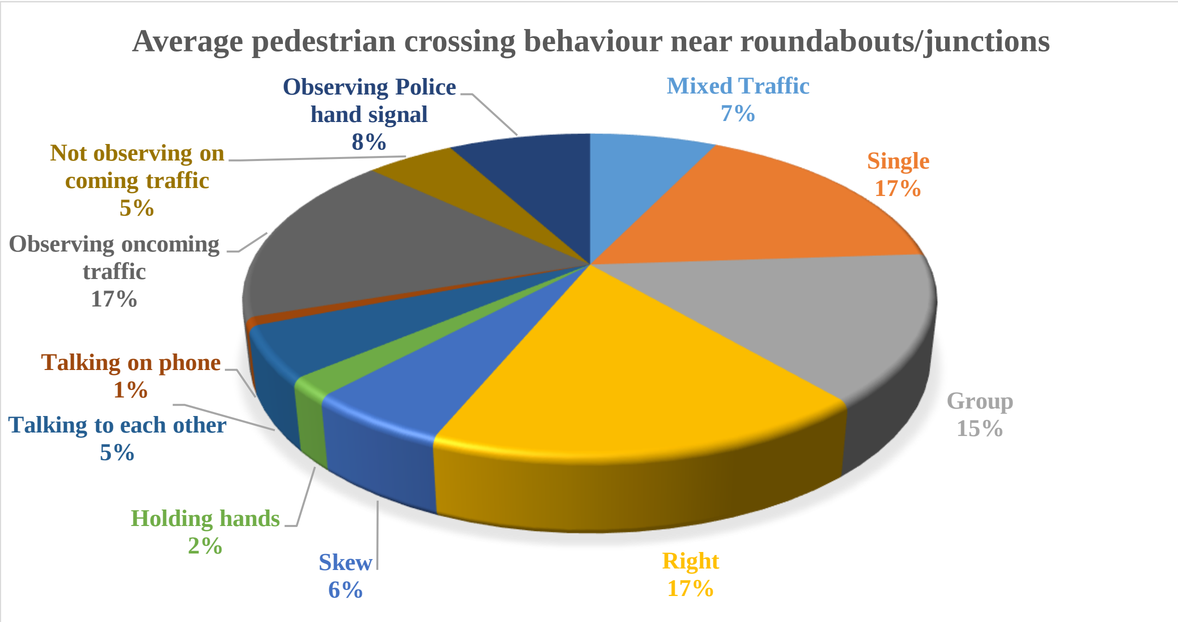

Figure 4-25: Average pedestrian crossing behaviour near roundabouts/junctions

Pedestrians' behaviour at two crossings located at midblock/section areas of Uhuru Highway were observed and the average behaviour was calculated based on certain characteristics. At midblock, 10% of pedestrians crossed the road in mixed traffic, 23% as single individuals, 9% as a group of individuals, 12 % crossed at right angel to road centerline, 6% at skew angle to road centerline, 5% crossed while holding hands, 4% while talking to each other, 4% while talking on phone, 15% crossed while observing oncoming traffic, 5% crossed while not observing oncoming traffic and 7% crossed while observing police hand signal as shown in Figure 4-26 below.

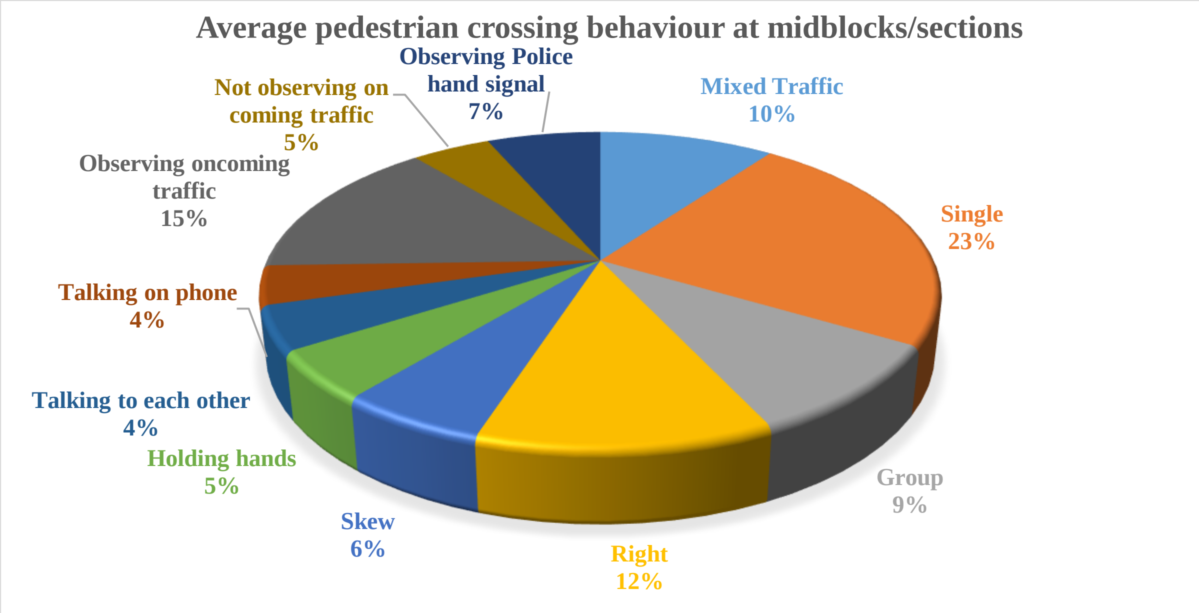

Figure 4-26: Average pedestrian crossing behaviour at midblock/sections

Analysis on pedestrian crashes by crash codes along Uhuru Highway revealed that majority of pedestrian crashed are caused 17% (68), 13% (29), 13% (63), 10% (14), 6% (7), 4% (Unknown), 4% (26), 4% (30), 4% 925), 2 % (61), 2% (43), 2% (23) 2% (19), 2% (18), 2% (17), 2% (98), 2% (70) and 2% (69) as shown in Figure 4-27 below.

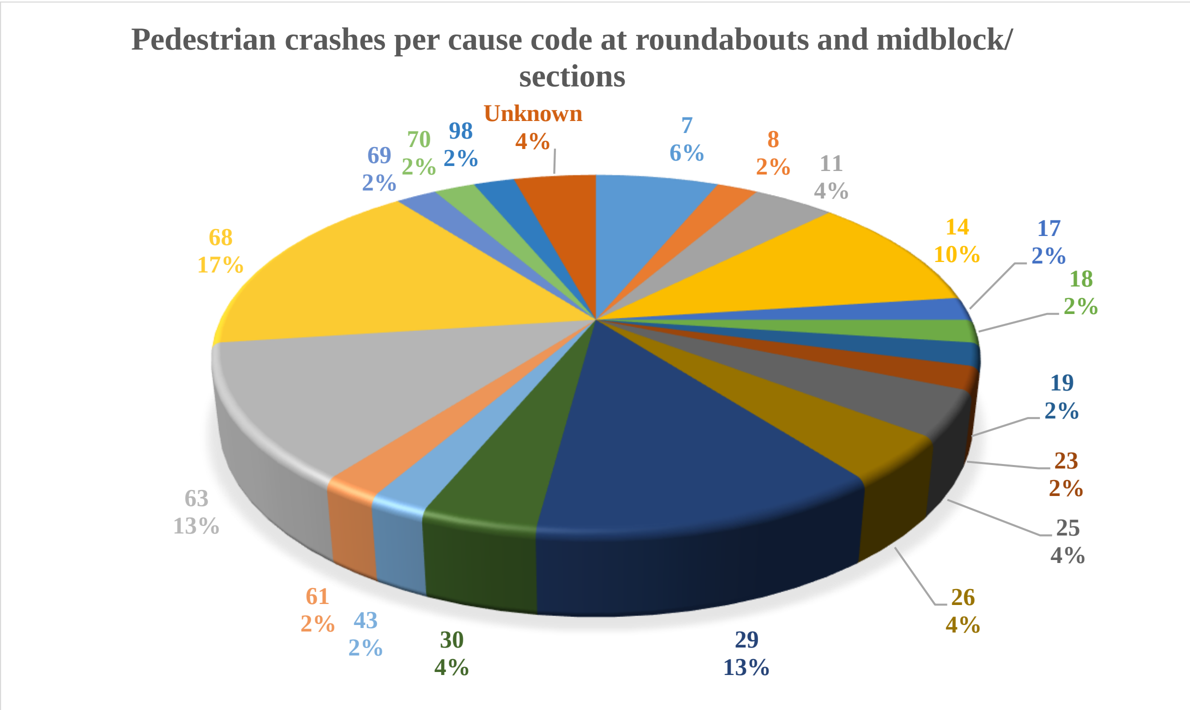

Figure 4-27: Pedestrian crashes per cause code

4.5 Pedestrian Crossing Warrants

Pedestrian crossing warrants helps in identifying the types of facilities to be improved at a particular location along a roadway. Several guidelines recommend that the type of pedestrian crossing facility to be provided is dependent on any given traffic and site conditions. Generally they can often be located based on macroscopic traffic parameters such as pedestrian volume, vehicle volume and vehicle speed. Other microscopic traffic parameters to be considered include pedestrian delay and crossing opportunities which is often referred to as acceptable gaps. A relationship between total numbers of pedestrian crossing a major street per hour (pedestrians/hr) against total vehicle volume of both sides on major street (vehicle/hr) is used to determine pedestrian crossing warrants.

Some of the factors considered in analysis include pedestrian volume, vehicle volume, speed limit, sight distances, crash history at proposed site for pedestrian crossing and distance to the nearest designated crosswalk. Walkability of crossings is a primary factor for assessing different facilities for midblock and uncontrolled intersections. Level of service criteria selected for design is based on pedestrian delay, pedestrian safety and overall walkability as shown in Table 4-1 below. Other standards provide recommendations on choice of crossing facility appropriate to traffic environment but also provides feasibility assessment.

Table 4-1: Levels of service on pedestrian delay

Average Pedestrian Delay (Sec.)	Level of Service (LOS)
<5	A
5-10	B
10-15	C
15-20	D
20-40	E
>40	F

Source: Highway Capacity Manual, (HCM, 2010)

4.5.1 Traffic Volume (Vehicular Traffic)

Figure 4-22 below shows the results obtained from analysis on field data collected during the study period. Based on secondary traffic data obtained during the study, it was realized that an average daily traffic (ADT) volume of 32,798 vehicles/day along Uhuru Highway. Cars comprised the highest proportion of vehicles at about 49%, LC/4WD (20%), Matatus (10%) and Private Van (7%) amongst other vehicle categories. Based on traffic counts conducted during the study, the distribution of motorized vehicles accessing the roundabout comprised of the following; 27% private cars, 25% public service vehicles, 18% motorcyclists, 10% pick-ups, 8% lorries, 8% trucks and 4% bicyclists as shown in the Figure 4-28 below:

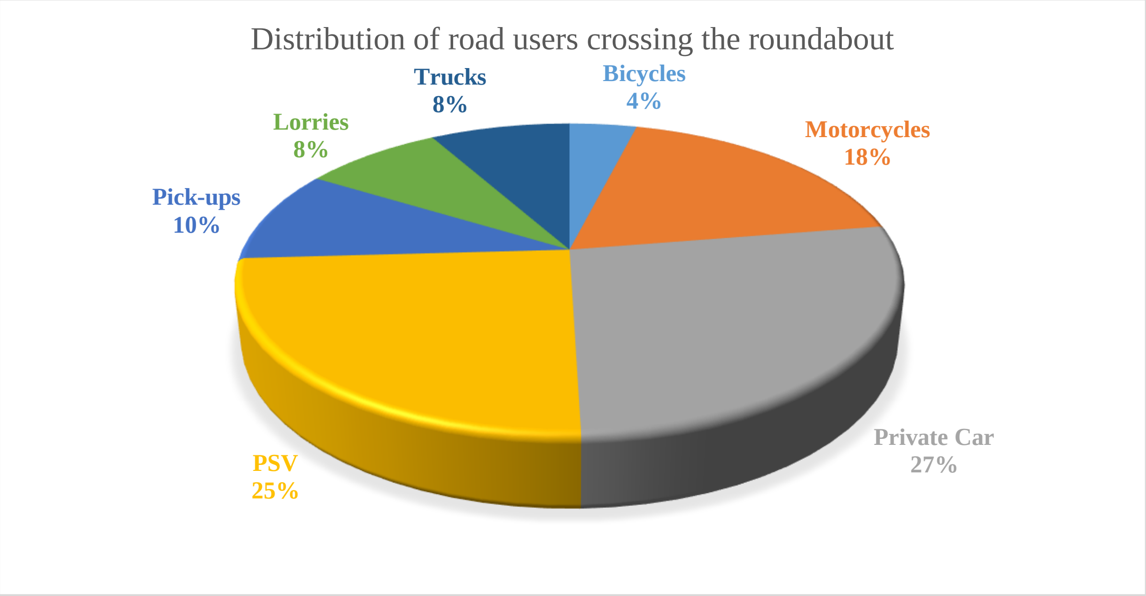

Figure 4-28: Distribution of motorized vehicles using the roundabout

The percentage distribution of motorized vehicles in the three roundabouts is as follows: 28% private car, 27% public service vehicle, 16% motorcyclists, 9% Lorries, 9% Pick-ups, 8% trucks and 3% bicyclists as shown in Figure 4-29 below.

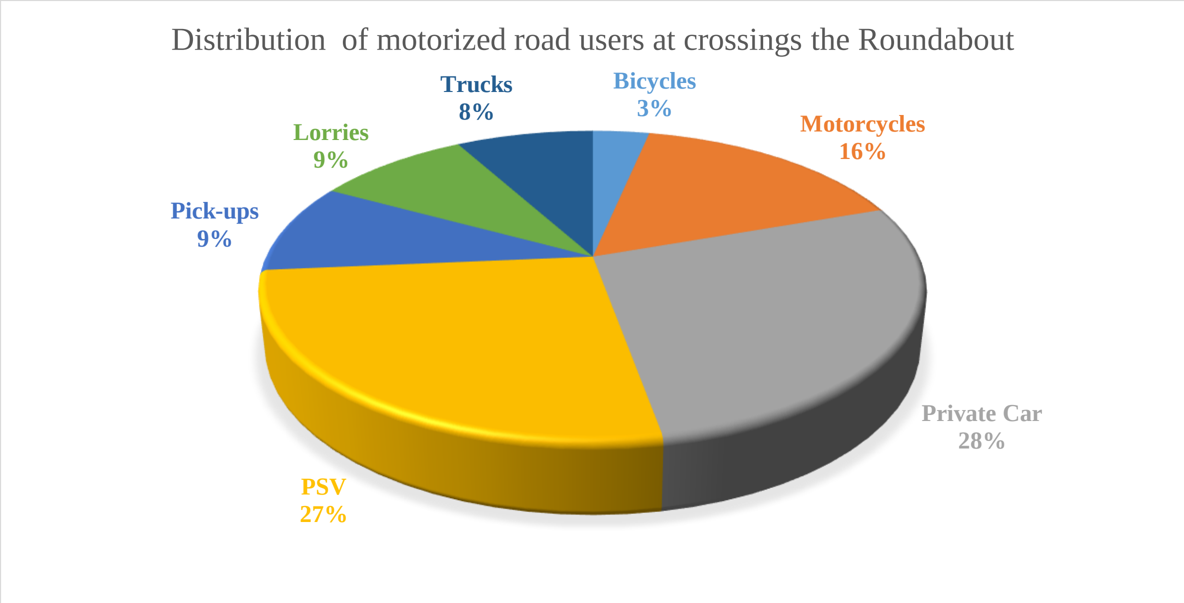

Figure 4-29: Distribution of motorized road users at crossings near the roundabout

Distribution of Vehicles at crossings near Roundabout 1 - University Way Roundabout

On average, the number of vehicles approaching pedestrian crossings per day comprised of 56% private car, 6% PSV, 22% Motorcyclists, 3% Pick-ups, 5% Lorries, 6% Trucks and 2% Bicyclists as shown in Figure 4-30 below.

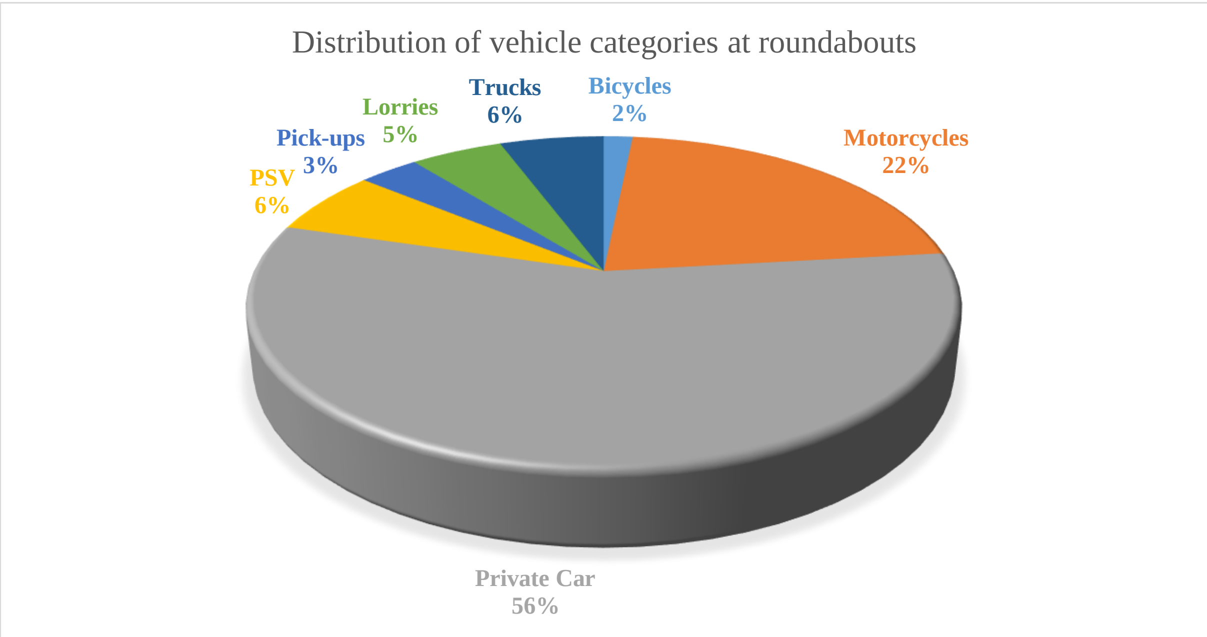

Figure 4-30: Distribution of vehicle categories at roundabouts

Distribution of Vehicles at Crossings at Roundabout 2-Kenyatta Avenue Roundabout

On average, the number of vehicles approaching pedestrians crossing per day comprised of 50% private car, 18% PSV, 16% Motorcyclists, 4% Pick-ups, 4% lorries, 5% Trucks and 3% Bicyclists as shown in Figure 4-31 below.

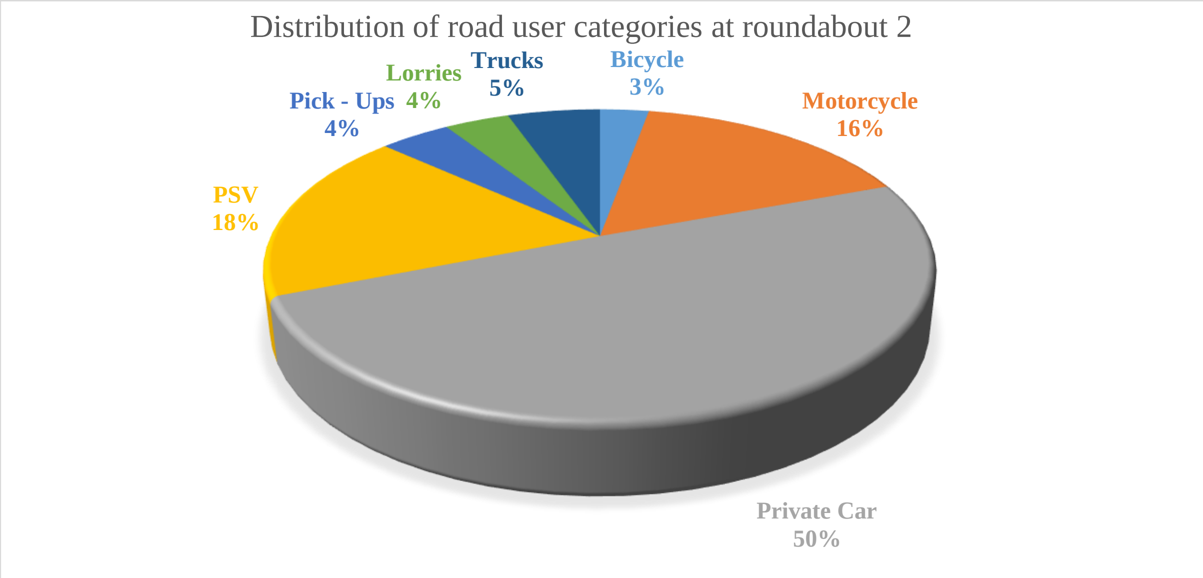

Figure 4-31: Distribution of road user categories

Distribution of Vehicles at Crossings at Roundabout 3-Haile Selassie Avenue Roundabout.

On average, the number of vehicles approaching pedestrians crossing per day comprised of 60% private car, 16% PSV, 15% Motorcyclists, 3% Pick-ups, 2% lorries, 2% Trucks and 2% Bicyclists as shown in Figure 4-32 below.

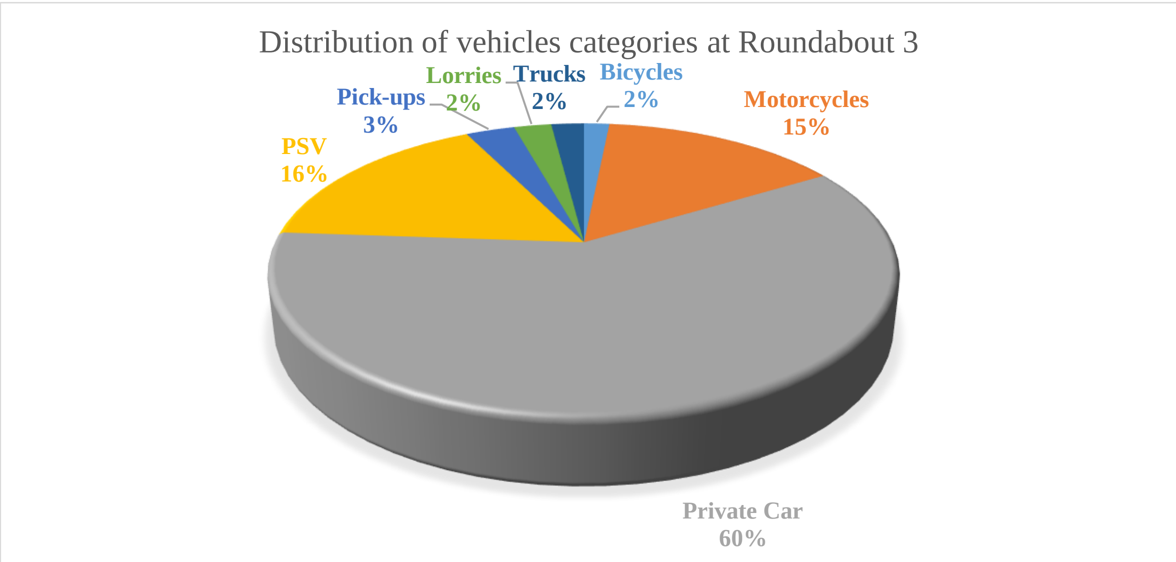

Figure 4-32: Distribution of vehicles categoreies at roundabouts

Distribution of Vehicles at Crossings at Midblock/Sections along Uhuru Highway

On average, the number of vehicles approaching pedestrians crossing per day comprised of 27% Private cars, 26% PSV, 9% Pick-ups, 14% lorries, 11% trucks, 11% motorcyclists, and 2 % bicyclists as shown in Figure 4-33 below.

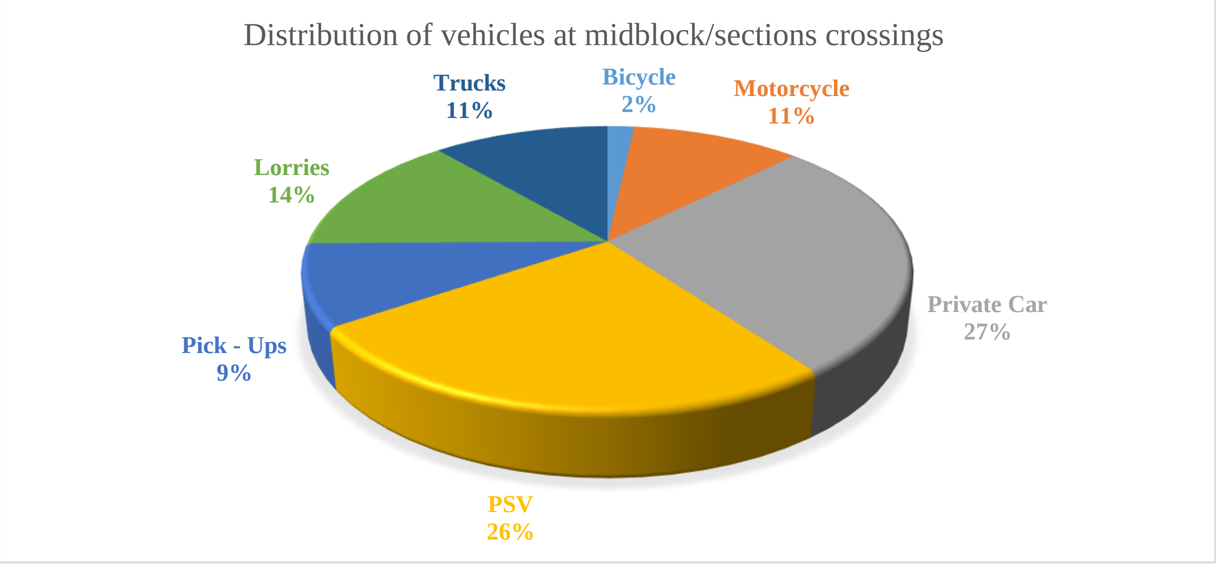

Figure 4-33: Distribution of vehicles at midblock crossings

4.5.2 Modal Split

About 57% of pedestrians interviewed preferred to use minibus (B), 18% preferred matatus (M), 14% preferred to use buses (B), 7% preferred Tuk-tuk while 4% preferred to walk (W). as shown in Figure 4-34 below.

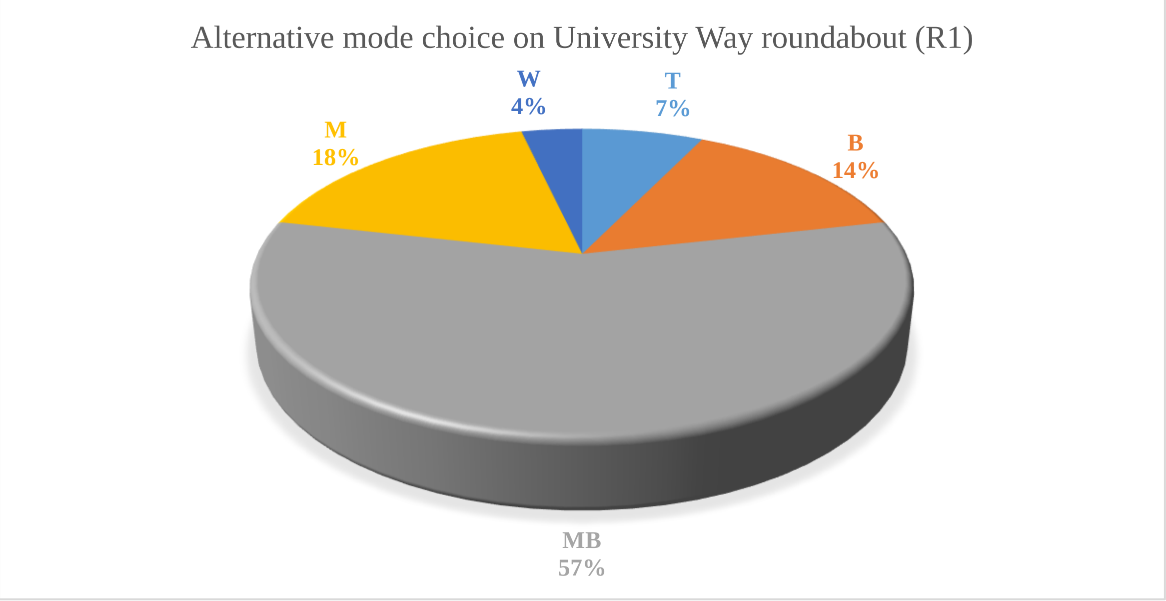

Figure 4-34: Alternative mode choice on Univeristy Way rounadout (R1)

At Roundabout 2, 43% of pedestrians interviwed prefered to use mini-buses (MB), 29% prefferred to u walk (W), 18% preferred to us a matatu (M), 7% preferred to use Tuk-tuk (T) and 3% preferred to use a bus (B) as shown in Figure 4-35 below.

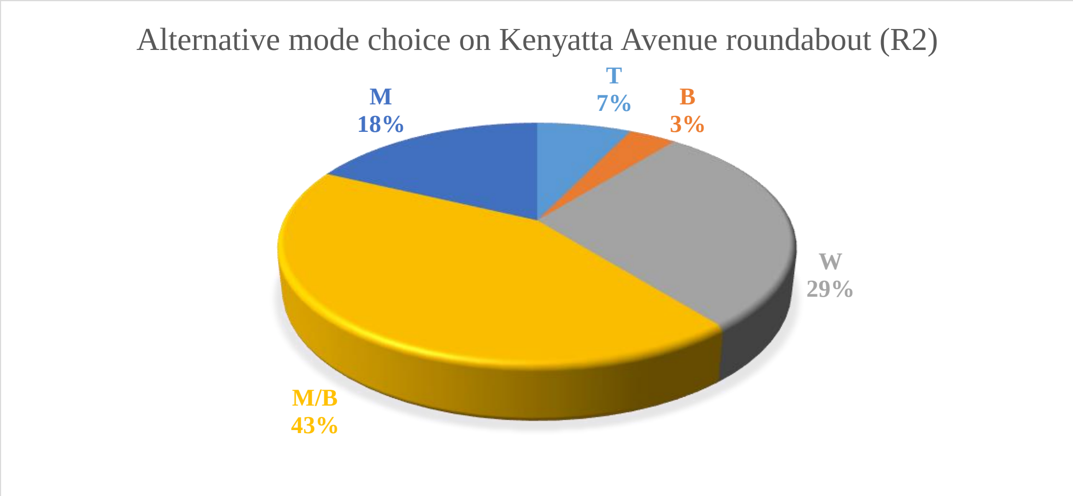

Figure 4-35: Alternative mode choice on Kenyatta Avenue roundabout (R2)

At Roundabout 3, 57% of pedestrians interviewed preferred to use Minibuses, 29% preferred Matatus, 7% preferred Tuk-tuks (T), 3% preferred to Buses and 4% preferred to walk as shown in Figure 4-36 below.

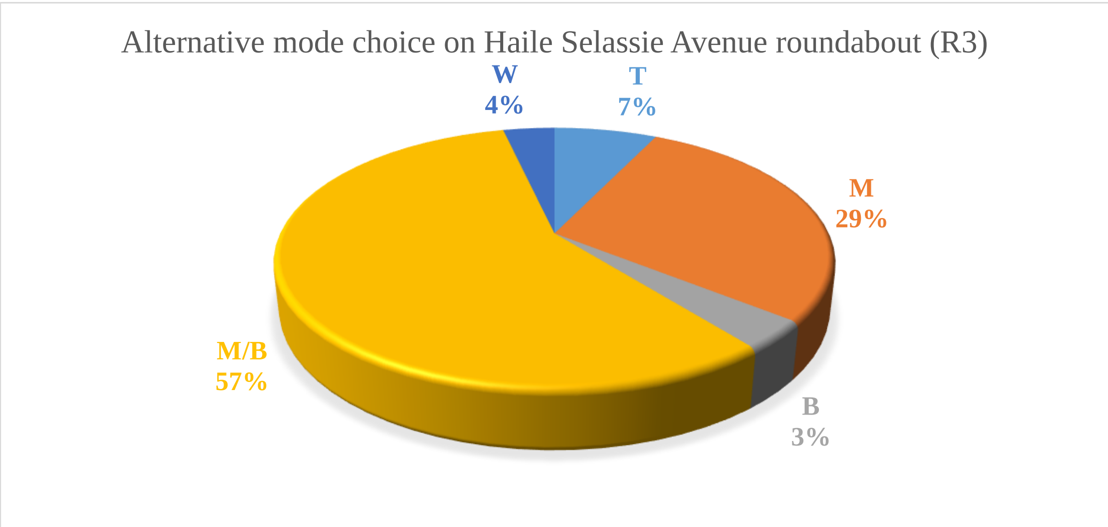

Figure 4-36: Alternative mode choice of Haile Selassie Avenue roundabout (R3)

Base on analysis of response obtained from pedestrians crossing Uhuru Highway at midblock sections, 71% of pedestrian preferred to use minibuses (M/B), 25% preferred ‘matatus’ (M), and none preferred to use buses (B) or tuk-tuks (T). However, 4% of pedestrians interviewed still preferred to walk as shown in Figure 4-37 below.

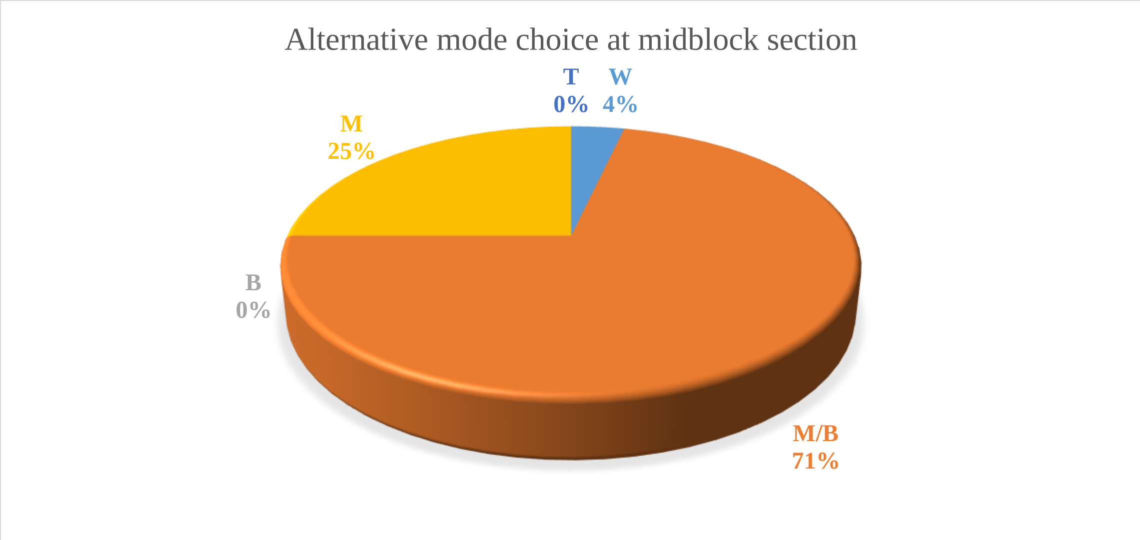

Figure 4-37: Alternative mode choice at midblock section

4.5.3 Driver/Rider Non-Yielding Behaviour near Roundabouts

The results obtained from direct observation on driver yielding behaviour indicates that car drivers constituted about 38% of all drivers who did not yield to pedestrians at crossings near roundabouts compared to 30% public service vehicle (PSV) drivers, 26% motorcycle riders, 5% truck drivers and 1% bicycle riders as shown in Figure 4-38 below. Therefore, pedestrians are at highest risk of collision with private cars compared to all other vehicle types while crossing near roundabouts along Uhuru Highway. Severity of crashes involving pedestrians is dependent on impact energy which is directly proportional to mass and velocity of two objects in this case a vehicle and a pedestrian.

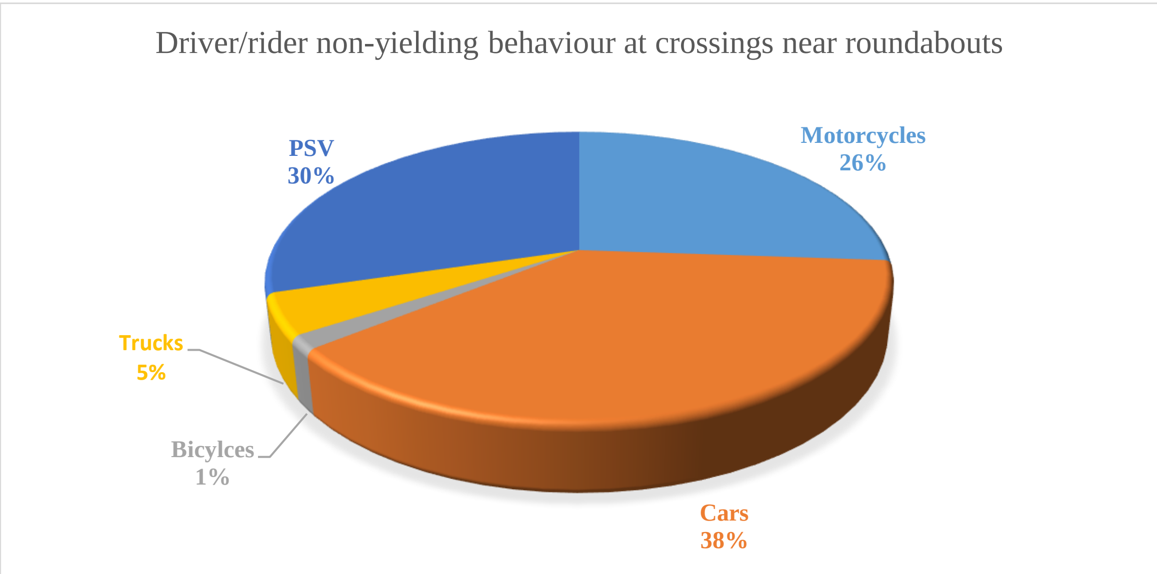

Figure 4-38: Driver/rider non-yielding behaviour near roundabouts

4.5.4 Pedestrian Waiting time versus Pedestrian Crossing Time

Roundabout 1: University Way Roundabout

The study also sought to establish the amount of delay (pedestrian waiting time) and pedestrian crossing time (gap size) at each major crossings located near three roundabouts along Uhuru Highway. The data consisted of the average pedestrian waiting time (seconds) per 15-minute interval from 0600hrs until 1800hrs as well as the average pedestrian crossing time. Comparative analysis on pedestrian waiting time against pedestrian crossing time at crossings near University Way roundabout was calculated per 15-minute peak hour interval for a week and the results obtained were presented in as shown in Figure 4-39 below.

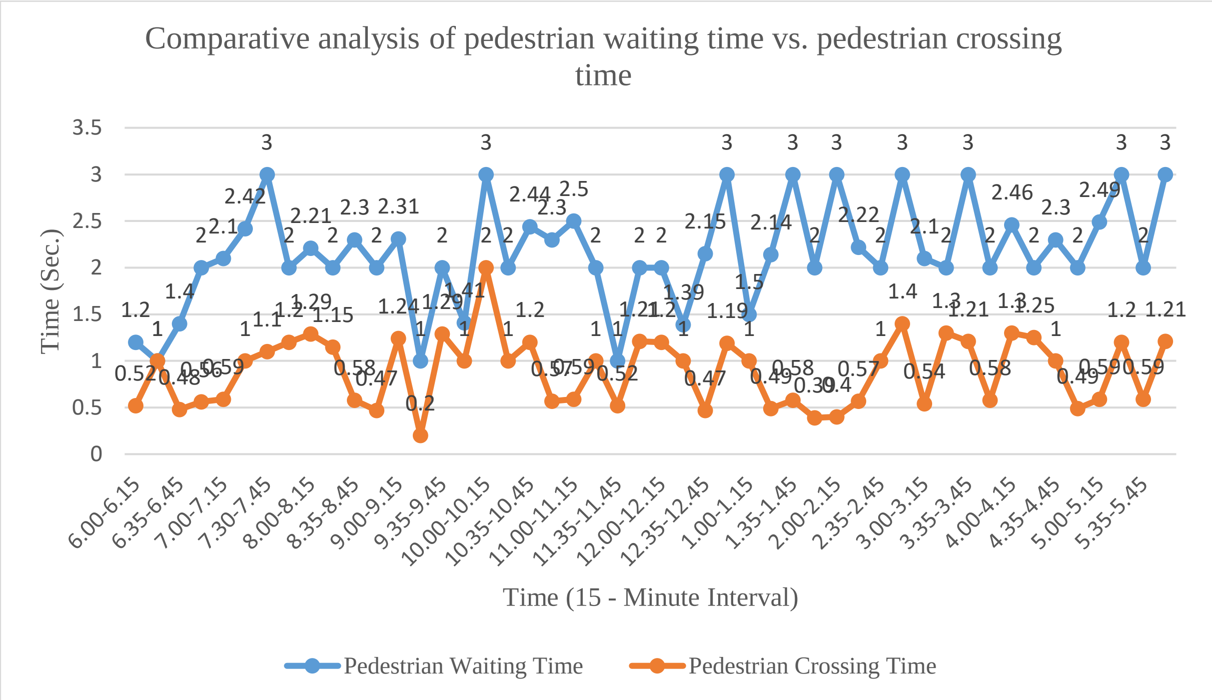

Figure 4-39: Comparative Analysis of Pedestrian waiting vs. pedestrian crossing time

The average pedestrian waiting time at crossings near University Way roundabout was calculated as 2 minutes and 9 seconds (2.15 minutes) compared to an average pedestrian crossing time of 54 seconds (0.9 minutes). Average crossing distance was measured to be 10.5m per carriageway along Uhuru Highway, the average walking speed by pedestrians is therefore calculated as 0.19 m/s.

Roundabout 2: Kenyatta Avenue Roundabout

Kenyatta roundabout is characterized by nearby bus stations located on either side of Kenyatta Avenue within 50m from the roundabout. This presents a new set of challenges for pedestrian safety since most pedestrians usually board or alight on public transport at the two GPO bus stations. A comparative analysis on pedestrian waiting time (delay) against pedestrian crossing time (gap size) at crossings located near Kenyatta Avenue roundabout was calculated per 15–minute peak hour interval for a week as shown Figure 4-40 below. The average pedestrian waiting time at crossings near Kenyatta Avenue roundabout was calculated as 1 minutes 58 seconds (1.97 minutes) compared to an average pedestrian crossing time of 55 seconds (0.93 minutes). Average crossing distance was measured to be 10.5m per carriageway along Uhuru Highway, the average walking speed by pedestrians is 0.19 m/s.

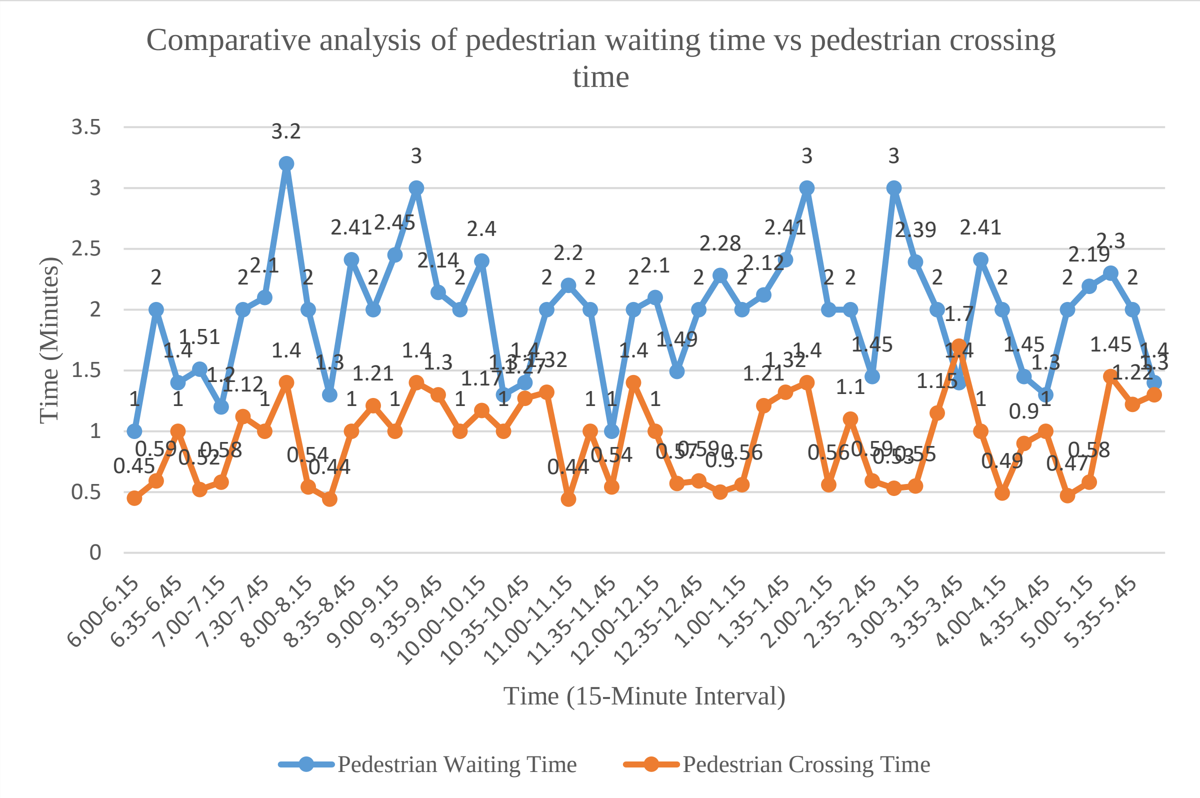

Figure 4-40: Comparative Analysis of pedestrian waiting time

Roundabout 3: Haile Selassie Roundabout

A comparative analysis on pedestrian waiting time against pedestrian crossing time at crossings near Haile Selassie Avenue roundabout was calculated per 15-minute peak hour interval for a week as shown in Figure 4-41 below. The average pedestrian waiting time at crossings near Haile Selassie Avenue roundabout was calculated as 2.07 minutes compared to an average pedestrian crossing time of 42 seconds (0.71 minutes). Average crossing distance was measured to be 10.5m per carriageway along Uhuru Highway, the average walking speed by pedestrians is 0.25 m/s.

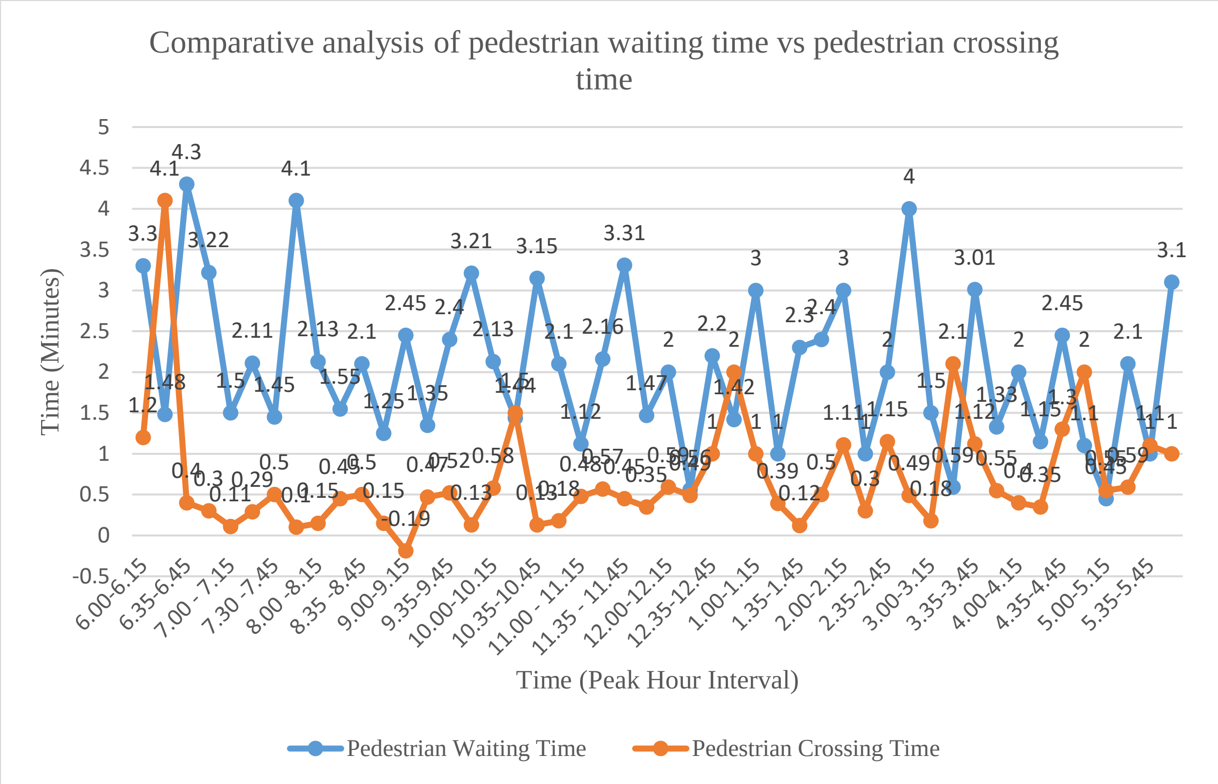

Figure 4-41: Comparative Analysis of pedestrian waiting time vs pedestrian crossing time

Mid-block/Section-1

A comparative analysis on pedestrian waiting time against pedestrian crossing time at crossings located at midblock/sections along Uhuru Highway was calculated per 15-minute peak hour interval for a week as shown in Figure 4-42 below. The average pedestrian waiting time at midblock crossings along Uhuru Highway was calculated as 1 minute 45 seconds (1.75 minutes) compared to an average pedestrian crossing time of 44 seconds (0.74 minutes). Average crossing distance was measured to be 10.5m per carriageway along Uhuru Highway, the average walking speed by pedestrians is 0.23 m/s.

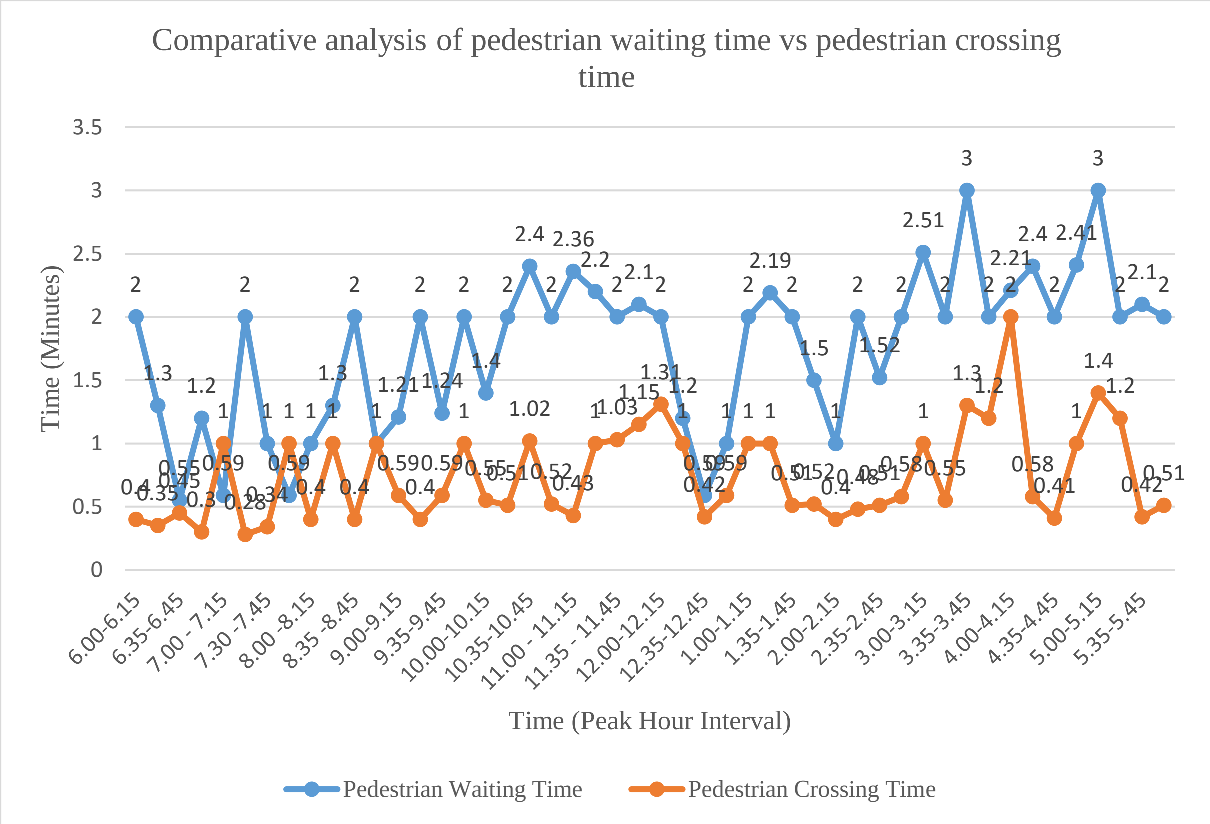

Figure 4-42: Comparative analysis of pedestrian waiting time vs pedestrian crossing time

Mid-block/Section-2

A comparative analysis on pedestrian waiting time against pedestrian crossing time at crossings located at midblock/sections along Uhuru Highway was calculated per 15-minute peak hour interval for a week as shown in Figure 4-43 below. The average pedestrian waiting time at midblock crossings along Uhuru Highway roundabout was calculated as 1 min 9 seconds (1.16 minutes) compared to an average pedestrian crossing time of 22 seconds (0.37 minutes). Average crossing distance was measured to be 10.5m per carriageway along Uhuru Highway, the average walking speed by pedestrians is 0.48 m/s.

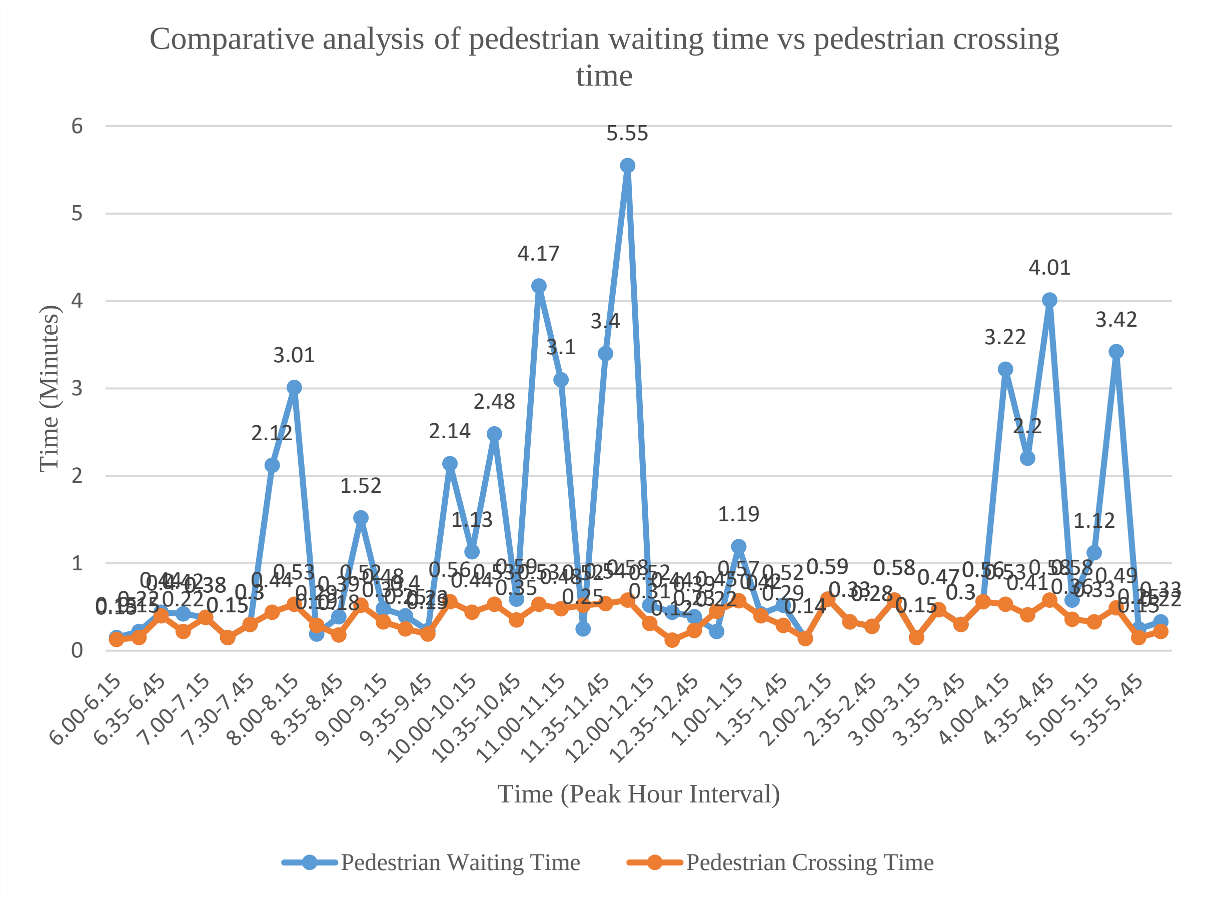

Figure 4-43: Comparative analysis of pedestrian waiting time vs. pedestrian crossing time

4.5.5 Pedestrian Volumes at Crossings

Roundabout 1 (University Way Roundabout) - Leg 1

Based on manual classified traffic count conducted at University Way roundabout, the number of pedestrians crossing Uhuru Highway per 15-minute interval was recorded and analysed for a week. An average daily pedestrian volume per 15-minute interval has been analysed and presented in Figure 4-44 below. Averagely, 677 pedestrians crossed Uhuru Highway between 5.00pm to 5.15pm hence being the highest peak volume.

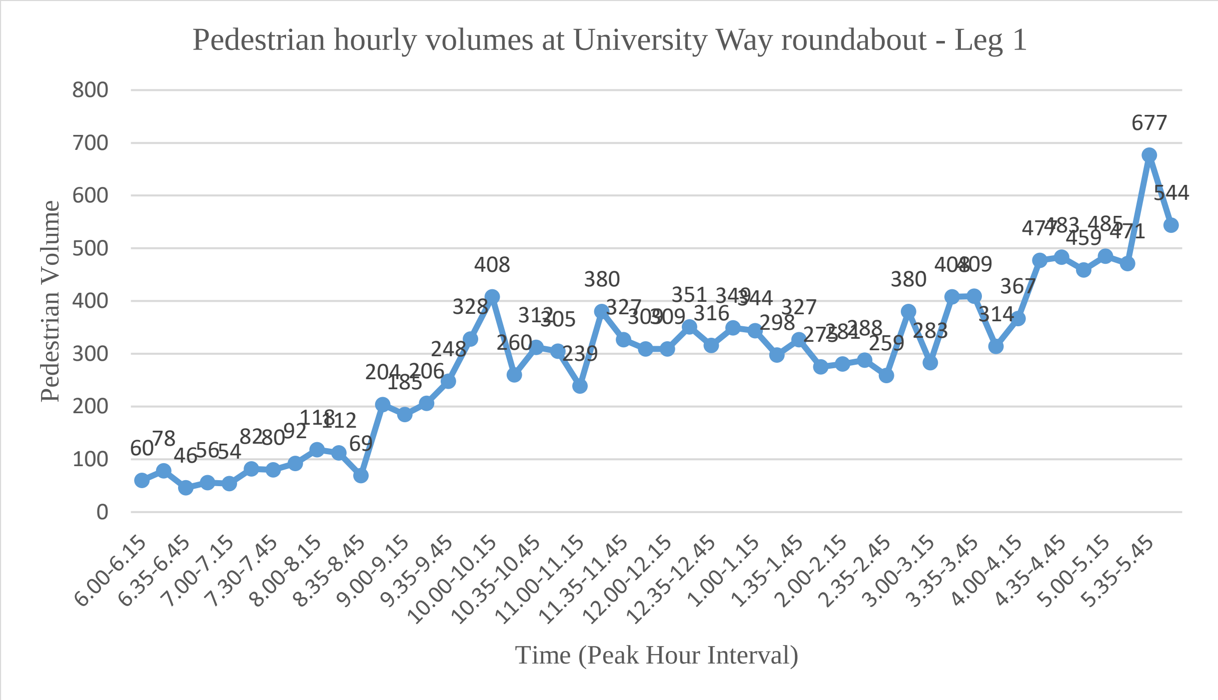

Figure 4-44: Pedestrian hourly volumes at University Way roundabout-Leg 1

Cumulatively, the total pedestrian volume per day was calculated as 13,712 with an average of 286 pedestrians per 15-minute interval.

Roundabout 1 (University Way Roundabout)-Leg 2

Based on manual classified traffic count conducted at University Way roundabout, the number of pedestrians crossing Uhuru Highway per 15-minute interval was recorded and analysed for a week. An average daily pedestrian volume per 15-minute interval has been analysed and presented in Figure 4-45 below. Averagely, 370 pedestrians crossed Uhuru Highway between 5.00pm to 5.15pm hence being the highest peak volume.

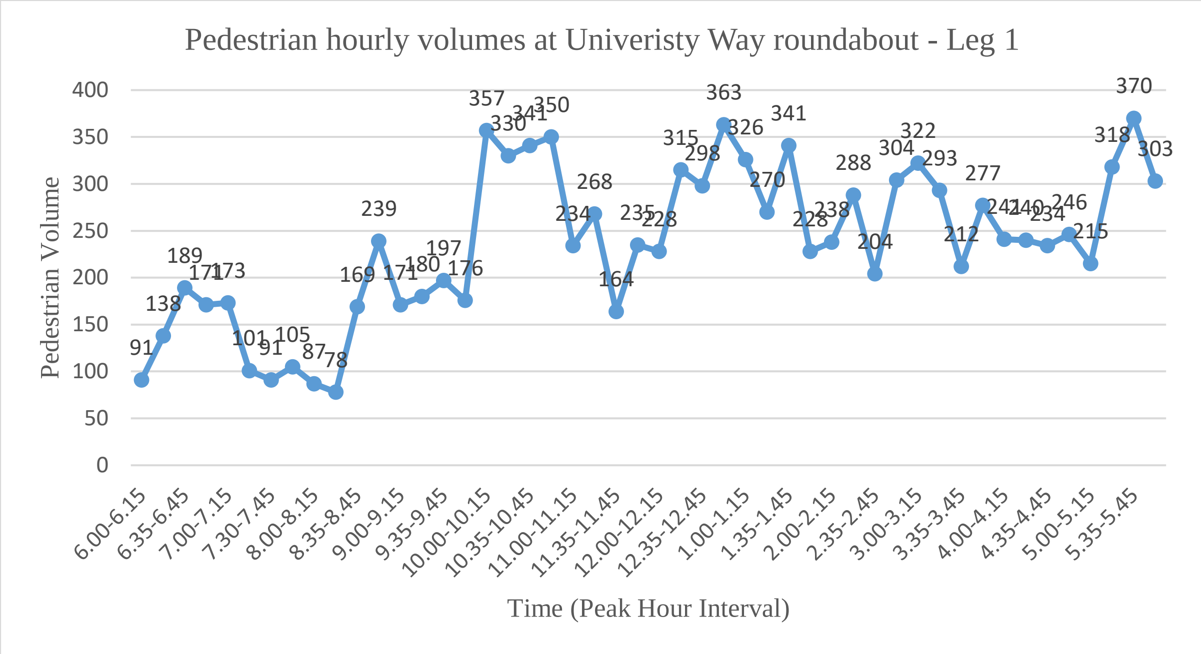

Figure 4-45: Pedestrian hourly volumes at University Way roundabout-Leg 1

Cumulatively, the total pedestrian volume per day was calculated as 11,309 with an average of 236 pedestrians per 15 - minute interval.

Midblock/Section 1 (Between University Way and Kenyatta Avenue Roundabout)

At Midblock 1 between University Way and Kenyatta Avenue roundabouts, the average number of pedestrians crossing Uhuru Highway was recorded daily for a whole week and the results obtained per 15 - minute interval are presented in Fig 4-46 below. The highest peak hour volume was recorded as 113 pedestrians between 8.00am and 8.15am.

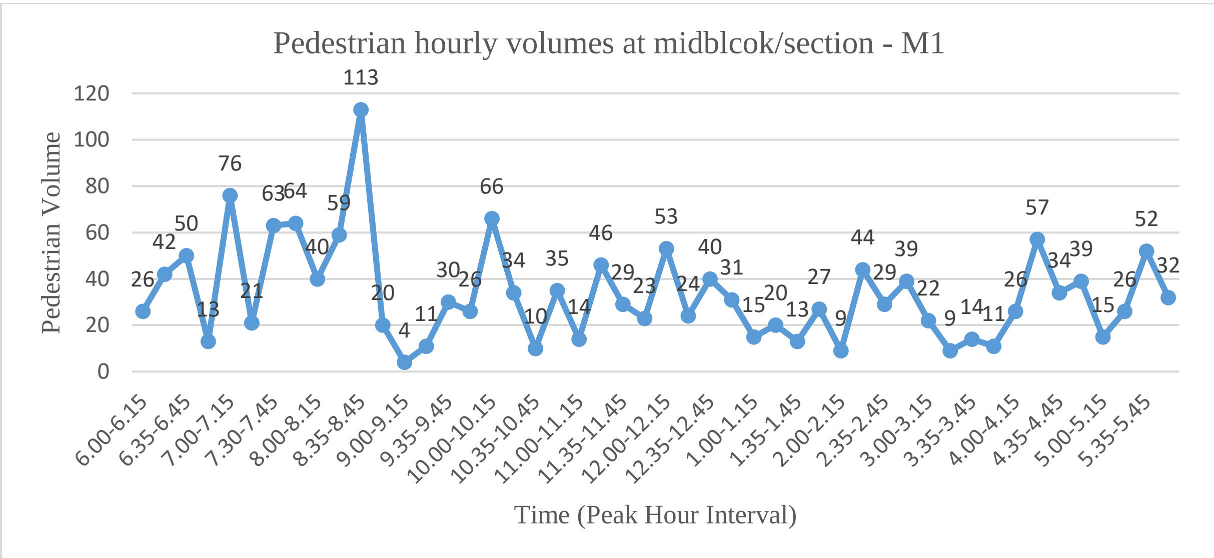

Figure 4-46: Pedestrian hourly volumes at midblock/section - M1

Cumulatively, 1,596 pedestrians crossed Uhuru Highway at midblock section between University Way and Kenyatta Avenue roundabouts. On an average, 34 pedestrians crossed Uhuru Highway at midblock per 15 - minute interval.

Roundabout 2 (Kenyatta Avenue Roundabout)-Leg 1

Based on a manual classified traffic count conducted at Kenyatta Avenue roundabout, the number of pedestrians crossing Uhuru Highway per 15-minute interval was recorded and analysed for a week. An average daily pedestrian volume per 15-minute interval has been presented in Figure 4-47 below. The highest peak hour volume recorded was 334 pedestrians who crossed Uhuru Highway between 4.00pm to 4.15pm.

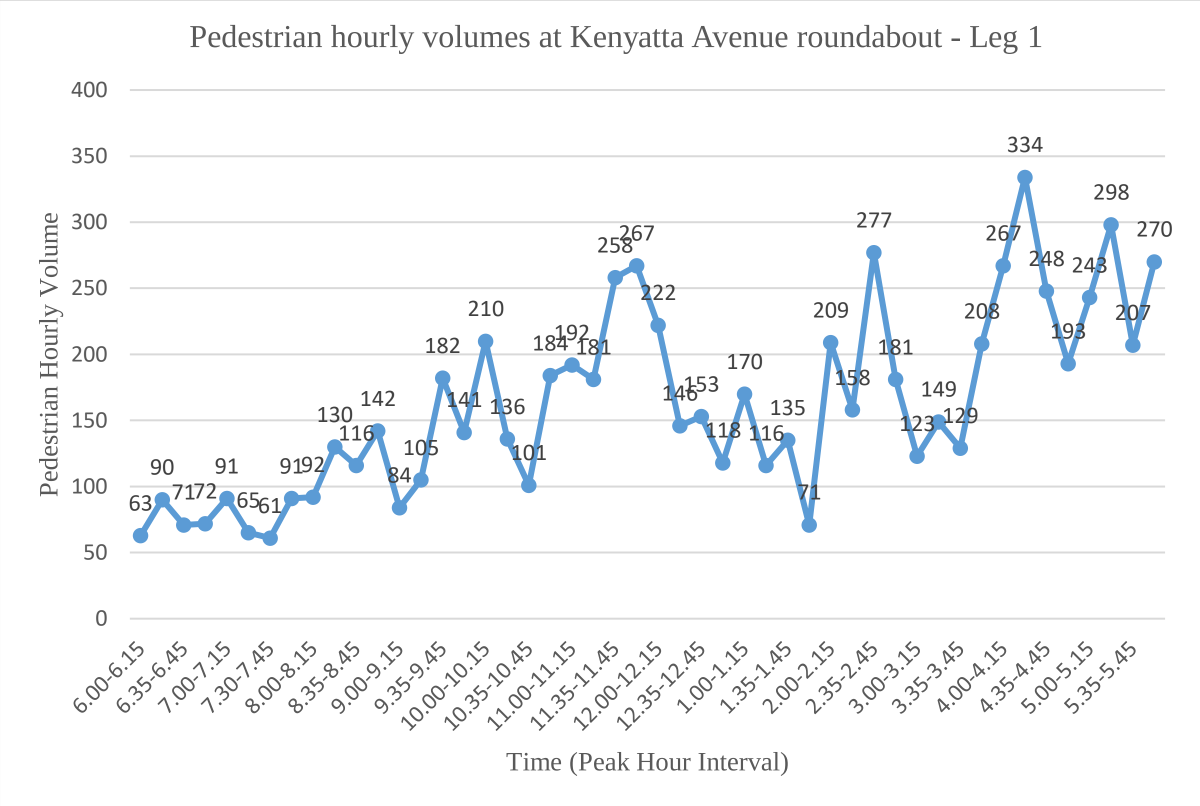

Figure 4-47: Pedestrian hourly volumes at Kenyatta Avenue roundabout-Leg 1

Cumulatively, 7,750 pedestrians crossed Uhuru Highway at crossings near Kenyatta Avenue roundabout. On an average, 162 pedestrians crossed Uhuru Highway at this location per 15-minute interval.

Roundabout 2 (Kenyatta Avenue Roundabout)-Leg 2

Based on manual classified traffic count conducted at Kenyatta Avenue roundabout, the number of pedestrians crossing Uhuru Highway per 15-minute interval was recorded and analysed for a week. An average daily pedestrian volume per 15-minute interval has been presented in Figure 4-48 below. The highest peak hour volume recorded was 454 pedestrians who crossed Uhuru Highway between 4.30 pm to 4.45 pm.

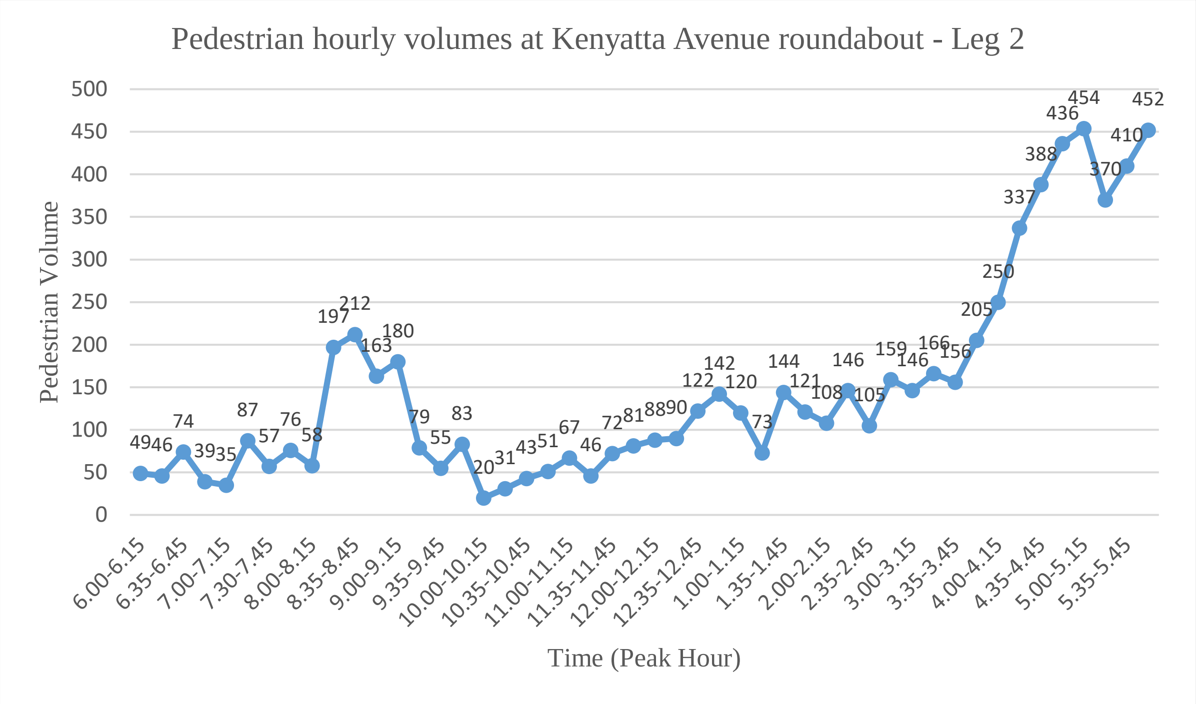

Figure 4-48: Pedestrian hourly volumes at Kenyatta Avenue roundabout-Leg 2

Cumulatively, 7,089 pedestrians crossed Uhuru Highway at crossings near Kenyatta Avenue roundabout. On an average, 148 pedestrians crossed Uhuru Highway at this location per 15-minute interval.

Roundabout 3 (Haile Selassie Roundabout)-Leg 1

Based on manual classified traffic count conducted at crossings near Haile Selassie roundabout, the number of pedestrians crossing Uhuru Highway per 15-minute interval was recorded and analysed for a week. An average daily pedestrian volume per 15-minute interval has been presented in Figure 4-49 below. The highest peak hour volume recorded was 1692 pedestrians who crossed Uhuru Highway between 7.00am to 7.15am.

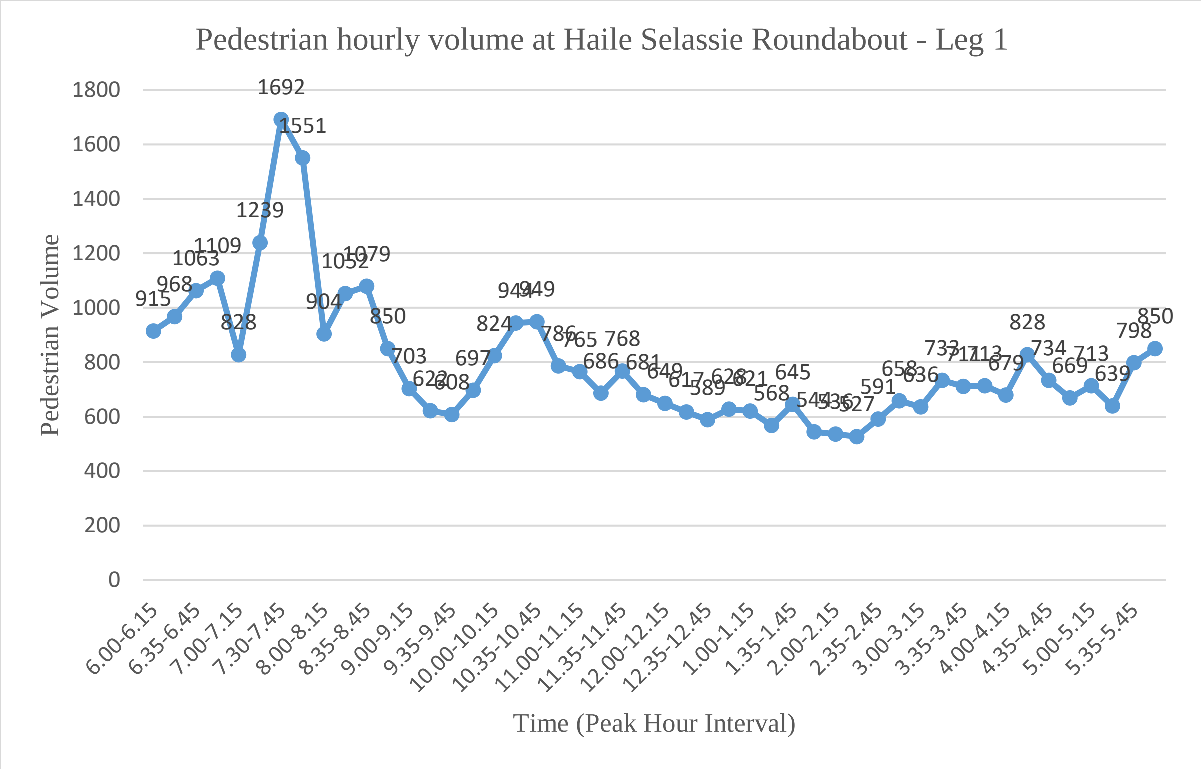

Figure 4-49: Pedestrian hourly volumes at Haile Selassie roundabout-Leg 1

Cumulatively, 38,159 pedestrians crossed Uhuru Highway at crossings near Haile Selassie Avenue roundabout. On an average, 794 pedestrians crossed Uhuru Highway at this location per 15-minute interval.

Roundabout 3 (Haile Selassie Roundabout)-Leg 2

Based on manual classified traffic counts conducted at crossings near Haile Selassie roundabout, the number of pedestrians crossing Uhuru Highway per 15-minute interval was recorded and analysed for a week. An average daily pedestrian volume per 15-minute interval has been presented in Figure 4-50 below. The highest peak hour volume recorded was 1736 pedestrians who crossed Uhuru Highway between 4.30pm to 4.45pm.

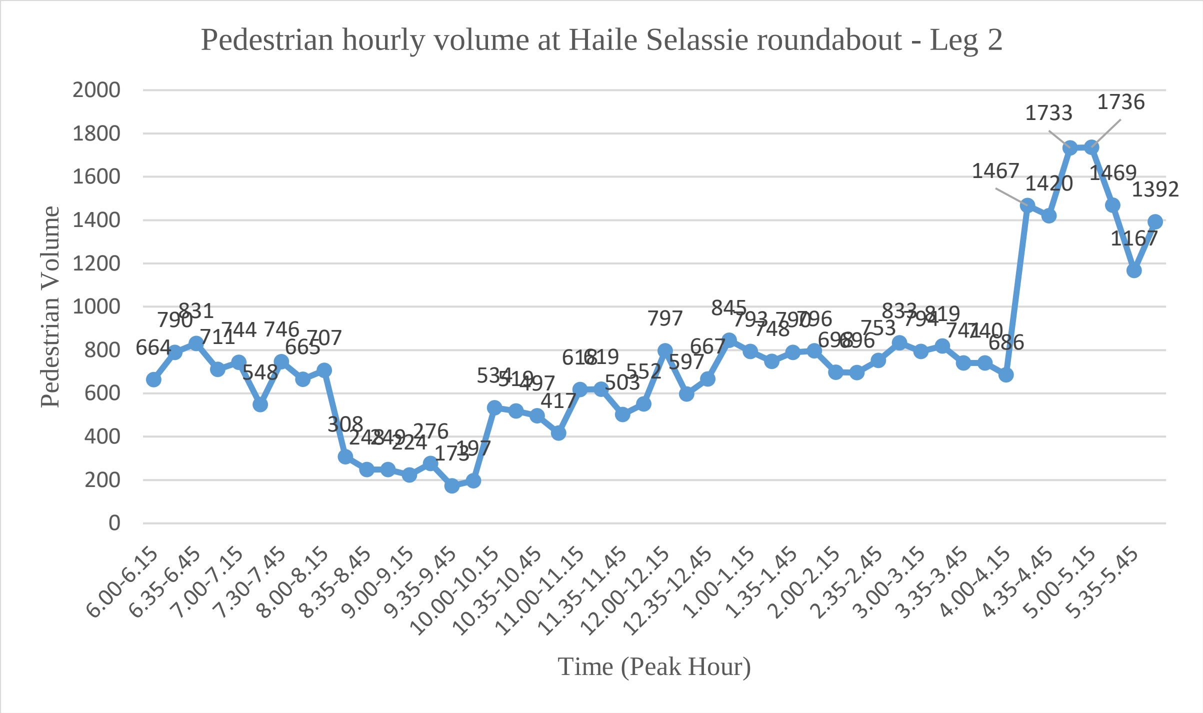

Figure 4-50: Pedestrian hourly volumes at Haile Selassie roundabout-Leg 2

Cumulatively, 35,517 pedestrians crossed Uhuru Highway at crossings near Haile Selassie Avenue roundabout. On an average, 739 pedestrians crossed Uhuru Highway at this location per 15-minute interval.

Midblock - 2 (Between Kenyatta Avenue and Haile Selassie Roundabout)

At midblock 2 between Kenyatta Avenue and Haile Selassie roundabouts, the average number of pedestrians crossing Uhuru Highway was recorded daily for a whole week and the results obtained per 15-minute interval are presented in Fig 4-51 below. The highest peak hour volume was recorded as 190 pedestrians between 5.45pm and 6.00pm.

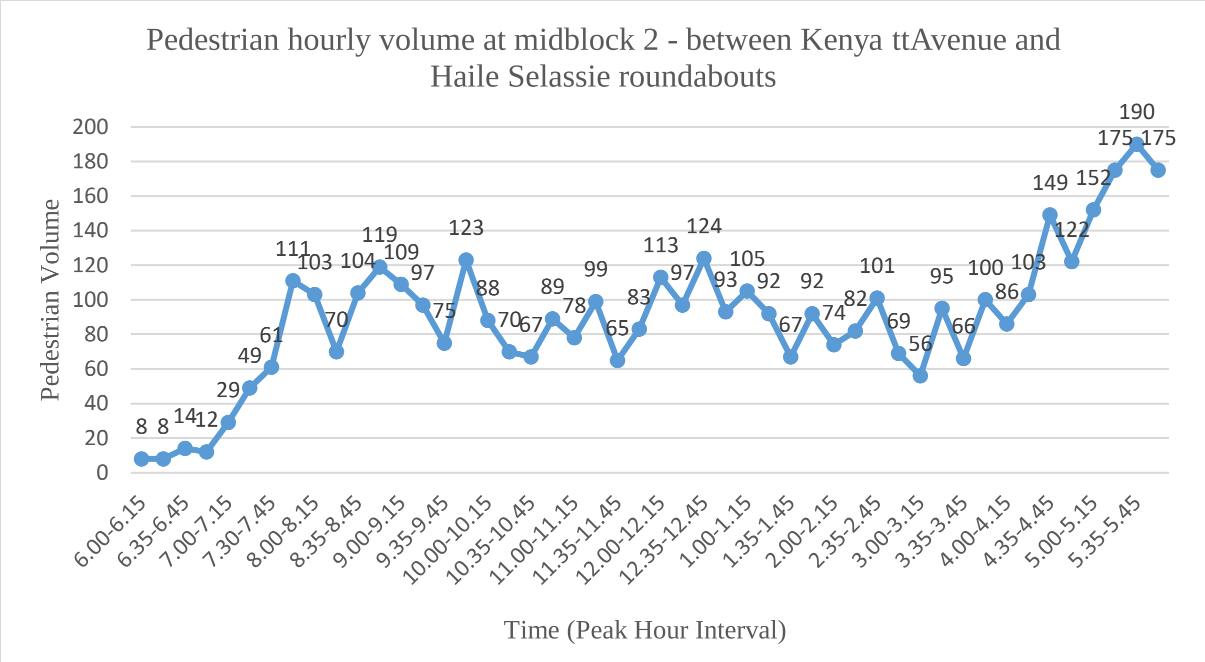

Figure 4-51: Pedestrian hourly volumes at midblock 2 - between Kenyatta Avenue and Haile Selassie roundabouts

Cumulatively, 4,309 pedestrians crossed Uhuru Highway at midblock section between Kenyatta Avenue and Haile Selassie roundabouts. On an average, 89 pedestrians crossed Uhuru Highway at midblock per 15-minute interval.

4.5.6 Vehicles Volumes Analysis

Roundabout 1 (University Way Roundabout)-Leg 1

Vehicle volume analysis was conducted on University Way roundabout-Leg 1 and the results shows that private cars and public service vehicles (PSV) are still dominant. On average, 1069 cars and 993 cars were counted along Uhuru Highway. Bicycles (66) and pick-ups (362) represented the lowest composition of traffic volume as shown in Figures 4-52 and Figure 4-53 shown below.

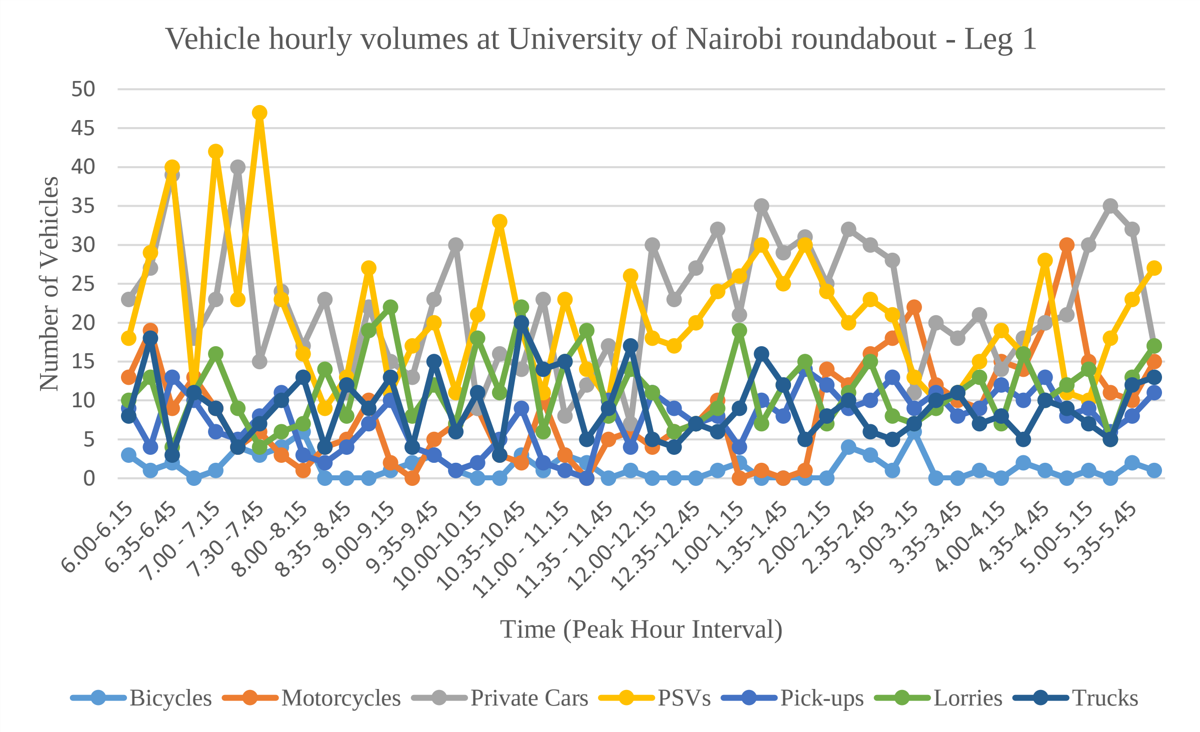

Figure 4-52: Vehicle hourly volumes at University of Nairobi roundabouts-Leg 1

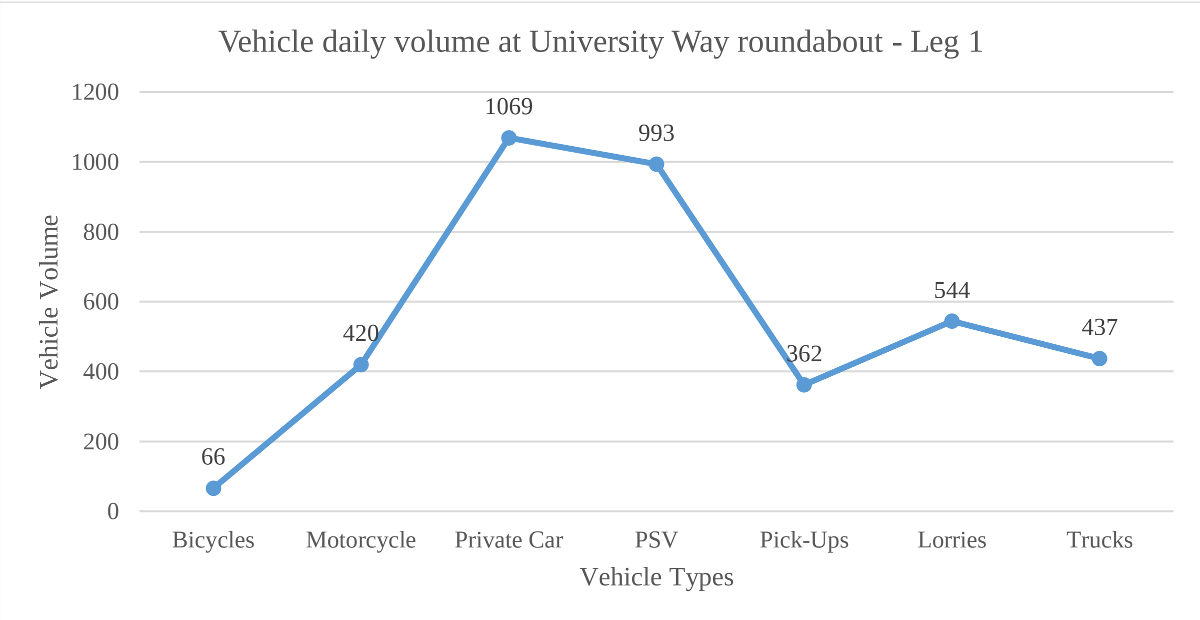

Figure 4-53: Vehicle daily volume at University of Nairobi roundabout-Leg 1

Roundabout R1 (University Way Roundabout)-Leg 2

Vehicle volume analysis was conducted on University Way roundabout-Leg 2 and the results shows that private cars and public service vehicles (PSV) are still dominant. On average, 853 private cars and 753 PSVs were counted along Uhuru Highway. Bicycles (37) and trucks (352) represented the lowest composition of traffic volume as shown in Figures 4-54 and 4-55 below.

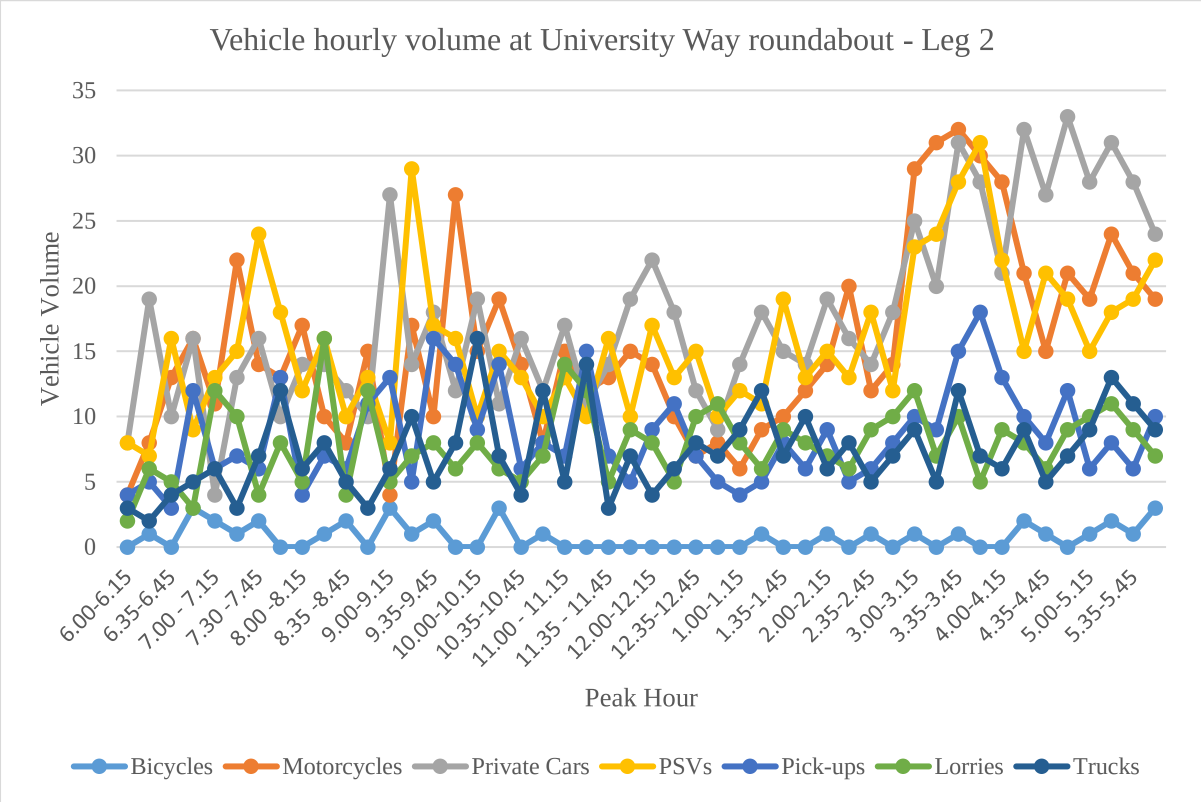

Figure 4-54: Vehicles hourly volume at University Way roundabout-Leg 2

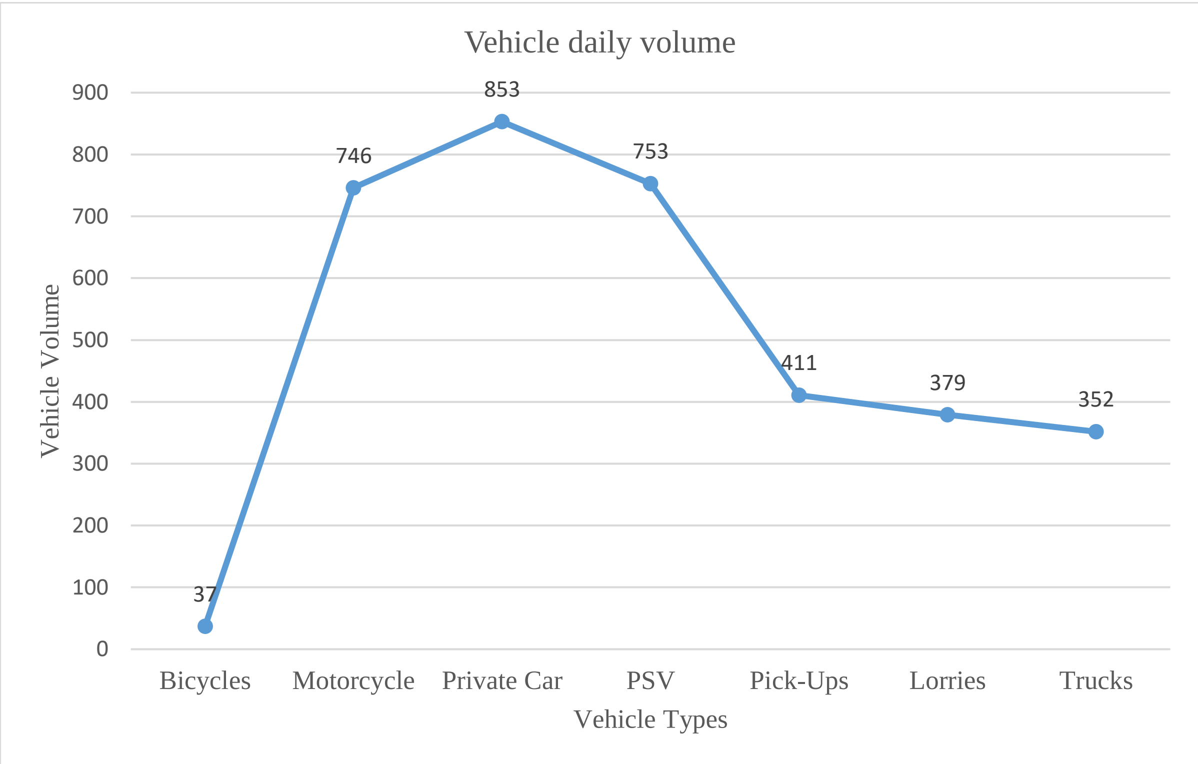

Figure 4-55: Vehicle daily volume at University Way roundabout-Leg 2

Midblock M1 (Between University Way and Kenyatta Avenue Roundabouts)

Vehicle volume analysis conducted on vehicle volume counts at midblock between University Way and Kenyatta Avenue roundabouts and the results shows that private cars and public service vehicles (PSV) are still dominant. On average, 844 private cars, 809 PSVs and 499 motorcyclists were counted along Uhuru Highway. Bicycles (101) and trucks (245) represented the lowest composition of traffic volume as shown in Fig. 4-56 and Fig. 4-57 below.

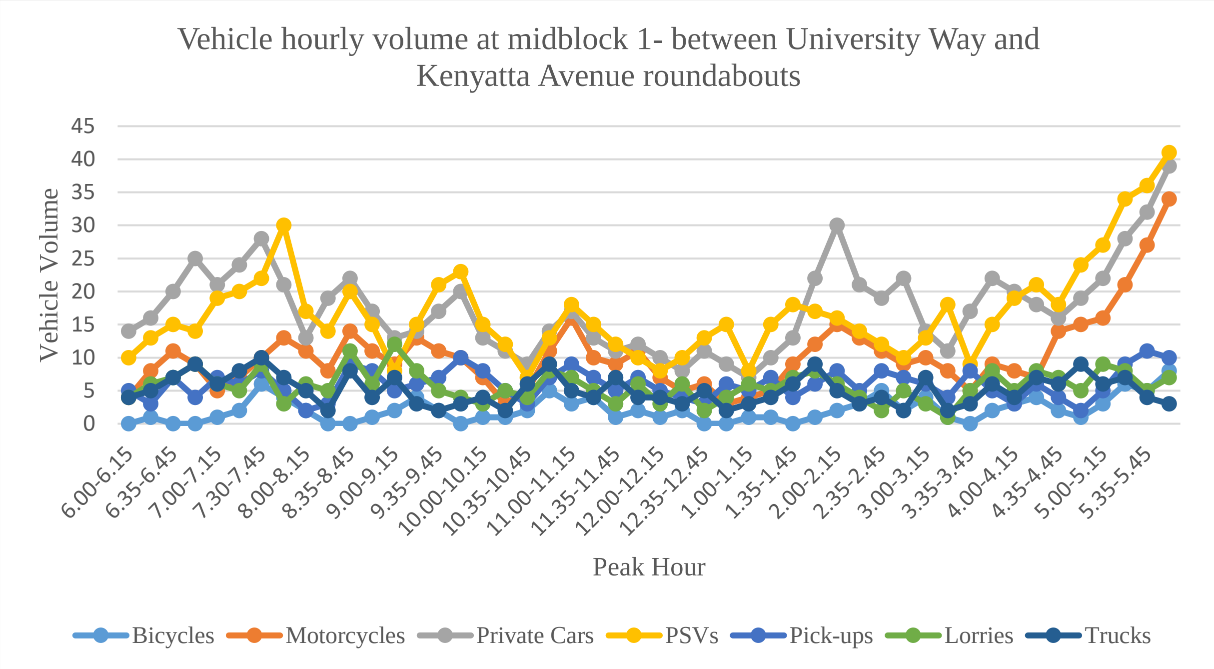

Figure 4-56: Vehicle hourly volume at midblock 1-between University Way and Kenyatta Avenue roundabouts

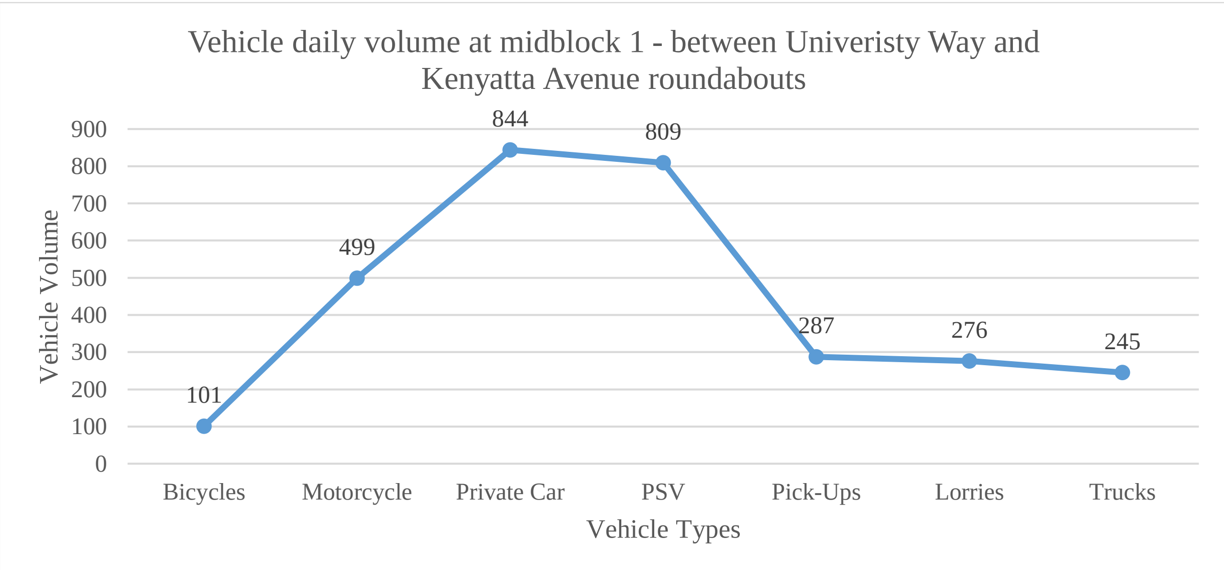

Figure 4-57: Vehicle daily volume at midblock 1

Roundabout 2 (Kenyatta Avenue Roundabout)-Leg 1

Vehicle volume analysis was conducted on Kenyatta Avenue roundabout-Leg 1 and the results shows that private cars and public service vehicles (PSV) are still dominant. On average, 853 private cars and 753 PSVs were counted along Uhuru Highway. Bicycles (211) and Lorries (281) represented the lowest composition of traffic volume as shown in Figure 4-58 and 4-59 below.

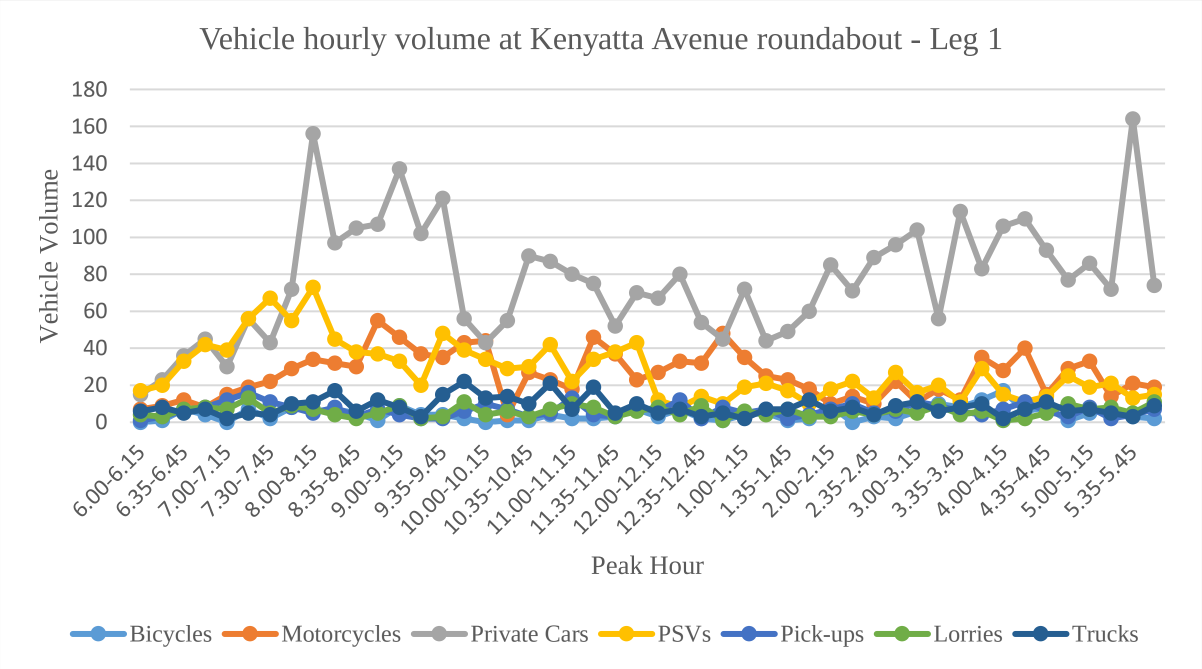

Figure 4-58: Vehicle daily volume at Kenyatta Avenue roundabout-Leg 1

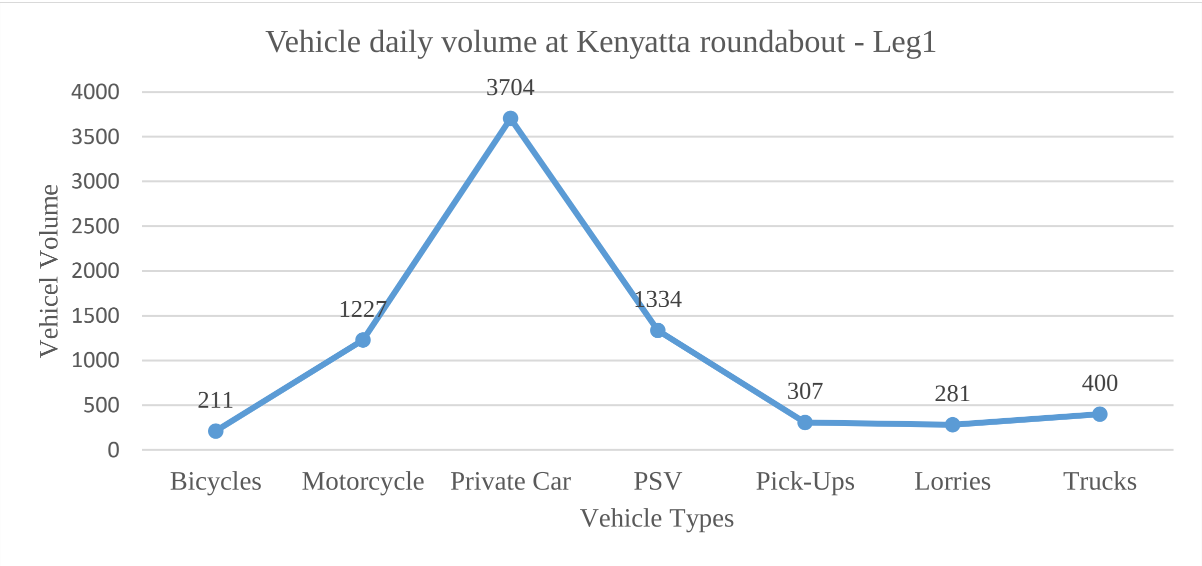

Figure 4-59: Vehicle daily volume at Kenyatta roundabout-Leg 1

Roundabout 2 (Kenyatta Avenue Roundabout) - Leg 2

Vehicle volume analysis was conducted on Kenyatta Avenue roundabout-Leg 2 and the results shows that private cars and public service vehicles (PSV) are still dominant. On average, 845 private cars, 716 PSVs and 673 motorcyclists were counted along Uhuru Highway. Bicycles (37) and trucks (293) represented the lowest composition of traffic volume as shown in Figures 4-60 and 4-61 below.

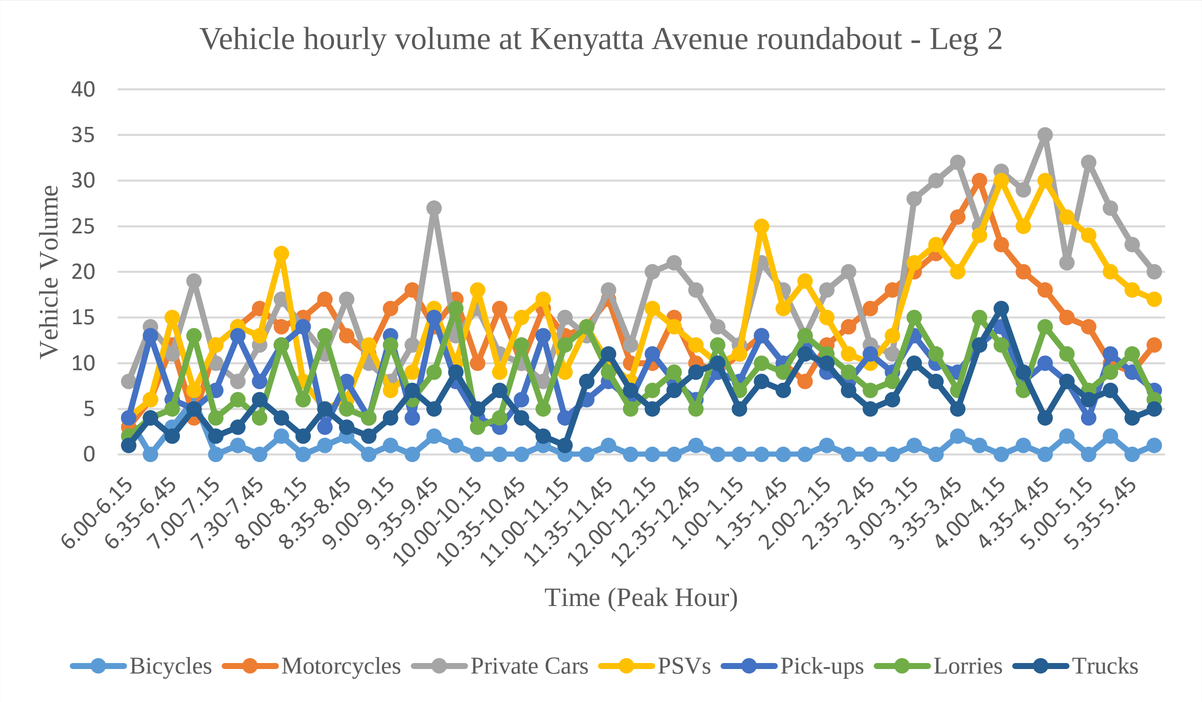

Figure 4-60: Vehicle daily volume at Kenyatta Avenue roundabout-Leg 2

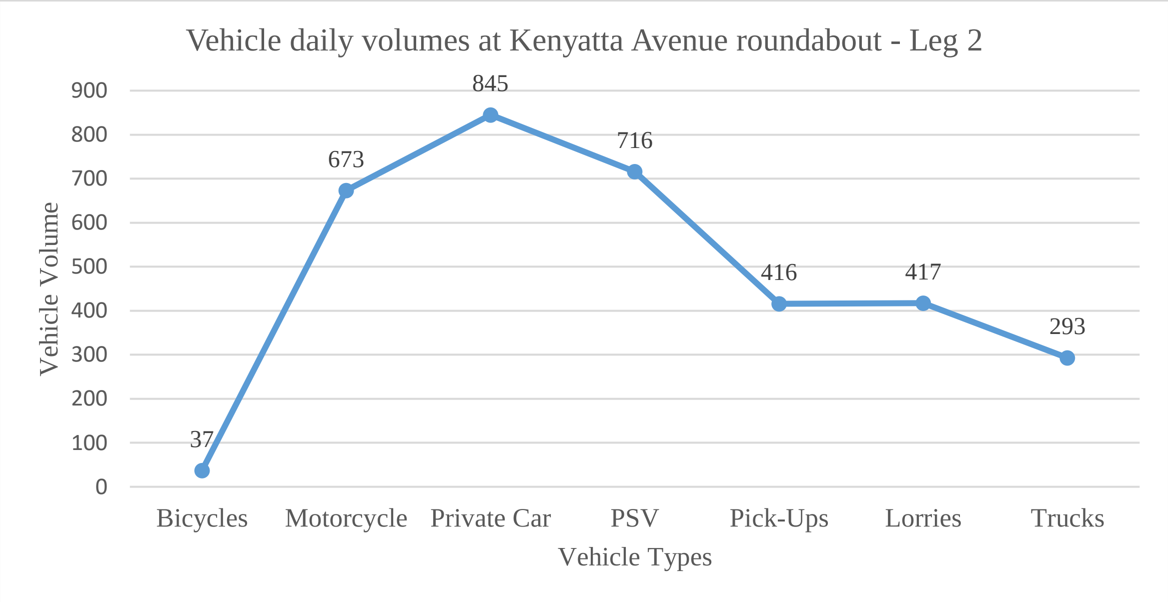

Figure 4-61: Vehicle daily volume at Kenyatta Avenue roundabout-Leg 2

Roundabout 3 (Haile Selassie Roundabout)-Leg 1

Vehicle volume analysis was conducted on Kenyatta Avenue roundabout-Leg 1 and the results shows that private cars and public service vehicles (PSV) are still dominant. On average, 2517 private cars, 696 PSVs and 622 motorcyclists were counted along Uhuru Highway. Bicycles (66) and trucks (95) represented the lowest composition of traffic volume as shown in Figure 4-62 and 4-63 below.

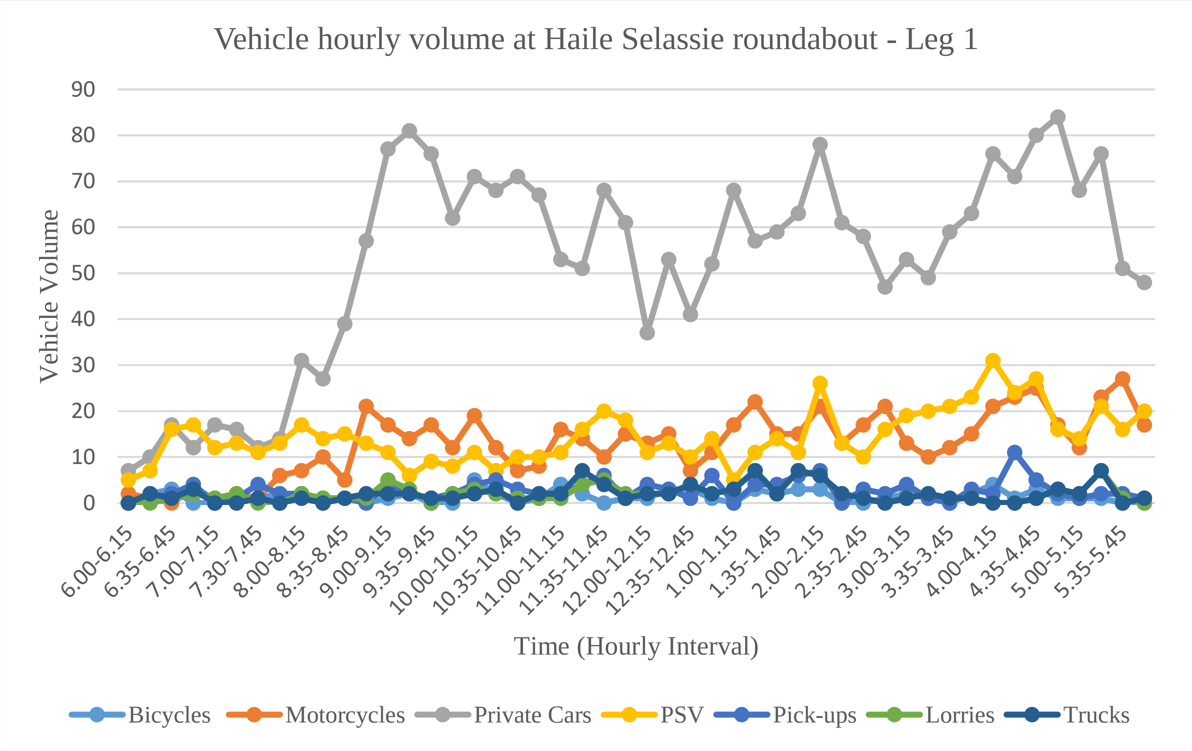

Figure 4-62: Vehicle daily volume at Haile Selassie roundabout-Leg 1

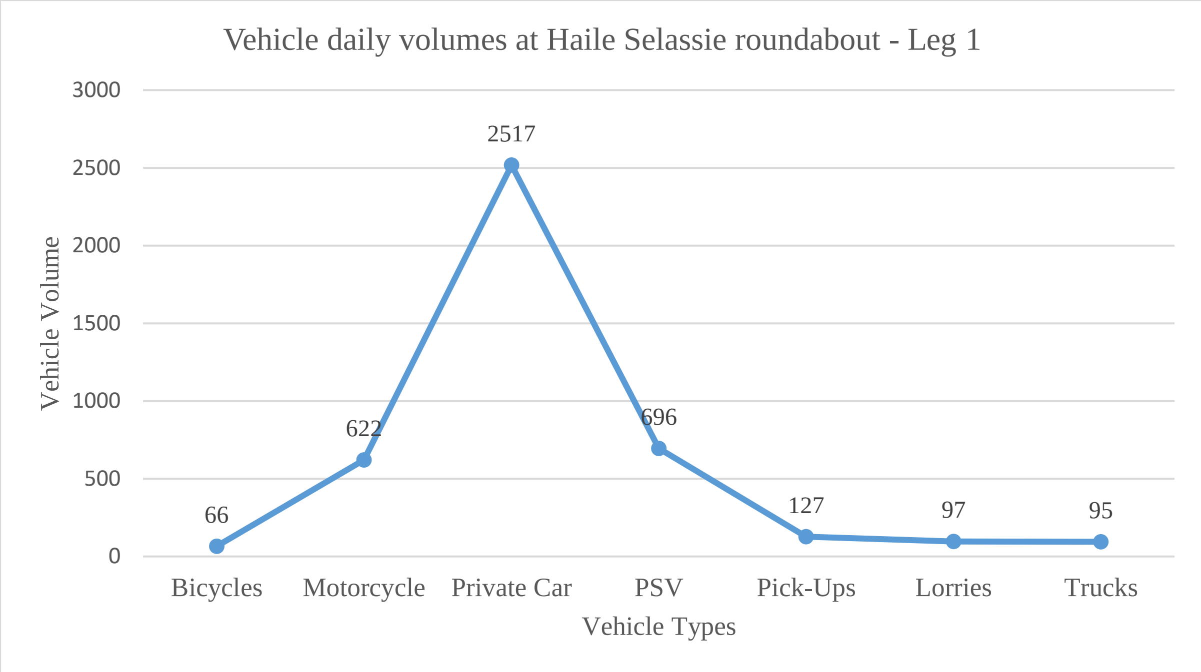

Figure 4-63: Vehicle daily volume at Haile Selassie roundabout-Leg 1

Roundabout 3 (Haile Selassie Roundabout)-Leg 2

Vehicle volume analysis was conducted on Kenyatta Avenue roundabout-Leg 2 and the results shows that private cars and public service vehicles (PSV) are still dominant. On average, 3082 private cars, 345 PSVs and 1179 motorcyclists were counted along Uhuru Highway. Bicycles (86) and trucks (179) represented the lowest composition of traffic volume as shown in Figure 4-64 and 4-65 below.

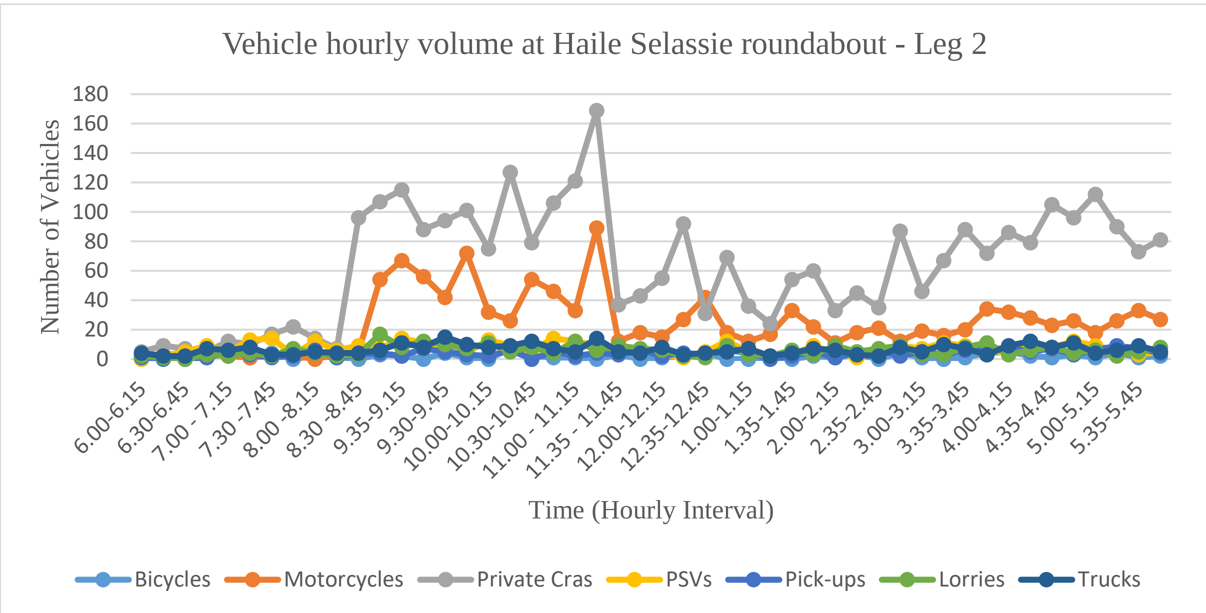

Figure 4-64: Vehicle hourly volume at Haile Selassie roundabout-Leg 2

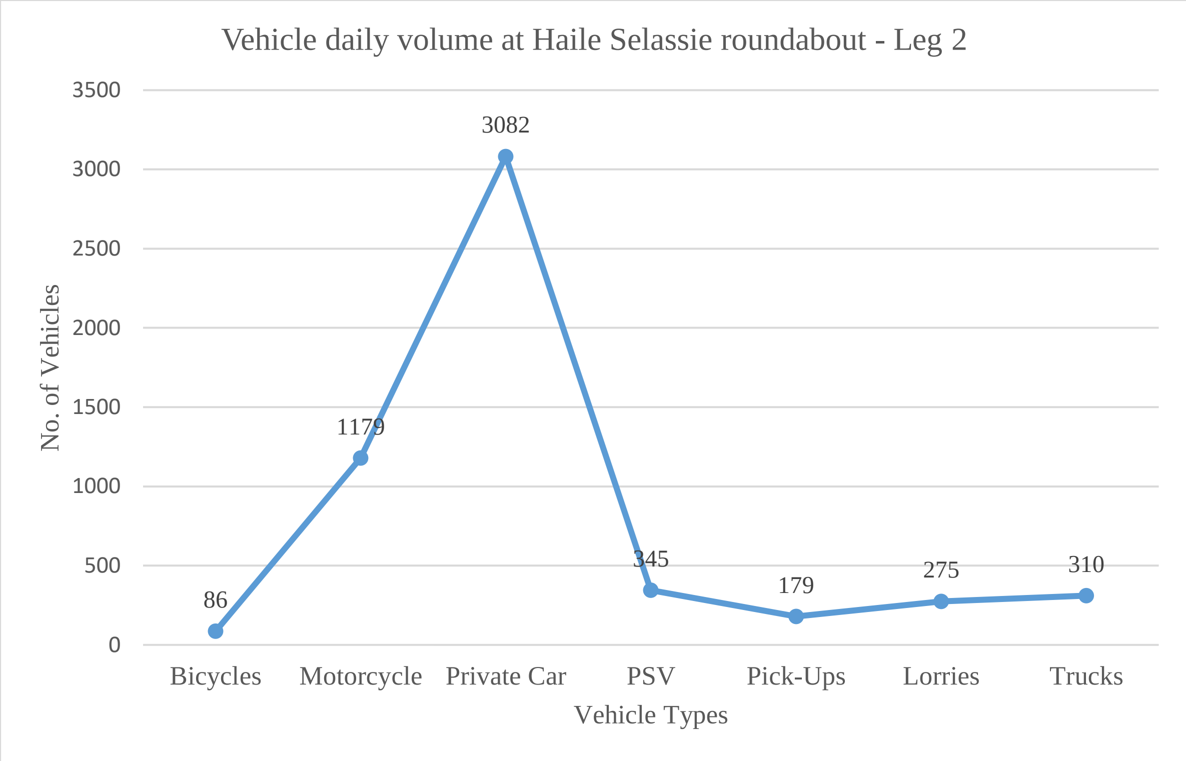

Figure 4-65: Vehicle daily volume at Haile Selassie roundabout-Leg 2

Midblock M2 (Between Kenyatta Avenue and Haile Selassie Roundabouts)

Vehicle volume analysis was conducted on vehicle volume counts at midblock between Kenyatta Avenue and Haile Selassie and the results shows that private cars and public service vehicles (PSV) are still dominant. On average, 2800 private cars, 1045 PSVs and 806 motorcyclists were counted along Uhuru Highway. Bicycles (68) and trucks (43) represented the lowest composition of traffic volume as shown in Figures 4-66 and 4-67 below.

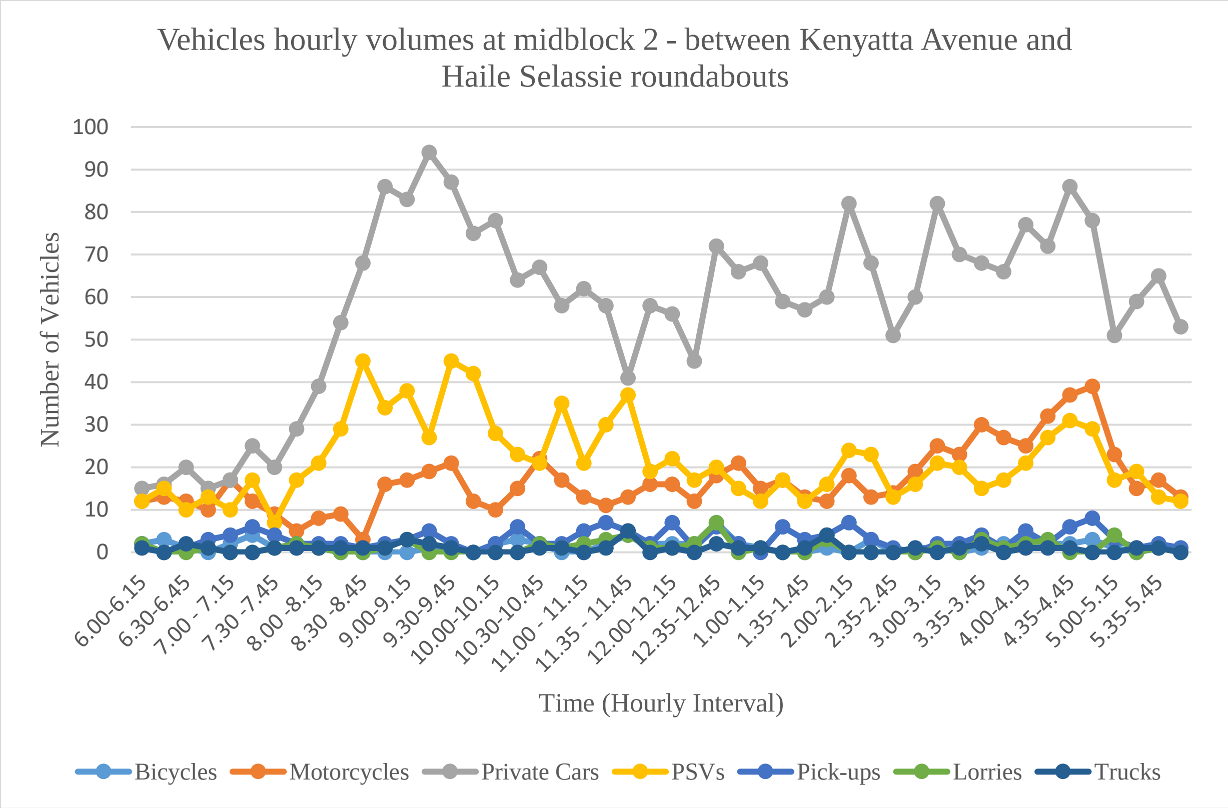

Figure 4-66: Vehicle hourly volume at midblock 2-between Kenyatta Avenue and Haile Selassie roundabouts

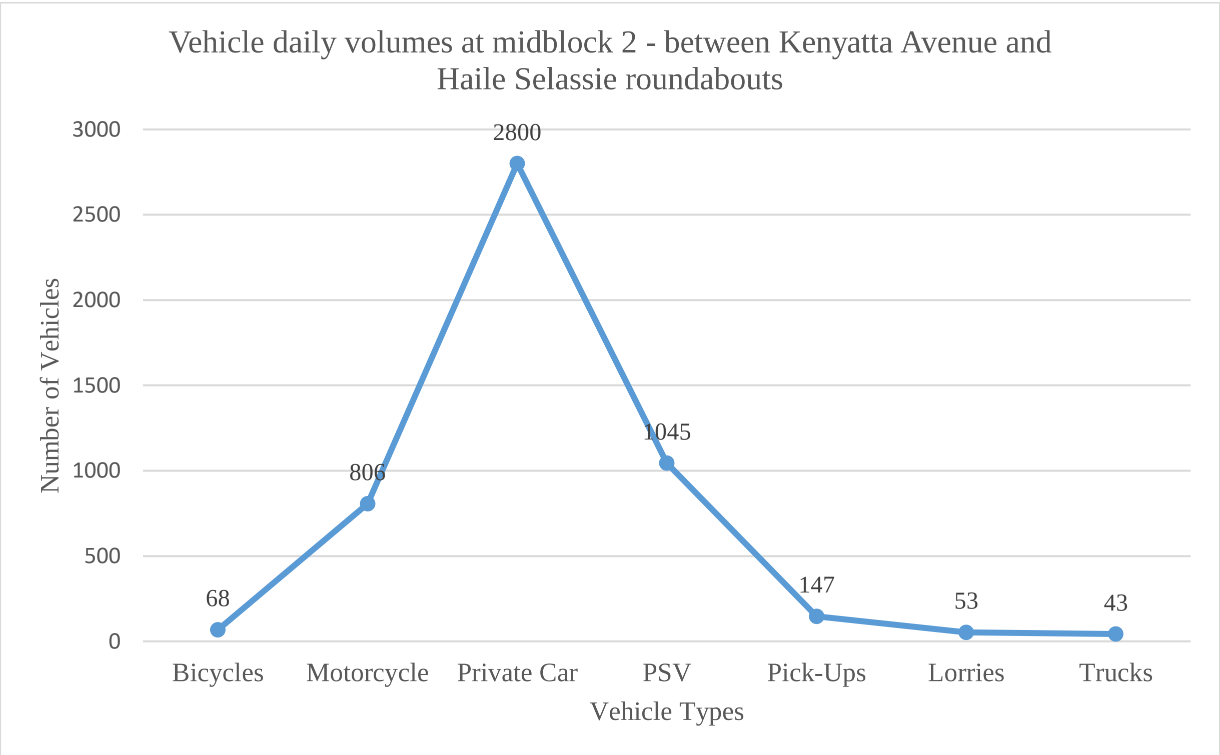

Figure 4-67: Vehicle daily volume at miblock 2-between Kenyatta Avenue and Haile Selassie roundabouts

4.5.6 Pedestrian Behaviour Analysis

Roundabout 1 (University Way Roundabout)-Leg 1

Analysis on pedestrian behaviour at crossings located near University Way roundabout shows that 1750 crossed as single individuals, 1263 crossed at right angles and 1099 crossed while observing oncoming traffic. Fewer pedestrians crossed while talking on phone (19) and holding hands (93) as shown in Fig 4-69 below.

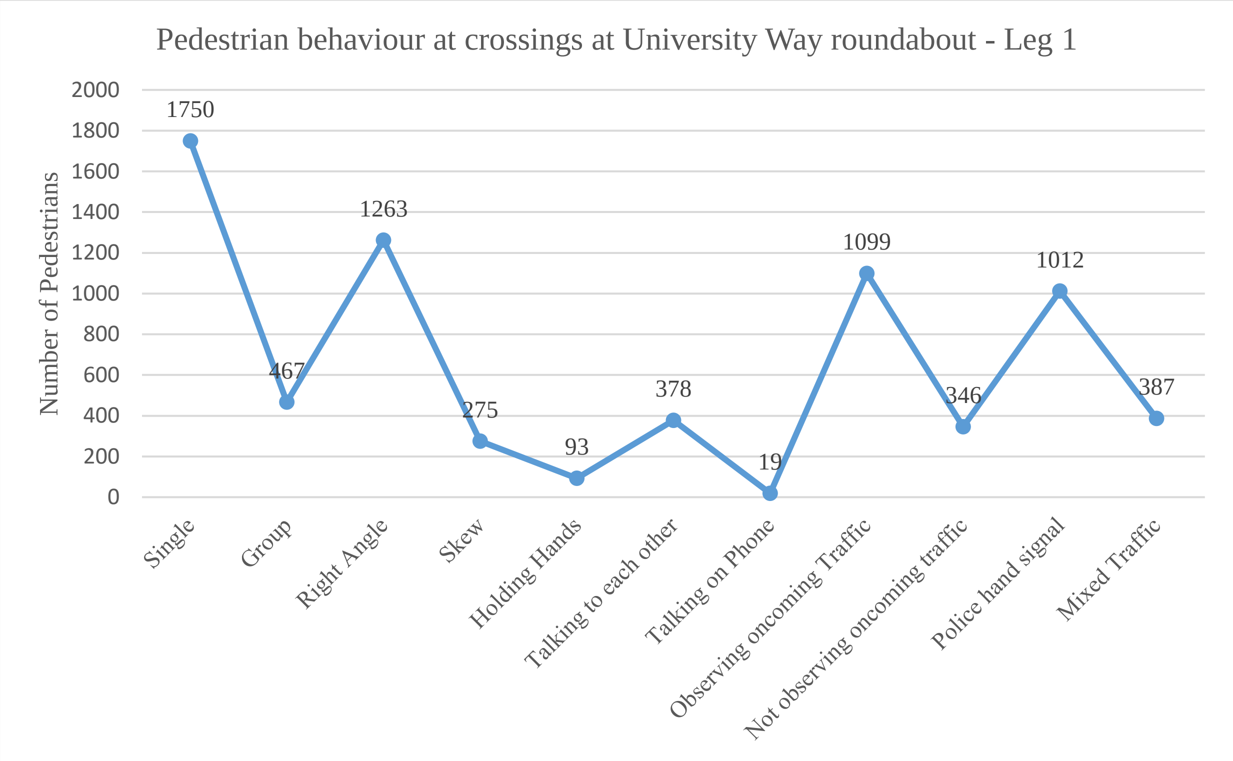

Figure 4-68: Pedestrian behaviour analysis at University Way roundabout-Leg 1

Roundabout 1 (University Way Roundabout)-Leg 2

Analysis on pedestrian behaviour at crossings located near University Way roundabout shows that 3,055 crossed while observing oncoming traffic, 2859 crossed at right angles and 1971 crossed as a group of individuals. Fewer pedestrians crossed while talking on phone (38) and holding hands (208) as shown in Fig 4-70 below.

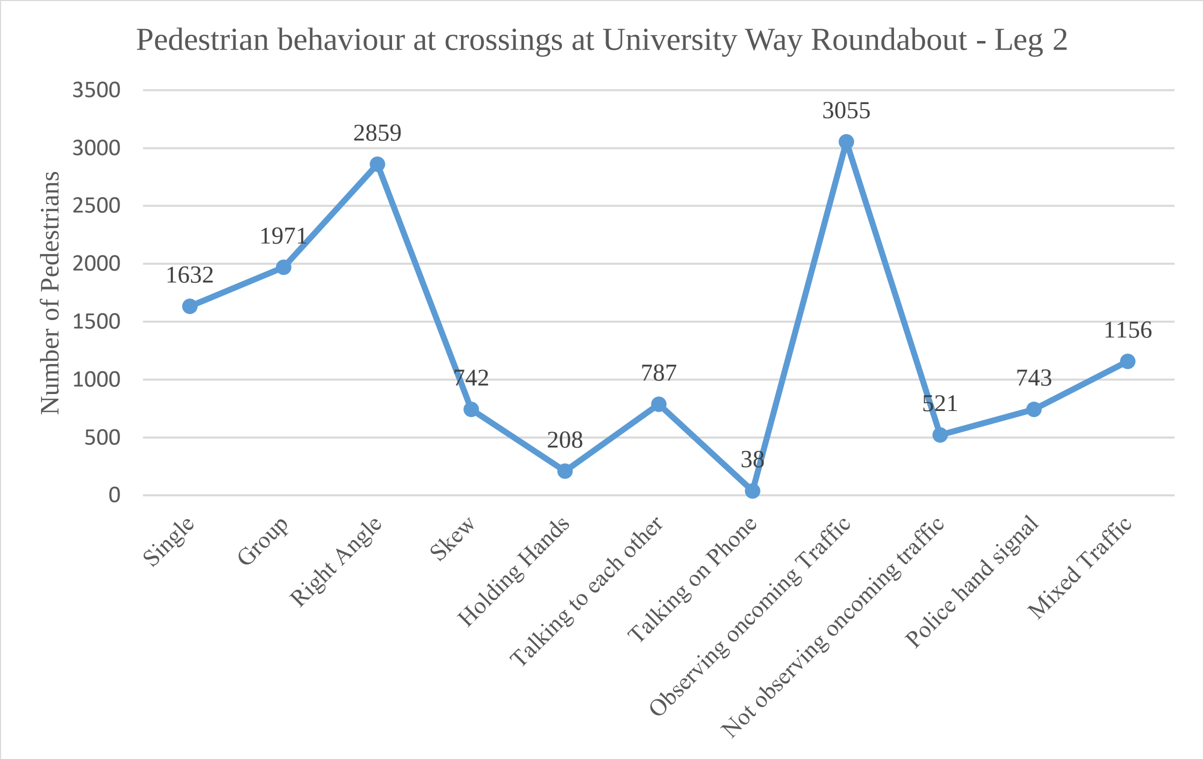

Figure 4-69: Pedestrian behaviour at crossing at University Way roundabout-Leg 2

Roundabout 2 (Kenyatta Avenue Roundabout)-Leg 1

Analysis on pedestrian behaviour at crossings located near Kenyatta Avenue roundabout shows that 9982 crossed while observing oncoming traffic, 9756 crossed at right angle and 8356 crossed as a group of individuals. Fewer pedestrians crossed while talking on phone (54) and holding hands (277) as shown in Figure 4-71 below.

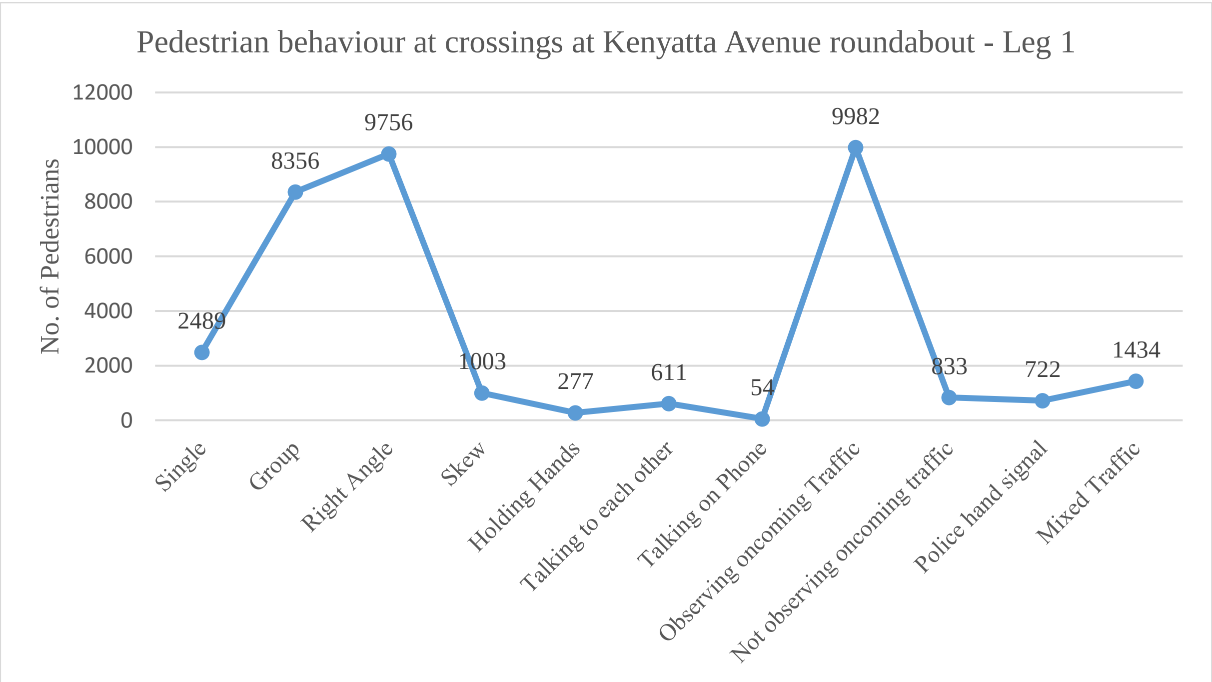

Figure 4-70: Pedestrian behaviour at crossing Kenyatta Avenue roundabout-Leg 1

Roundabout 2 (Kenyatta Avenue Roundabout)-Leg 2

Analysis on pedestrian behaviour at crossings located near Kenyatta Avenue roundabout shows that 2,521 crossed while observing oncoming traffic, 2251 crossed at right angle and 1575 crossed as a group of individuals. Fewer pedestrians crossed while talking on phone (43) and holding hands (114) as shown in Figure 4-72 below.

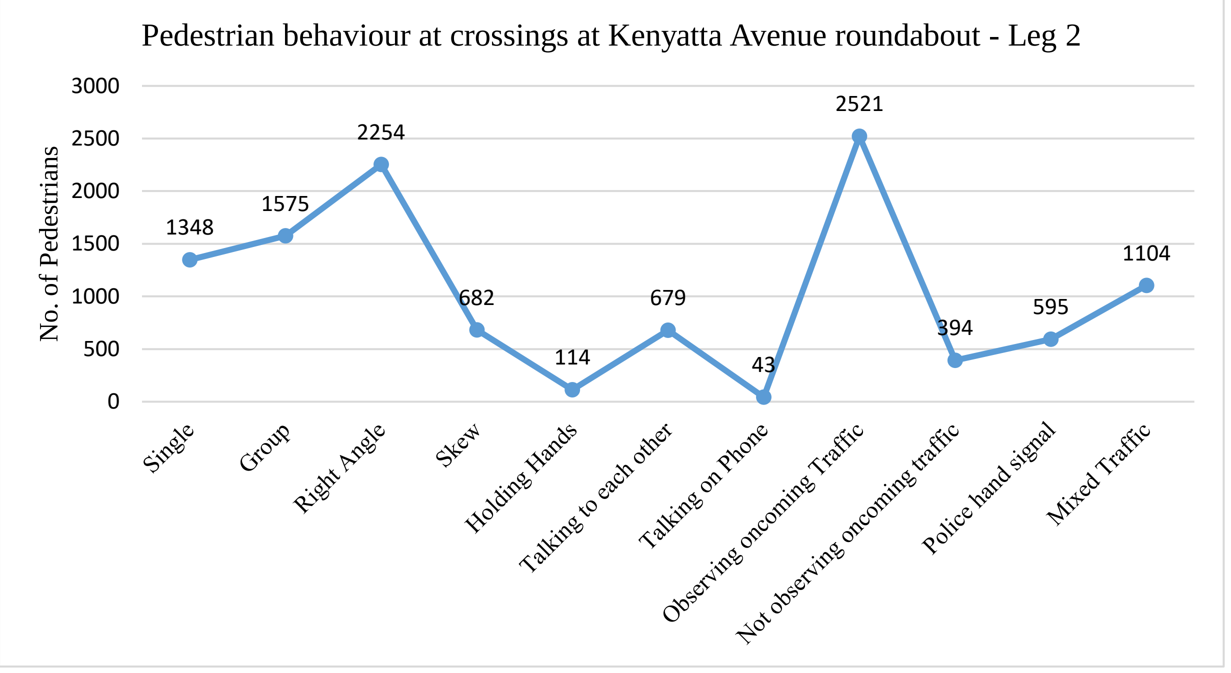

Figure 4-71: Pedestrian behaviour at crossing at Kenyatta Avenue roundabout-Leg 2

Roundabout 3 (Haile Selassie Roundabout)-Leg 1

Analysis on pedestrian behaviour at crossings located near Haile Selassie roundabout shows that 10310 while observing oncoming traffic, 10049 crossed at right angle and 8417 crossed as a group of individuals. Fewer pedestrians crossed while talking on phone (47) and holding hands (275) as shown in Figure 4-73 below.

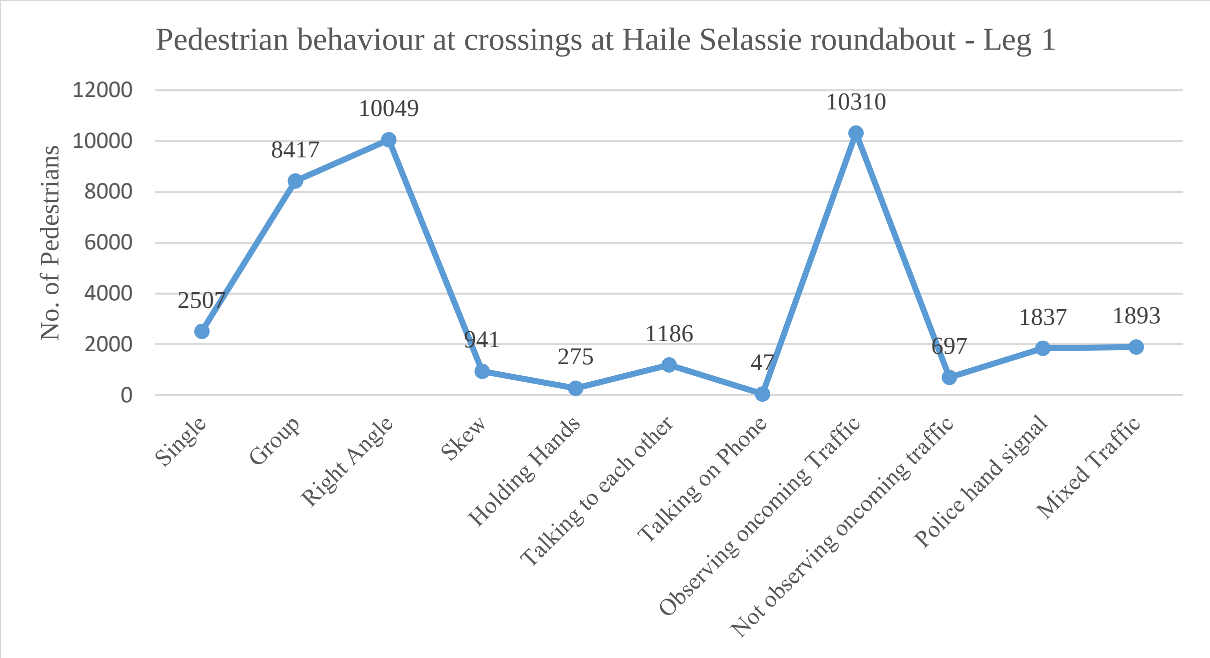

Figure 4-72: Pedestrian behaviour at crossing at Haile Selassie roundabout-Leg 1

Roundabout 3 (Haile Selassie Roundabout)-Leg 2

Analysis on pedestrian behaviour at crossings located near Haile Selassie roundabout shows that 8644 pedestrians crossed the road at right angle, 7682 crossed as a group of individuals and 7603 pedestrians crossed while observing oncoming traffic. Fewer pedestrians crossed the road while talking on phone (65) and holding hands (128) as shown in Figure 4-74 below.

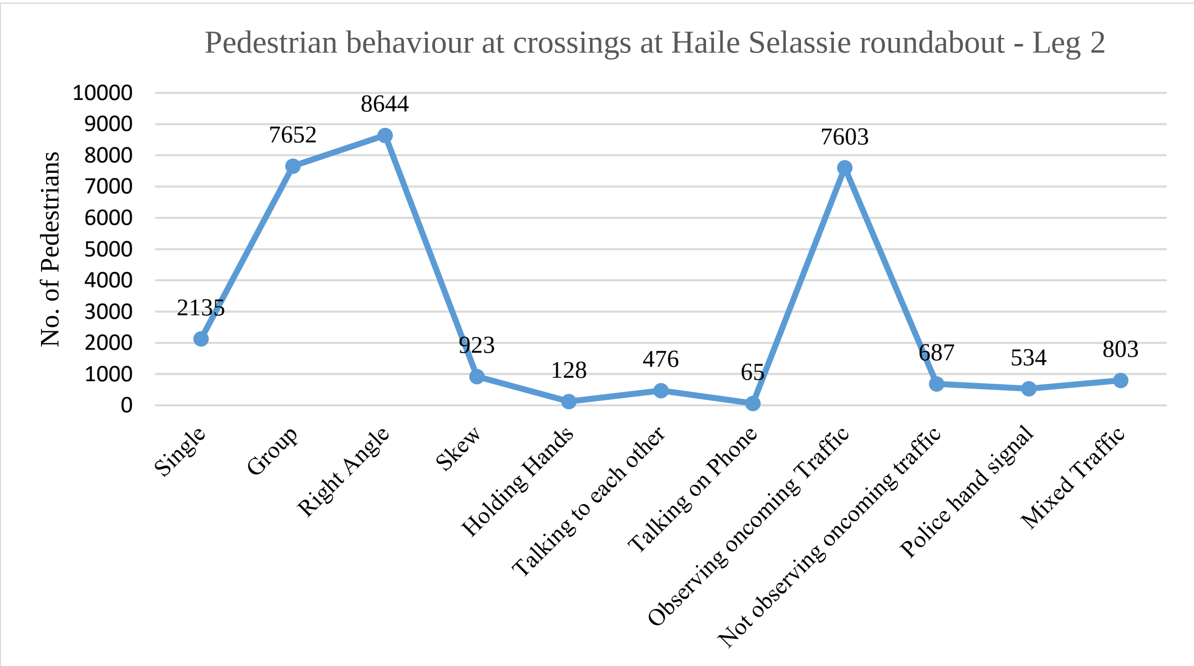

Figure 4-73: Pedestrian behaviour at crossing near Haile Selassie roundabout-Leg 2

Midblock M1 (Between University Way and Kenyatta Avenue Roundabouts)

Analysis on pedestrian behaviour at crossings located between University Way and Kenyatta Avenue shows that 409 pedestrians crossed as single individuals, 260 crossed with police hand signal, 254 crossed at right angle and 250 crossed while observing oncoming traffic. Fewer pedestrians crossed while talking on phone (9) and holding hands (36) as shown in Figure 4-75 below.

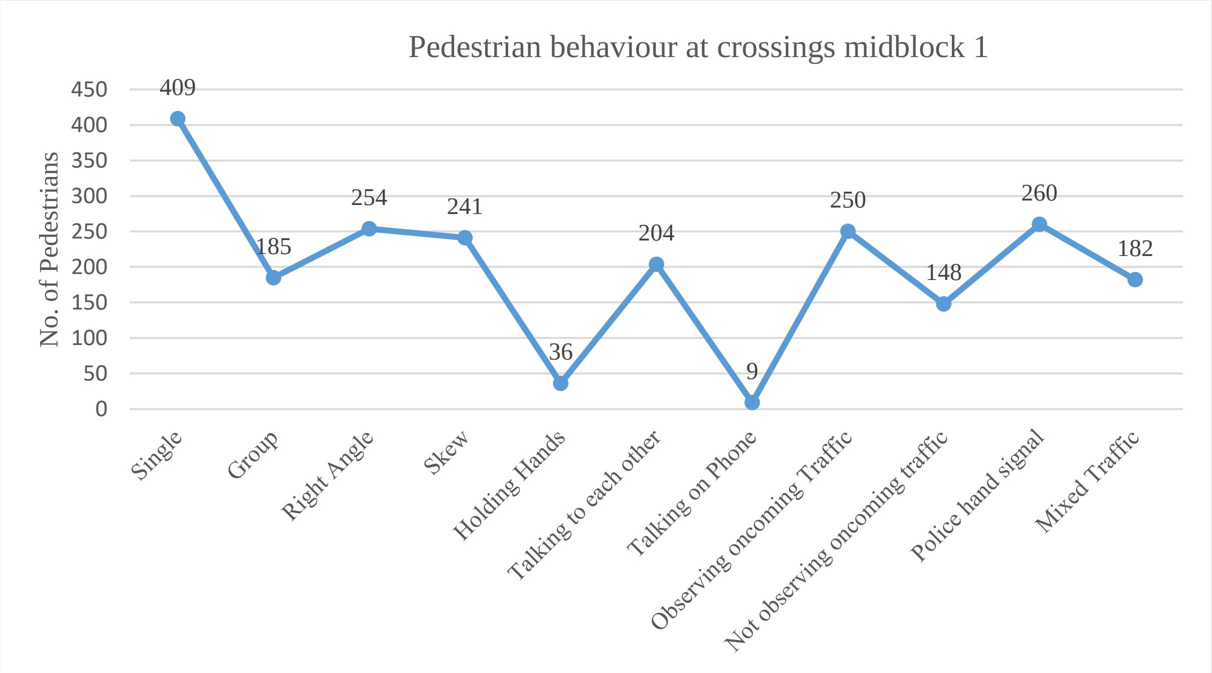

Figure 4-74: Pedestrian behaviour at crossing at midblock M1

Midblock M2 (Between Kenyatta Avenue and Haile Selassie Roundabouts)

Analysis on pedestrian behaviour at crossings located between Kenyatta Avenue and Haile Selassie roundabouts showed that 1,007 pedestrians crossed as a group of individuals, 531 crossed at right angle and 690 crossed while observing oncoming traffic. Fewer pedestrians crossed while observing police signal (9) and holding hands (39) as shown in Figure 4-76 below.

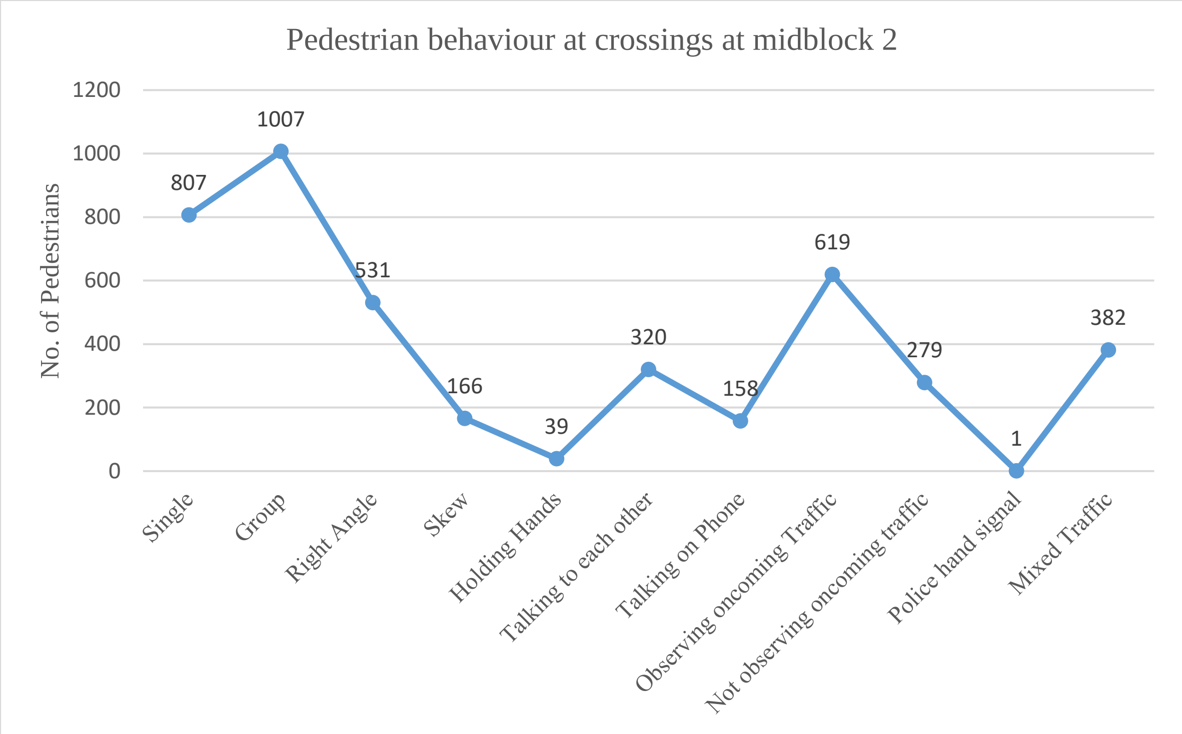

Figure 4-75: Pedestrian behaviour at crossing at midblock M2

4.6 Risk Factor Calculation

4.6.1 Pedestrian Crash Risk Factor Calculations

The probability of being killed in a road traffic accident depends on the conditions/properties of the trip such as safety indicators, road safety measures and traffic law enforcement. In Kenya, collisions can be described as fatal (F), serious injuries (SI), slight injuries (I) or property damage only (PDO) collisions. The number of people killed (N) is calculated as a product of risk of travel (r) and mobility (M). Risk of travel is dependent on factors or characteristics of the trip which is different and unique to each trip while mobility is measured as the total distance travelled often defined as exposure (E).

Number of People Killed (N) = Risk (r)*Mobility (M) ……………… Equation 3

There are different categories of risk factors in road crashes such as factors influencing exposure to risk, factors influencing crash involvement, factors influencing crash severity and factors influencing post-crash outcome. This study explored risk factors in the three categories except factors influencing post-crash outcome due to lack of hospital data. A calculation based on several factors has been worked out whereby Risk (W) has been calculated as a product of a number of factors identified as key determinants of pedestrian safety at crossings near roundabouts along Uhuru Highway.

These factors have been described and different weighting factors applied to each of them for the purposes of calculating the overall risk factor. The value of risk has been calculated for each level crossing located near three roundabouts along Uhuru Highway. Risk level for each pedestrian crossing has been described on a scale of 1-4 as follows; Very High/Dangerous (Level 1), High Risk Crossing (Level 2), Average/Moderate Risk Crossing (Level 3) and Low Risk or Safe Crossing (Level 4) as shown in Table 4-2 below.

Table 4-2: Risk factors description

Risk Score, W	**W > or = 15**	**10 < W < or = 15**	**5 < W < or = 10**	**W < or = 5**
Risk Level	1	2	3	4
Risk Description	Dangerous Crossing	High Risk Crossing	Moderate Risk Crossing	Safe Crossing

Risk factors in pedestrian safety at roundabouts can further be described in the following categories;

i. Geometrics of pedestrian crossings:-width, lanes, separating strip/median, length of crossing, number of traffic lanes, presence of central island, length of crossing, presence of dividing strip or median,

ii. Traffic Control:-signal, marshal, signs and markings

iii. Road Environment:-traffic system, visibility of road users, visibility of road signs and traffic lights (vehicles and pedestrian),

iv. Existing safety measures:-traffic engineering measures, traffic law enforcement measures, road infrastructure improvements

v. Road crash data:-previous accidents analysed to estimate accident rates

4.6.2 Determinants of pedestrian safety/risk factors at level crossings near roundabouts

1. Road width (b), ***m1***
2. Number of traffic lanes-use by vehicle traffic (m2=p/8+0.7), ***m2***
3. Presence of kerbs, ***m3***
4. Bicycle paths, ***m4***
5. Street lighting, ***m5***
6. Angle crossing, ***m6***
7. Bus stop, ***m7***
8. Neighbouring crossings, ***m8***
9. Horizontal road markings, ***m9***
10. Pedestrian visibility due to vertical marking, ***m10***
11. Pedestrian visibility due to parked vehicles, ***m11***
12. Road sign visibility, ***m12***
13. Speed limit, ***m13***
14. Pedestrian targets, ***m14***
15. Raised crossing, ***m15***
16. Road types, ***m16***
17. Coloured horizontal markings, ***m17***
18. Safety island/median, ***m18***
19. Narrowing of the road, ***m19***
20. Additional road signs, ***m20***
21. Additional lighting, ***m21***
22. Barriers, ***m22***
23. Other factors, ***m23***
24. Behavioural factors decreasing safety: - unsafe behaviour, ***m24***
25. Actual speeds of vehicles, ***m25***
26. Previous Accidents (x), ***m26***

The value of risk factor calculation (**W**) involves obtaining a product of all the above factors as observed in each crossing point as described Table 4-3 shown below. As described above, Roundabout 1 (University Way roundabout), Roundabout 2 (Kenyatta Avenue roundabout), Roundabout 3 (Haile Selassie Avenue roundabout), midblock M1 (between university way and Kenyatta Avenue roundabouts) and midblock M2 (between Kenyatta Avenue and Haile

Selassie roundabouts). The risk factor elements were identified previous by Basile et al., (2017).

Table 4-3: Risk factor calculation per crossing

S/No.	**Roundabout**	**Pedestrian Crossing**
1.	Roundabout R1 (University Way)	Crossing on First Leg (R11)
2.		Crossing on Second Leg (R12)
3.		Crossing on Third Leg (R13)
4.		Crossing on Fourth Leg (R14)
5.	Roundabout R2 (Kenyatta Avenue)	Crossing on First Leg (R21)
6.		Crossing on Second Leg (R22)
7.		Crossing on Third Leg (R23)
8.		Crossing on Fourth Leg (R24)
9.	Roundabout R3 (Haile Selassie Avenue)	Crossing on First Leg (R31)
10.		Crossing on Second Leg (R32)
11.		Crossing on Third Leg (R33)
12.		Crossing on Fourth Leg (R34)
13.	Midblock M1; (Between University Way and Kenyatta Avenue roundabouts)	Crossing on midblock 1 (*M1*)
14.	Midblock M2; (Between Kenyatta Avenue and Haile Selassie roundabouts)	Crossing on midblock 2 (M2)

The results obtained indicate that pedestrian crossings located at midblock sections are the most dangerous considering all factors determining pedestrian safety at crossing located along Uhuru Highway whereby Risk (W) has been calculated as 43.2 as shown in Figure 4-77 below. All pedestrians' crossings located along Uhuru Highway can be classified as dangerous or highest risk since all risk factor calculate yields values of W above 15. Pedestrian crossing located on second leg of University Way roundabout is considered safer than all other crossings located along Uhuru Highway since lowest Risk has been calculated for this crossing as W = 19.3.

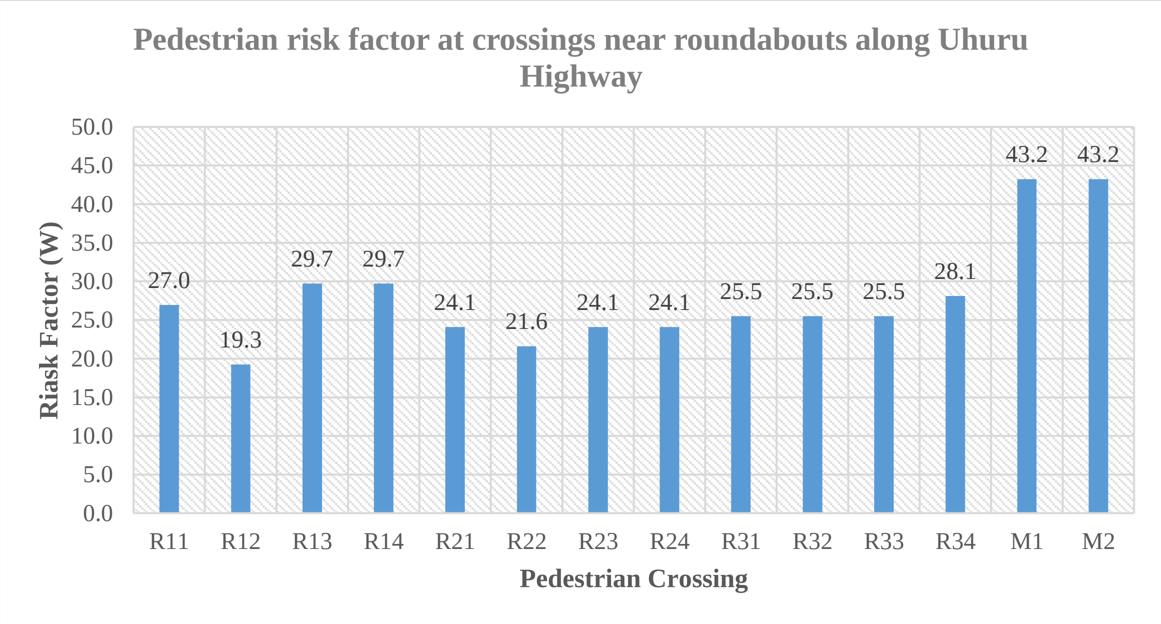

Figure 4-76: Pedestrian risk factor at crossings near roundabouts

4.6.3 Summary of results from secondary data analysis

Road crash data was obtained from the National Police Service (Nairobi Central Division) and records from NTSA included collisions recorded for the period 2016 to 2021. Data analysis focussed on risk factors in pedestrian safety at roundabouts along Uhuru Highway. Table 4-4 below shows the number of pedestrians involved in different types of collisions whereby more pedestrians were involved in serious injuries collisions compared to other types of collisions such as fatal and slight injuries collision hence suggesting a higher risk compared to other types of collisions.

Table 4-4: Pedestrian fatalities and injuries statistics

Gender	Fatal	Serious Injuries	Slight Injuries	Total
Male	74	302	45	421
Female	12	156	24	192
Total	86	458	69	613

In Table 4-5 below, a comparative analysis on pedestrian safety and risk of fatalities in road traffic collisions were classified by gender and accident location along Uhuru Highway. The results show that most accidents occur at midblock/sections compared to roundabouts/ junctions. Male pedestrians are at a higher risk of being involved in fatal collisions compared to female pedestrians along the study area.

Table 4-5: Summary statistics on pedestrian crashes by road section type

Gender	Roundabouts	Mid-block/Section	Total
Male	11	14	25
Female	2	9	11
Total	13	23	36

Comparing risk amongst other road users, pedestrians are still at highest risk of involvement in road traffic collisions across Kenya as shown in Table 4-6 below. The statistics indicate a steady rise in the number of pedestrians killed in road accidents from 2016 to August 202 according to data obtained from NTSA. The highest proportion of pedestrians killed in road traffic during this period occurred in 2019.

Table 4-6: Road traffic fatalities in Kenya

Year	2016	2017	2018	2019	2020	2021	Aug. 2022
Pedestrians	1,097	1,060	1,205	1,390	1,383	1,557	1,154
Drivers	350	314	306	345	347	446	293
Passengers	729	773	746	704	580	767	567
Pillion Passengers	217	219	247	348	439	451	285
Bicyclists	71	57	63	74	90	87	43
Motorcyclists	501	496	591	725	1,136	1,271	868
Total	**2,965**	**2,919**	**3,158**	**3,586**	**3,975**	**4,579**	**3,210**
% Fatalities (Pedestrians)	**37.0%**	**36.3%**	**38.2%**	**38.8%**	**34.8%**	**34.0%**	**36.0%**

Source: NTSA (2021)

Figure 4-78 and 4-79 below shows trends in fatalities in road traffic collisions in Kenya which suggests that most fatalities amongst all road users occurred between 2019 and 2021 despite low motorized traffic volumes during the Covid-19 pandemic. During this period of low traffic volumes within urban and rural areas resulting from lock downs and travel restrictions, the few motorists in Nairobi operated at better service level conditions hence necessitating higher operational speeds within the road transport system. Speed is directly proportional to crash severity hence at higher operational speeds there is a higher likelihood of fatal and serious injuries collisions compared to slight injuries collisions.

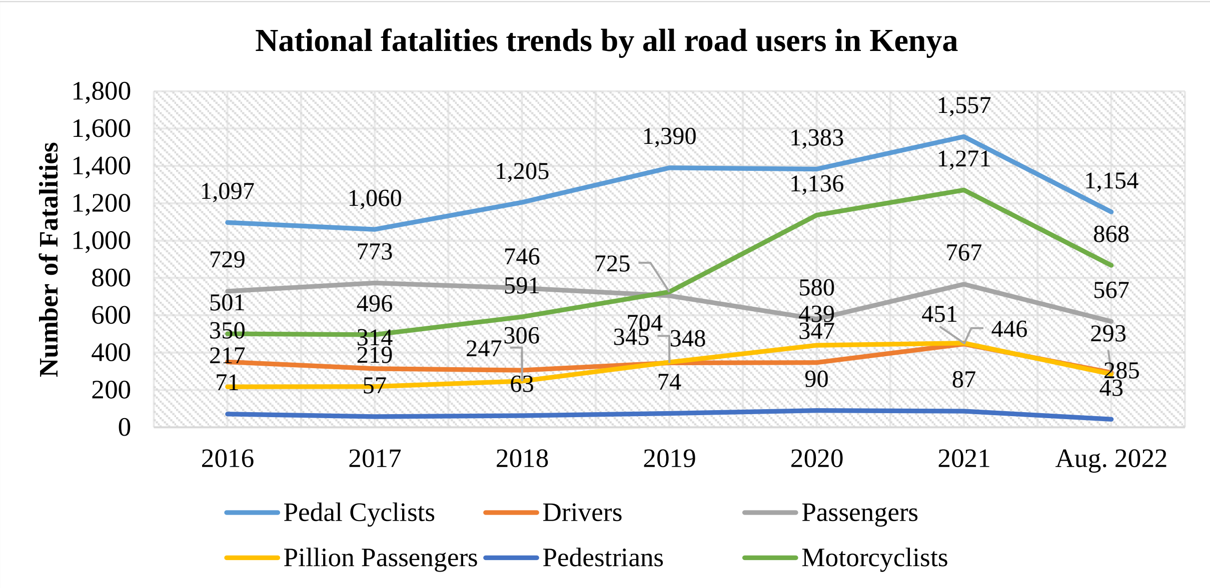

Figure 4-77: Road traffic fatalities trends in Kenya, NTSA (2021)

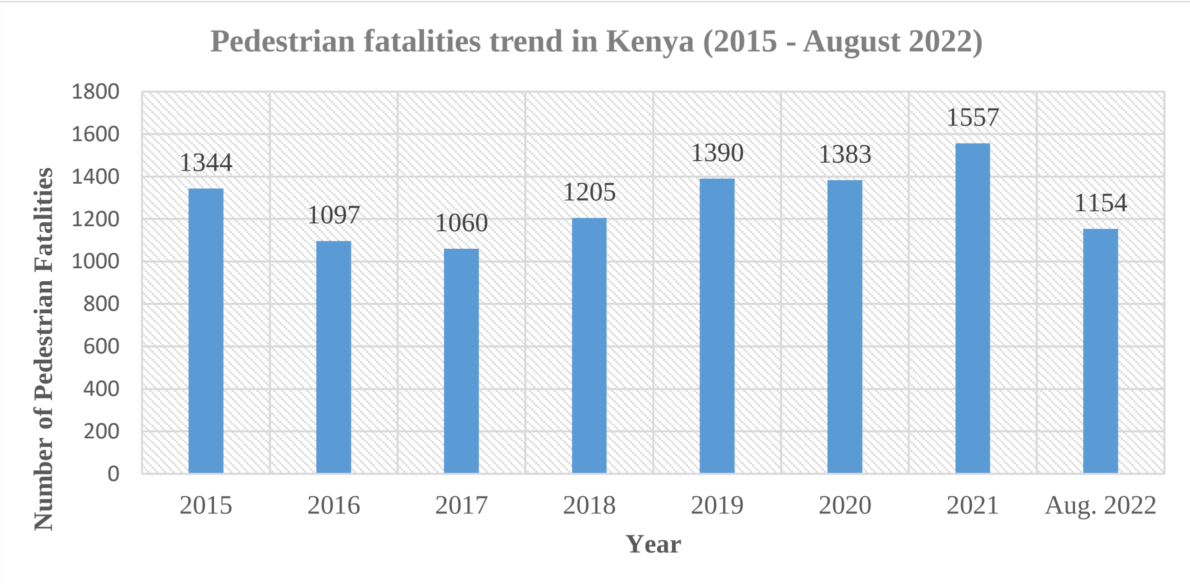

Figure 4-78: Pedestrian fatalities trends in Kenya, NTSA (2021)

4.6.4 Summary of pedestrian fatalities and injury statistics along Uhuru Highway

In total, 613 pedestrians were involved in different types of collisions along Uhuru Highway according to analysis conducted on road crash data obtained from the national police service between 2016 and 2021. The results obtained indicated the following statistics; 74 males and 12 female pedestrians were killed in road traffic collisions, 302 male and 156 female pedestrians were involved in serious injuries collisions and 45 male and 24 female pedestrians were involved in slight injuries collisions along Uhuru highway as shown in Figure 4-80. In conclusion, pedestrians are at highest risk of being involved in serious injuries collisions compared to other types of collisions.

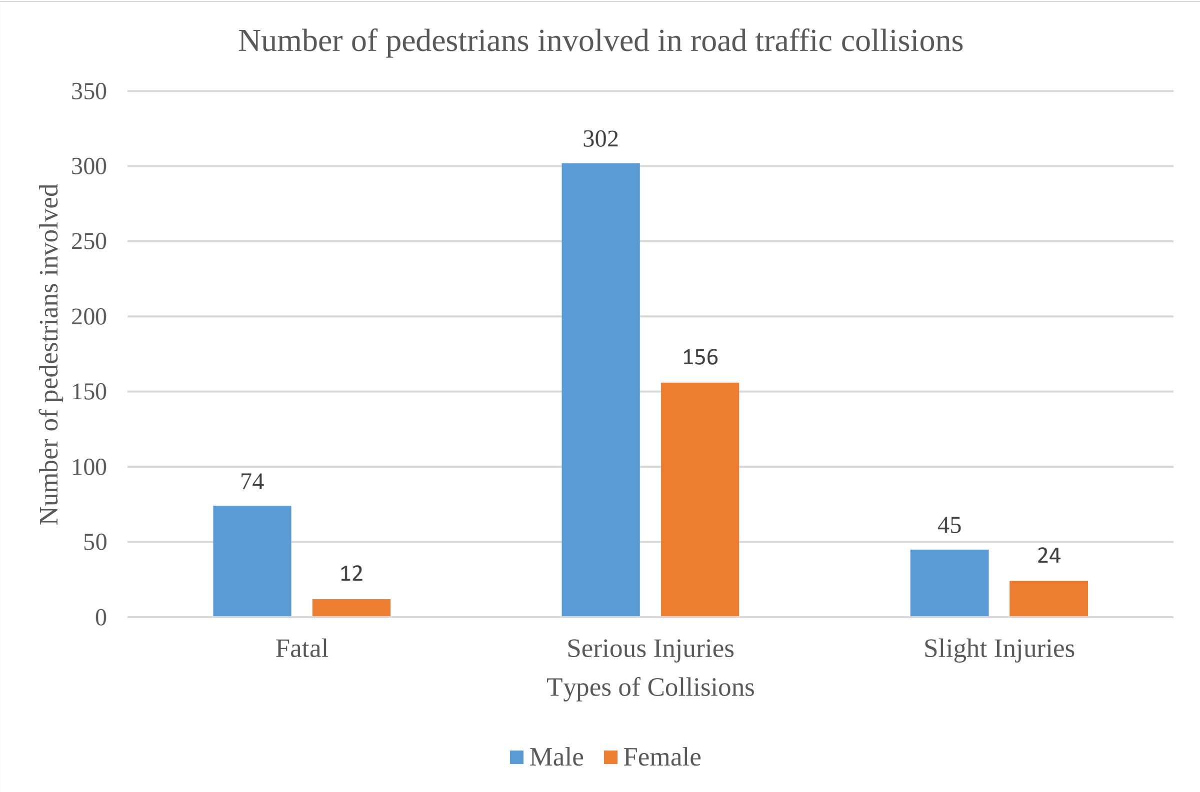

Figure 4-79: Number of pedestrians involved in road traffic collisions

4.6.5 Road safety interventions along Uhuru Highway

Currently there a number of road safety interventions in place which could improve the quality of service and safety of pedestrians crossing Uhuru Highway near roundabouts or at mid-block sections. These interventions are likely to increase visibility of pedestrians, improve driver yielding behaviour, improved traffic law enforcement and management, separate pedestrians from motorized traffic as shown in the following Plates 4-4 and Plate 4-5 and Plate 4-6 below. To improve road environment for pedestrians around Green Park Terminal, Nairobi City County government has banned the dropping passengers especially those moving between residential estates to the city centre. However, to reduce passenger activities within the terminal the government has pledged to change the use of the terminal to long distance passenger vehicles only. This has significantly increased pedestrian volume and waiting time at crossings near Haile Selassie Avenue Roundabout. Traffic bollards are now installed around Haile Selassie Avenue roundabout to prevent pedestrian-vehicle crashes due to the surging number of people crossing at this location or passengers alighting at Green Park terminal and crossing into the city centre and vice versa as shown in Plate 4-4 below.

Plate 4-4: Crash barriers installed at midblock crossing. Source: Author, 2023

Plate 4-5: Improved pedestrian walkway along Uhuru Highway. Source: Author, 2023

Plate 4-6: Pavement markings installed at crossings near roundabouts. Source: Author, 2023

4.6.6 Causes of road traffic accidents in Kenya

In Kenya, majority of road traffic accidents is still unknown and therefore still recorded as 'hit and run' in the national road crash database as shown in Figure 4-79 below. Since most crashes involving pedestrians are 'hit and run', these statistics suggest that the most proactive approach to mitigate fatalities and injuries amongst pedestrians perhaps is to establish the true cause of these crashes before designing and implementing road safety interventions. This can be achieved especially along Uhuru highway by use of crash detection technologies such as CCTV Cameras to capture images and record video evidence along the study area.

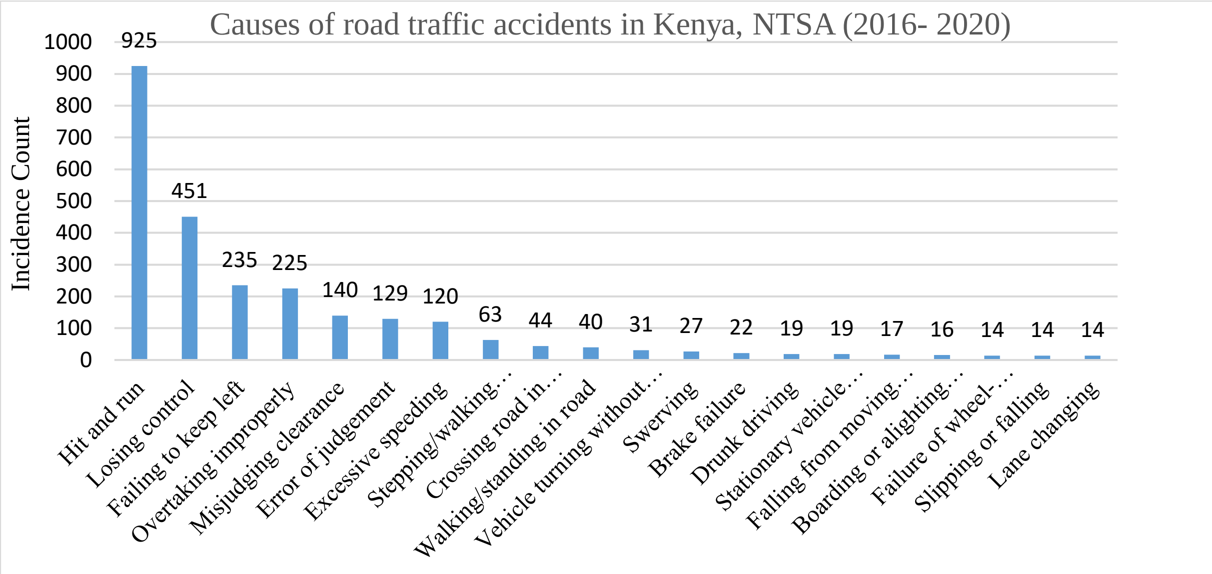

Figure 4-80: Causes of road traffic accidents in Kenya, NTSA (2021)

4.6.7 Traffic volume along Uhuru Highway

Since most crashes occurring near roundabouts involved more cars than other vehicle types along Uhuru Highway, pedestrians are at highest risk of fatalities and injuries when involved in collision with cars compared to other vehicles. Analysis on traffic volume indicated that cars are the dominant vehicle type with an ADT of 16037 vehicles per day as shown in Figure 4-80. In calculating exposure to traffic this result, shows that pedestrians are more exposed to cars than those other vehicles along Uhuru Highway. The outcome of this study also suggests that a proactive traffic law enforcement should therefore focus on key risk factors such as behaviour of car drivers along Uhuru highway both day and night. According to Tulu S., (2015), pedestrian exposure to traffic accidents can measured through a number of methods such as; product of pedestrian volume and vehicle volume or square root of the product of vehicle volume and pedestrian volume, average distance travelled and exposure based on time.

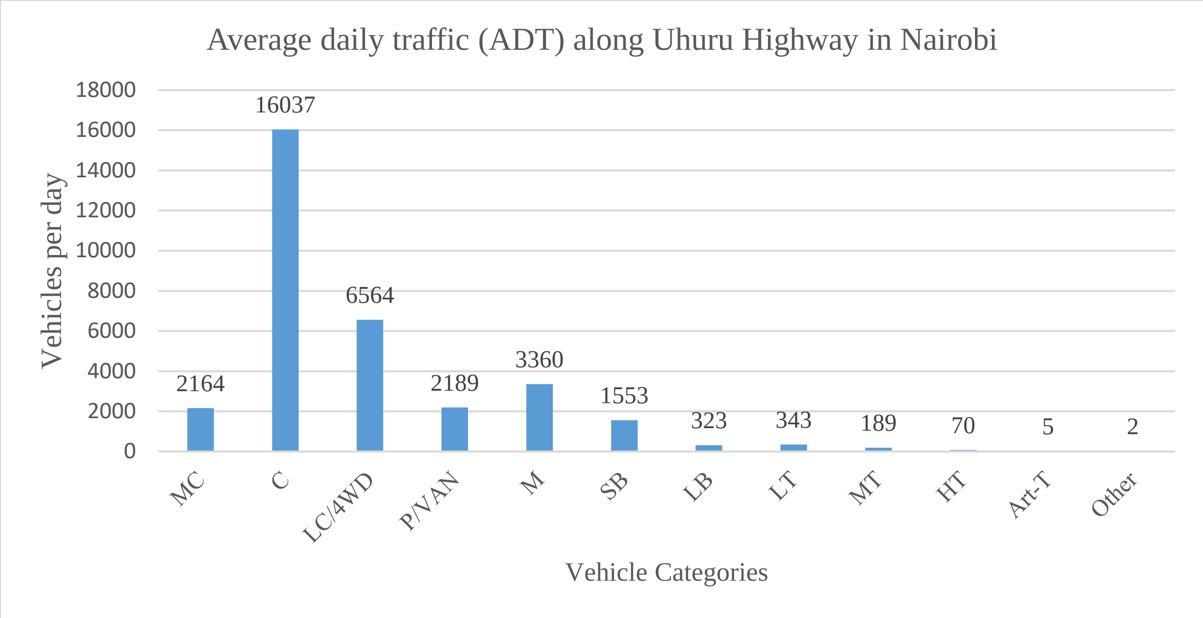

Figure 4-81: Average daily traffic (ADT) along Uhuru Highway in Nairobi, Kenya Urban Roads Authority (2021)

4.7 Discussion Summary

In summary, road traffic fatalities and injuries amongst pedestrians near roundabouts along Uhuru Highway is dependent on key safety risk factors such as pedestrian demographics (age and gender), road user behaviour, traffic control and management, land use practices and road infrastructure condition. This study agrees with the findings from a previous study in Addis Ababa, Ethiopia by Tulu S., (2015) on pedestrian safety challenges in developing countries. Walking still plays a key role in mobility of people in Nairobi and around the world and should be prioritised for more socio-economic and health benefits. It also plays a key role in connecting people to last mile destinations for all transport services. As human population grows in Nairobi at a rate estimated as 3.9%, it is expected that travel demand shall rise rapidly within the city and its metropolitan area hence more walking needs are anticipated. Safety of pedestrians should be prioritized within the urban areas by first improving safety at level crossings near roundabouts, walkways along arterial roads and within urban environment.

As the City grows, new sustainable transport infrastructure will be needed for more inclusive mobility and liveability. Such transport demand requires development of mass rapid transit systems, investment in pedestrian and bicycle safety facilities and integration of transport modes for coherence. Technology and innovation has also played a key role in traffic management in cities across the developed world and this has proven to be an effective countermeasure to pedestrian safety at crossings near roundabouts and intersections. There is need to employ technology in traffic control and management at the roundabouts across Nairobi city especially at junctions and intersections. Human factors still emerge as the dominant cause of most road traffic crashes across the world hence needed to be considered when planning and designing pedestrian infrastructure and safety facilities near roundabouts along Uhuru Highway.

Demographic factors such as age and gender have significant impacts on pedestrian safety at crossings near roundabouts. It is prudent to develop transport infrastructure that will be responsive to the needs of people of all ages and gender. This study concludes that children from the ages 0-19 years and young adults aged between 21-30 years old are the most vulnerable in road traffic since they are the leading persons involved in fatal and serious injuries collisions. The location of pedestrian crossing points is still a burning debate amongst stakeholders in the transport sector in Nairobi and this study concludes that it is important to apply engineering principles such as pedestrian crossing warrants in selection of the most convenient location and types of crossing facility. Some critical aspects to consider include; pedestrian volume, vehicle volume, pedestrian crossing time, pedestrian waiting time, desire lines, visibility and land use activities nearby. Moreover, traffic management authorities such as the Traffic Police should prioritize implementation of road safety measures targeting pedestrians especially at crosswalks along major urban arterials like Uhuru Highway.

Most pedestrians still require assistance from Traffic Police officers and prefer to cross the road as groups of individuals in order to cross the road safely near roundabouts along Uhuru Highway. This study suggests that implementing the use of traffic management devices such as traffic signs, marked crossings, traffic signals, raised pedestrian crossings and accessible pedestrian refuge is likely to improve safety of pedestrians while crossing near roundabouts along Uhuru Highway. Most pedestrians cross the road by observing oncoming traffic due to poor yielding behaviour by motorists hence the need to implement road safety measures targeting non-yielding motorists at crossings near roundabouts. Other technologies used in some cities around the globe include intelligent traffic management systems which can also enhance pedestrian safety at crossings. Such systems could improve pedestrian or vehicle detection, digital counters synchronized with traffic signal timing to inform pedestrians on change of traffic signal phase, in-pavement lighting devices at pedestrian crossings amongst other technologies. Appendices (I), (II), (III), (IV), (V) and (VI) give further details on results and data collection tools used to achieve the results in this study.

Chapter 5

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The following conclusions were drawn from the study:-

i. Male pedestrians are at highest risk of fatalities and serious injuries at level crossings near roundabouts along Uhuru highway in Nairobi compared to female pedestrians. Age is still a key determinant of pedestrian crash outcome along the study area.

ii. Road infrastructure and environment conditions such as land use, traffic volume and speed have significant impact on pedestrian crashes and hence determines the severity of crashes. Fatal crashes are likely to occur when pedestrian cross at midblock compared to near roundabouts due to higher operating speeds and low number of pedestrians crossing the road. Land use factors determine level of activity by walkers and hence a key risk factor for pedestrian safety at crossings.

iii. Pedestrian safety at crossings near roundabouts is determined by pedestrian crossing behaviour. The highest proportion of pedestrians require police presence to cross safely.

iv. Pedestrians crossings located near roundabouts along Uhuru highway are safer than those located at a distance away from the roundabout i.e. at midblock sections.

5.2 Recommendations

5.2.1 Recommendations

This study recommends that pedestrian safety at crossings near roundabouts is dependent on a number of factors related to pedestrian demographics, road infrastructure design and environment, road user behaviour and pedestrian crossing warrants at roundabouts located along Uhuru Highway. In order to enhance safety of pedestrians near roundabouts located along Uhuru Highway in Nairobi, this study recommends the following:

i. Improve road infrastructure design especially pedestrian safety facilities which could have a positive impact by reducing the number of fatalities and injuries.

ii. Construct a grade separated pedestrian crossing facility connecting the Nairobi Green Park terminus to reduce pedestrian–vehicle conflicts at crossings near Haile Selassie roundabout along Uhuru Highway hence reducing the risk of fatal and serious injuries collisions.

iii. Implement traffic law enforcement along Uhuru Highway and limit pedestrians to only use marked crossings along the road either near roundabouts or at midblock/sections.

iv. Pedestrians are safer to cross Uhuru Highway at crossings located near roundabouts are safer compared to those located at midblock/sections.

v. Implement proactive traffic control and management at crossings near the roundabouts both during the day and night to reduce the risk of fatal and serious injuries collisions involving pedestrians

vi. Install all necessary pedestrian crossing warrants such as traffic control signals, road signs and pedestrian signs that are currently lacking along the section under study especially at the roundabouts where pedestrian–vehicle conflict is prevalent.

vii. Install marked pedestrian crosswalks near roundabouts to improve visibility and direct pedestrians to safe crossing points near roundabouts and midblock/section area along Uhuru Highway

viii. Install streetlights especially along Uhuru Highway to improve visibility of pedestrians

ix. Install safety infrastructure responsive to pedestrians of all needs especially people living with disability (PWDs) at all crossing points along Uhuru highway

x. Enhance pedestrian safety education especially for school children and students crossing the road at University Way roundabout

5.2.2 Recommended areas for further research

Further studies are recommended to establish a number of factors determining safety of pedestrians at crossings near roundabouts in Kenya as follows:

i. Further studies are needed to establish the impact of intelligent traffic management systems (ITS) on safety of pedestrians at level crossing near roundabouts considering the upcoming project on intelligent traffic systems in Nairobi.

ii. Further studies are needed to establish the relationship between land use practices and pedestrian safety at crossings near roundabouts.

iii. Further studies are needed to determine the impact of autonomous vehicles on pedestrian safety at roundabouts in the context of a developing city like Nairobi.

iv. Further studies are need to establish the overall effect of in-pavement lighting devices on pedestrian safety at crossings near roundabouts.

v. Further studies are needed to compare safety of pedestrians crossing the road at grade and safety of pedestrians crossing using grade separated infrastructure near roundabouts.

vi. Further studies are recommended to establish the true cost of road crashes involving pedestrians that could be useful during planning and budgeting for road safety improvement works along urban roads in Nairobi.

vii. Further studies are needed to establish the true cause of road traffic collisions leading to pedestrian fatalities which are often recorded as hit and run by traffic police.

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APPENDICES

Appendix I: Accident Cause Codes in Kenya, NTSA, (2021)

Table I-1: Accident Cause Codes in Kenya

Driver	*Pedal Cyclist*	*Description*
1	31	Fatigued
2	-	Asleep
3	32	Ill
4	33	Under the influence of drink or a drug
5	34	Physically defective
6	35	Inexperienced with type of vehicle in use at the time
7	36	Proceeding at excessive speed having regard to conditions
8	37	Failing to keep to near side or to the proper traffic lane
9	38	Cutting in
10	39	Overtaking improperly
11	40	Swerving
12	41	Skidding (give cause of skid)
13	42	Forcing way through persons boarding or alighting from omnibus
14	43	Failing to stop to afford free passage to pedestrians at pedestrian crossing place
15	44	Turning round in road negligently
16	-	Reversing negligently (other than form parking area)
17	45	Failing to comply with traffic sign or signal
18	46	Failing to signal or giving indistinct or incorrect signal
19	47	Pulling out from near side or from one traffic lane (not from parking area) to another without due care
20	48	Inattentive or attention diverted
21	49	Hampered by passenger, animal or luggage in or on vehicle
22	50	Turning right without due care
23	51	Turning left without due care
24	-	Driver negligently opening door of vehicle
25	52	Crossing without due care at road junctions

Driver	***Pedal Cyclist***	***Description***
-	53	Pedal cyclist holding onto another vehicle
26	54	Losing control (particulars to be specified)
27	55	Dazzled by lights of another vehicle
28	56	Stopping suddenly
29	57	Misjudging clearance, distance or speed (vehicles or objects)
30	58	Other apparent error of judgment or negligence (specify)
30*a*	-	Reversing from *angle* parking space negligently
30*b*	-	Entering parking space (angle *or* flush) negligently
30*c*	-	Leaving flush-parking space negligently
	Pedestrian	
	59	Heedless of traffic-crossing road masked by stationary vehicle
	60	Heedless of traffic-crossing road not masked by stationary vehicle
	61	Heedless of traffic-walking or standing in road
	62	Heedless of traffic-playing in road
	63	Heedless of traffic-stepping, walking or running off footpath or verge into road
	64	Slipping or falling
	65	Physical defects or sudden illness
	66	Under the influence of drink or a drug
	67	Holding onto vehicle
	68	Error of judgment or negligence, other than above (specify below)
Passengers, etc.		
	69	Boarding or alighting from vehicle without due care
	70	Falling when inside or falling from vehicle
	71	Other negligence on part of the passenger
	72	Stealing ride
	73	Negligence on part of conductor or goods-vehicle attendant
	Animal	
	74	Dog in carriageway

Driver	***Pedal Cyclist***	***Description***
	75	Other animal in carriageway, including bolting horse
	Obstruction	
	76	Stationery vehicle dangerously placed
	77	Other obstruction (specify)
Vehicle Defect		
	78	Mechanical defect or failure-brakes
	79	Mechanical defect or failure-tyres or wheels
	80	Mechanical defect or failure-steering
	81	Mechanical defect or failure-other cause
	82	No front light
	83	Inadequate front light
	84	No rear light
	85	Inadequate rear light
	86	Unattended vehicle running away
	87	Driver’s view obstructed, e.g. by equipment, load or obscured windscreen
	88	Vehicle overloaded, shifted or defective load
	89	Any other feature of vehicle or equipment which contributed to the accident (specify below)
	Road Defect	
	90	Road surface slippery
	91	Excessive dust obscuring driver’s view
	92	Road surface in need of repair (state defect)
	93	Other road condition, view obscured, etc. (specify)
	Weather	
	94	Fog or mist
	95	Torrential rain
	96	Glaring sun
	Other Cause	
	97	Other cause (specify)
	98	Cause not traced

APPENDIX II: Analysis on Primary Data Collected at Study Location

Table II-1: Vehicle Volumes at University Way Roundabout (R1)

Bicycles	127
Motorcycles	600
Private Car	878
PSV	796
Pick-ups	312
Lorries	263
Trucks	264

Source: Author, 2023

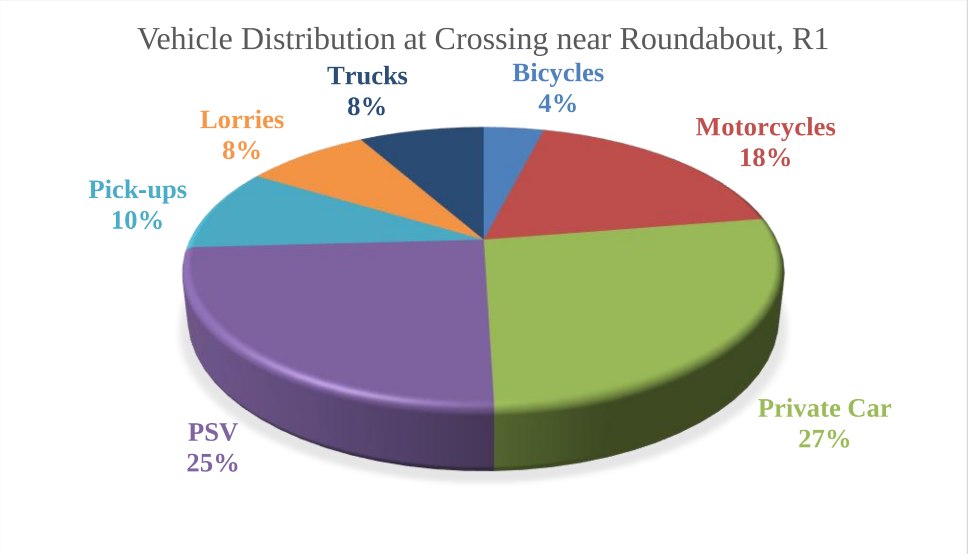


Figure II-1: Distribution of Vehicles at Crossing near University Way Roundabout R1. Source: Author, 2023

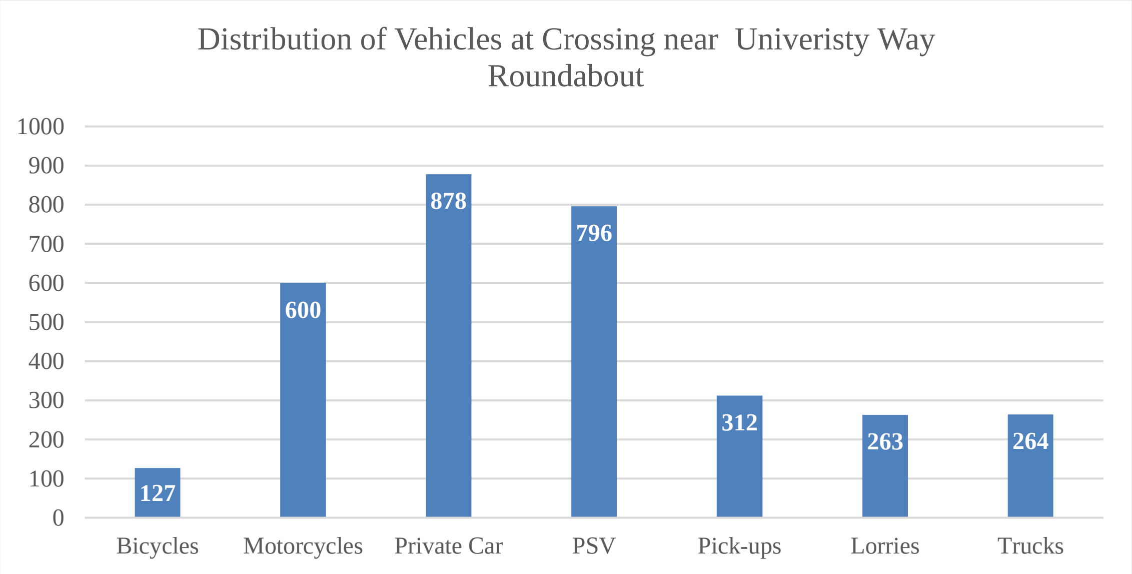


Figure II-2: Distribution of Road User Crossing on University Way Roundabout R1. Source: Author, 2023

Table II-2: Vehicle Volumes at University Way Roundabout, R1

Bicycles	101
Motorcycles	499
Private Car	844
PSV	809
Pick-ups	287
Lorries	276
Trucks	245

Source: Author, 2023

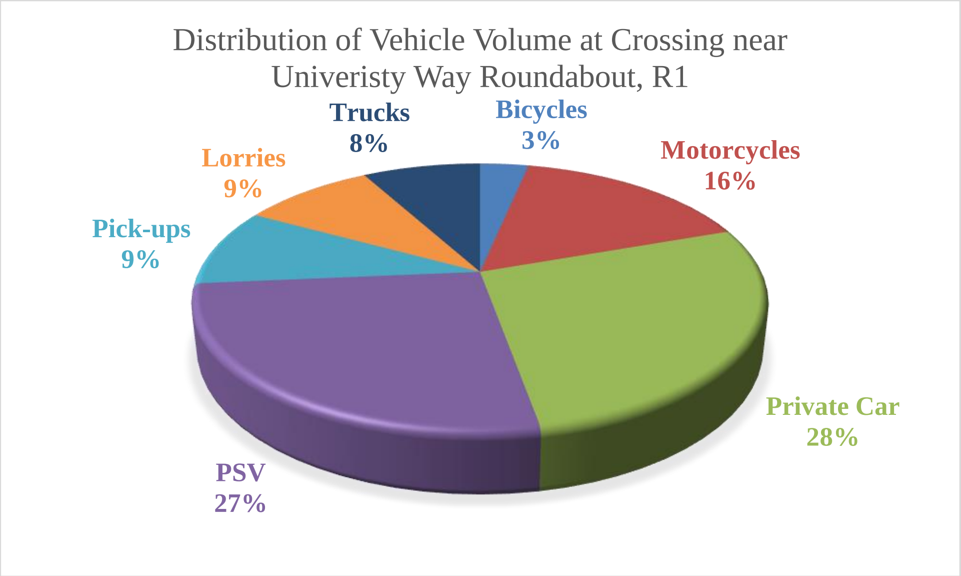


Figure II-3: Distribution of Vehicle Volume at Crossing near University Way Roundabout R1. Source: Author, 2023

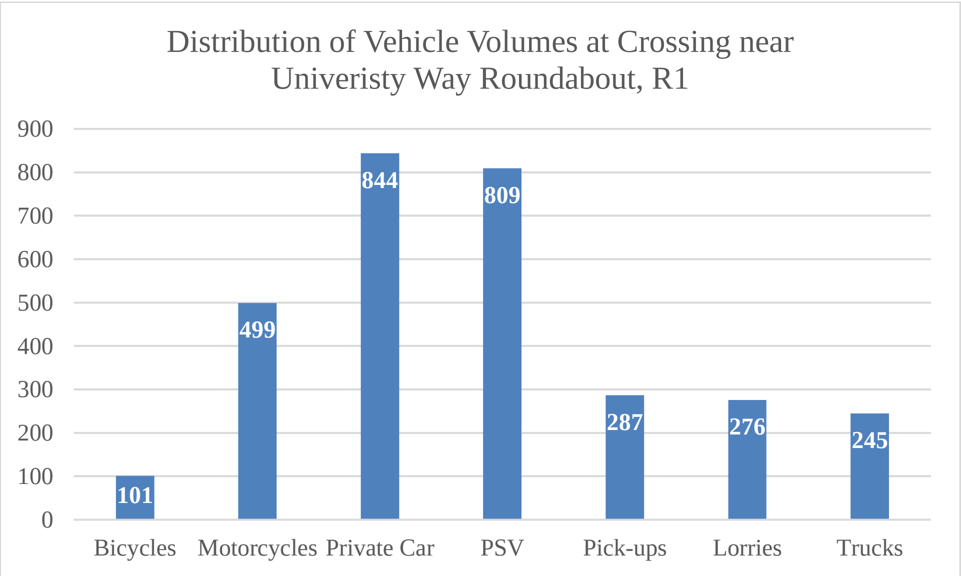


Figure II-4: Distribution of Vehicles at Crossing near University Way Roundabout R2. Source: Author, 2023

Table II – 3: Pedestrian Crossing Behaviour at University Way Roundabout, R1

Single	1632
Group	1971
Right Angle	2859
Skew	742
Holding Hands	208
Talking to Each Other	787
Talkning on phone	38
Observing oncoming traffic	3055
Not observing oncoming traffic	521
Police hand signal	743
Mixed traffic	1156

Source: Author, 2023

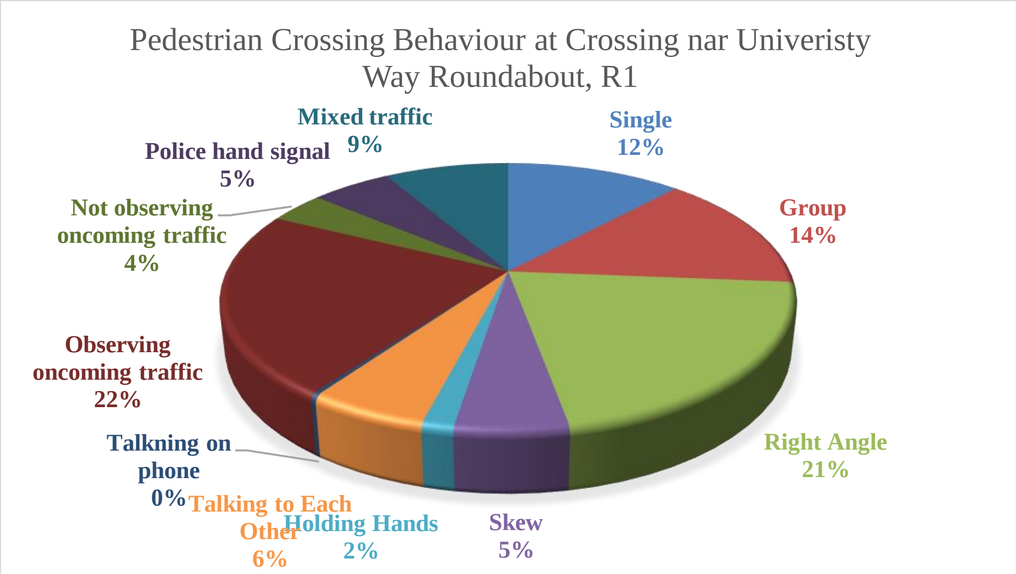


Figure II-5: Pedestrian Crossing Behaviour at University Way Roundabout, R1

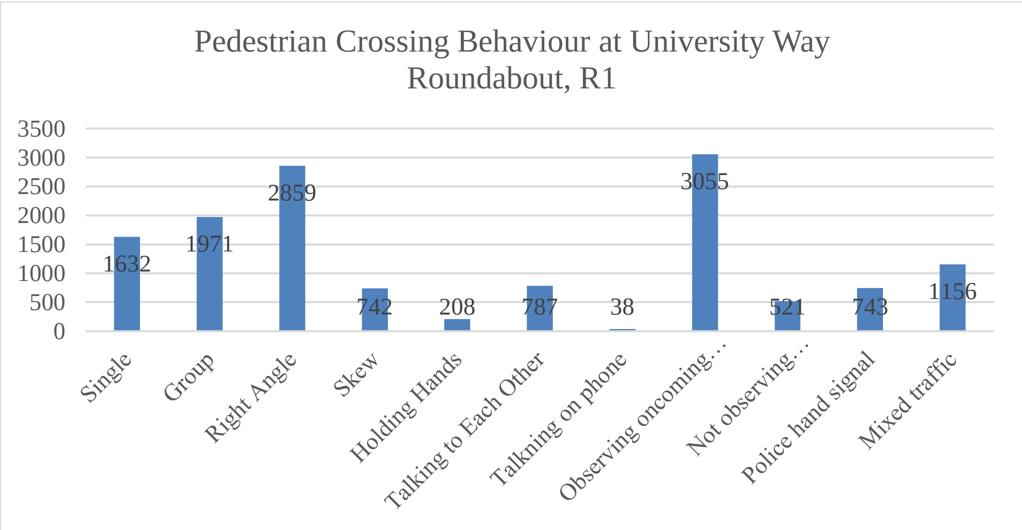


Figure II-6: Pedestrian crossing behaviour at crossing near University Way Roundabout, R1.
Source: Author, 2023

Table II -4: Pedestrian Crossing Behaviour at Crossings near Kenyatta Avenue Roundabout

Single	1348
Group	1575
Right Angle	2254
Skew	682
Holding Hands	114
Talking to Each Other	679
Talkning on phone	43
Observing oncoming traffic	2521
Not observing oncoming traffic	394
Police hand signal	595
Mixed traffic	1104

Source: Author, 2023

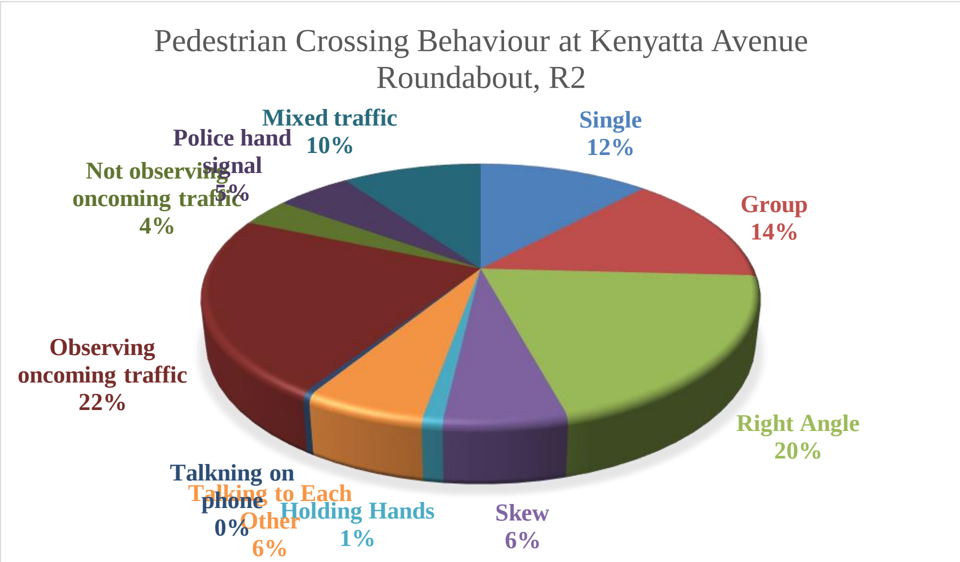


Figure II-7: Pedestrian Crossing Behaviour at Crossing near Kenyatta Avenue Roundabout. Source: Author, 2023

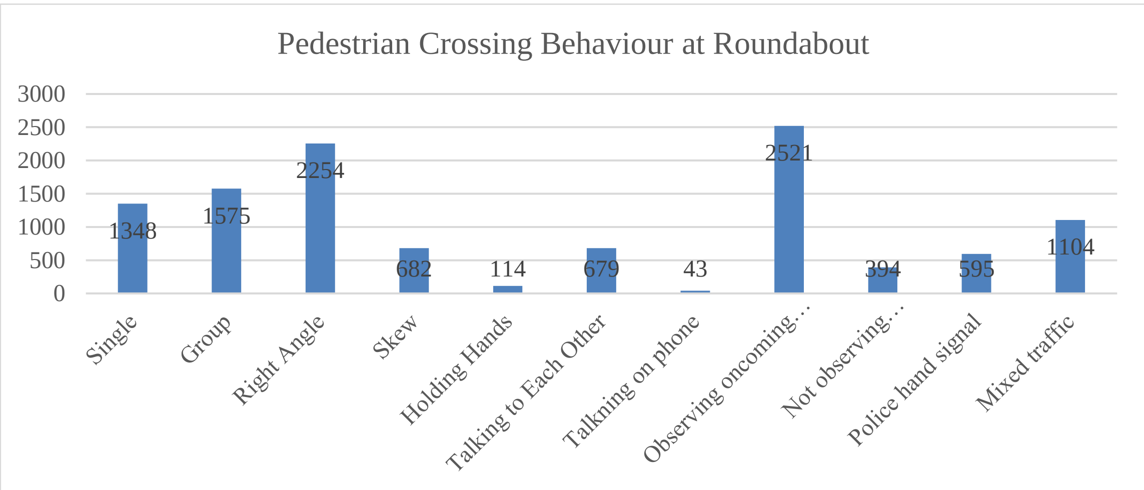


Figure II-8: Pedestrian Crossing Behaviour at Crossing near Kenyatta Avenue Roundabout. Source: Author, 2023

Table II – 5: Vehicle Volumes at Haile Selassie Roundabout, R3

Bicycle	66
Motorcycle	420
Private Car	1069
PSV	993
Pick - Ups	362
Lorries	544
Trucks	437

Source: Author, 2023

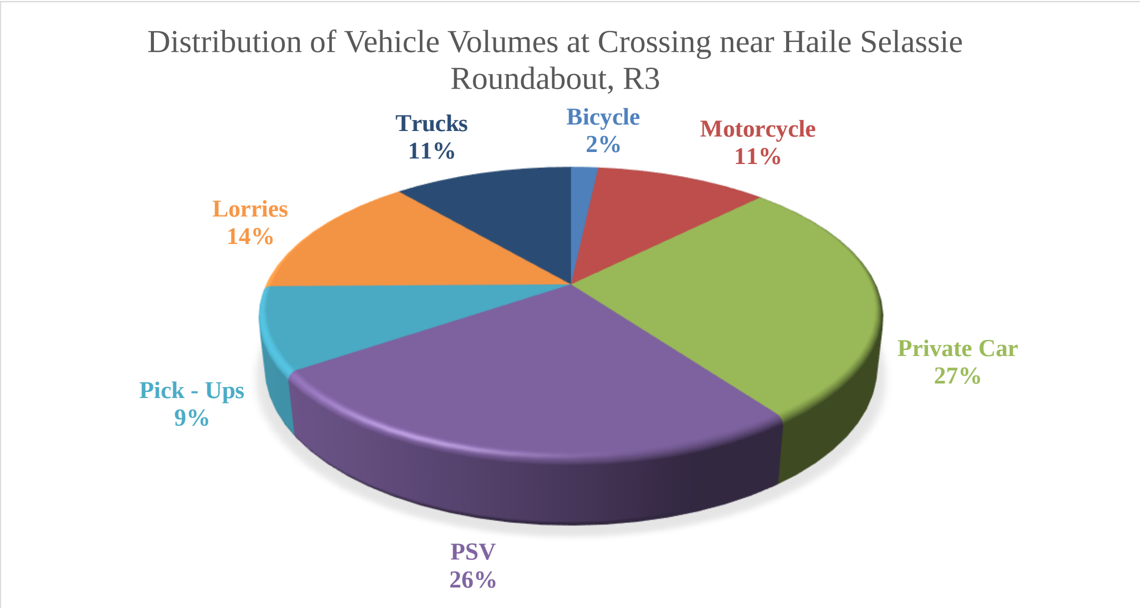


Figure II-9: Distribution of Road Users Crossing Roundabout R3. Source: Author, 2023

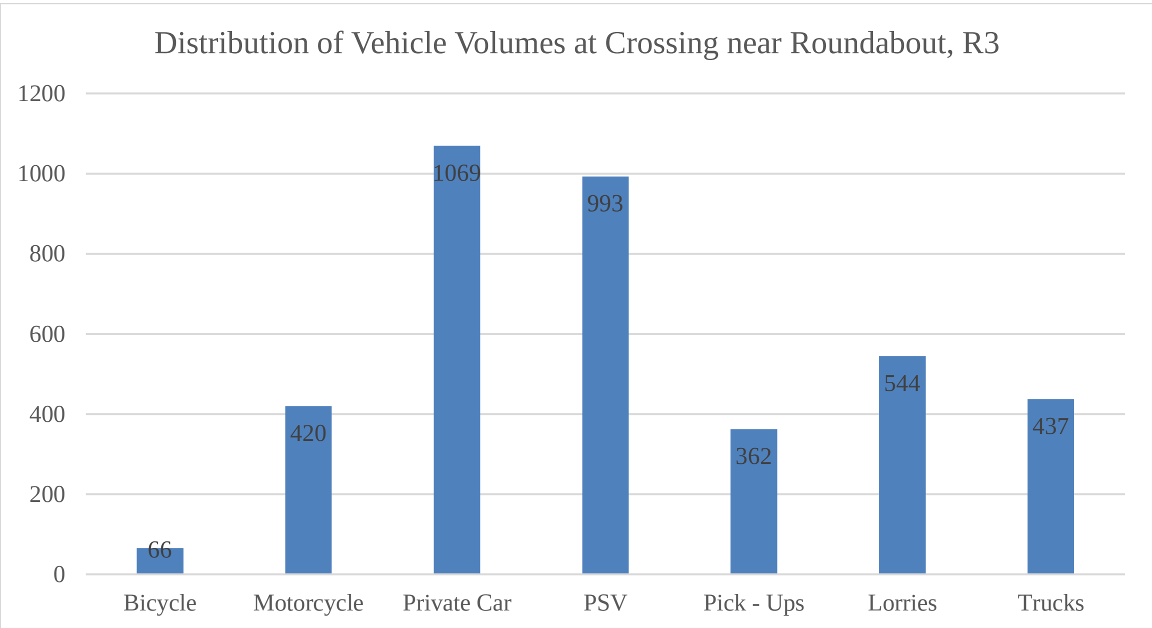


Figure II-10: Distribution of Vehicle Volume at Crossing near Haile Selassie Avenue Roundabout, R3. Source: Author, 2023

Table II – 5: Vehicle Volumes at Roundabout, R3

Bicycle	37
Motorcycle	746
Private Car	853
PSV	753
Pick - ups	411
Lorries	379
Trucks	352

Source: Author, 2023

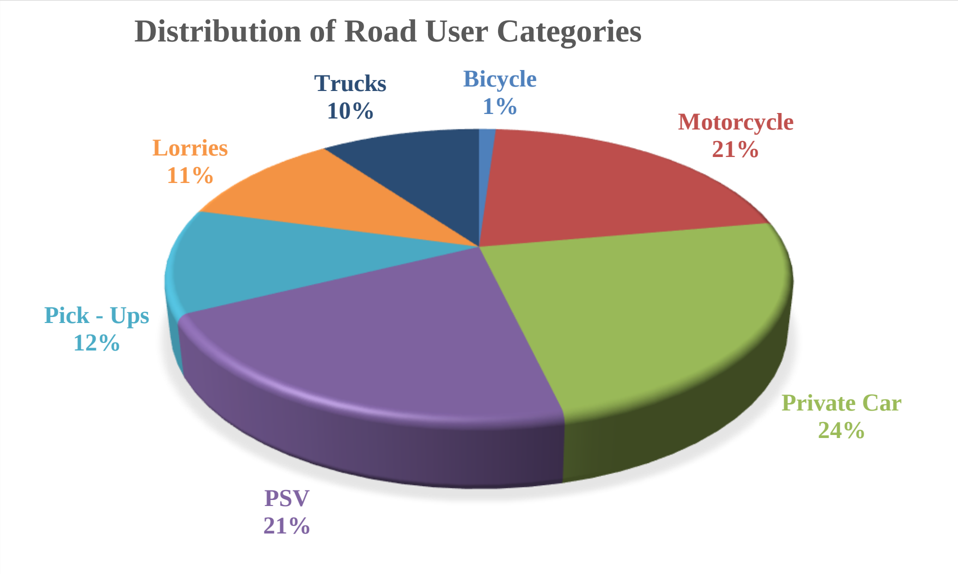


Figure II-11: Distribution of Road Users Crossing Roundabout, R3. Source: Author, 2023

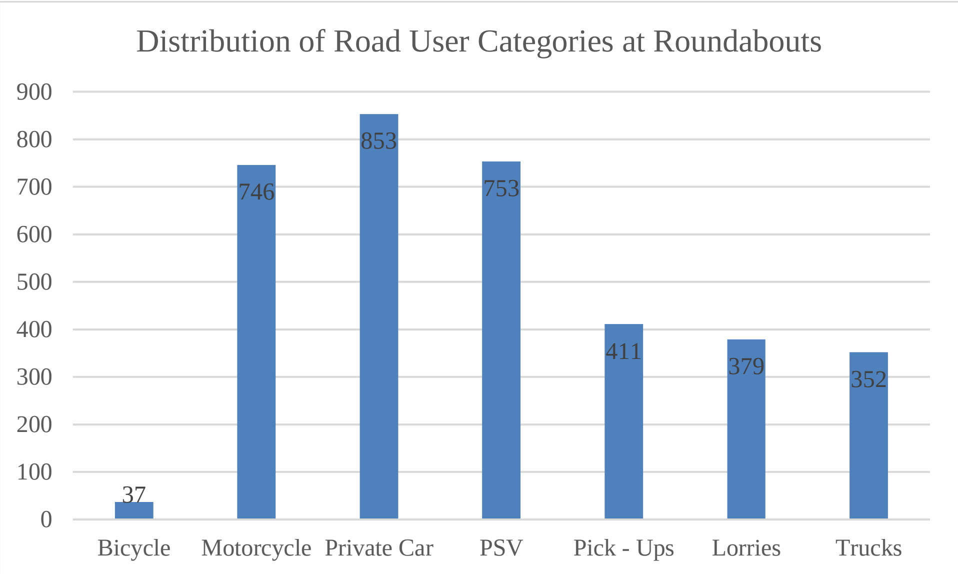


Figure II-12: Distribution of Road Users Crossing Roundabout, R3. Source: Author, 2023

Table II – 5: Vehicle Volumes at Roundabout, R3

Bicycle	211
Motorcycle	1227
Private Car	3704
PSV	1334
Pick - Ups	307
Lorries	281
Trucks	400

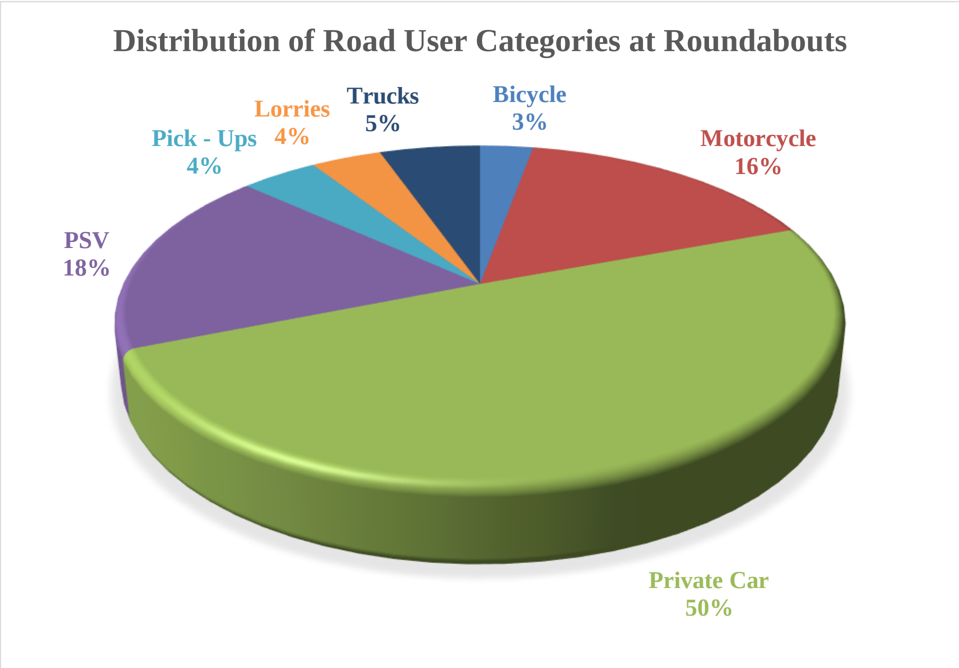


Figure II-13: Distribution of Road Users Crossing Roundabout, R3. Source: Author, 2023

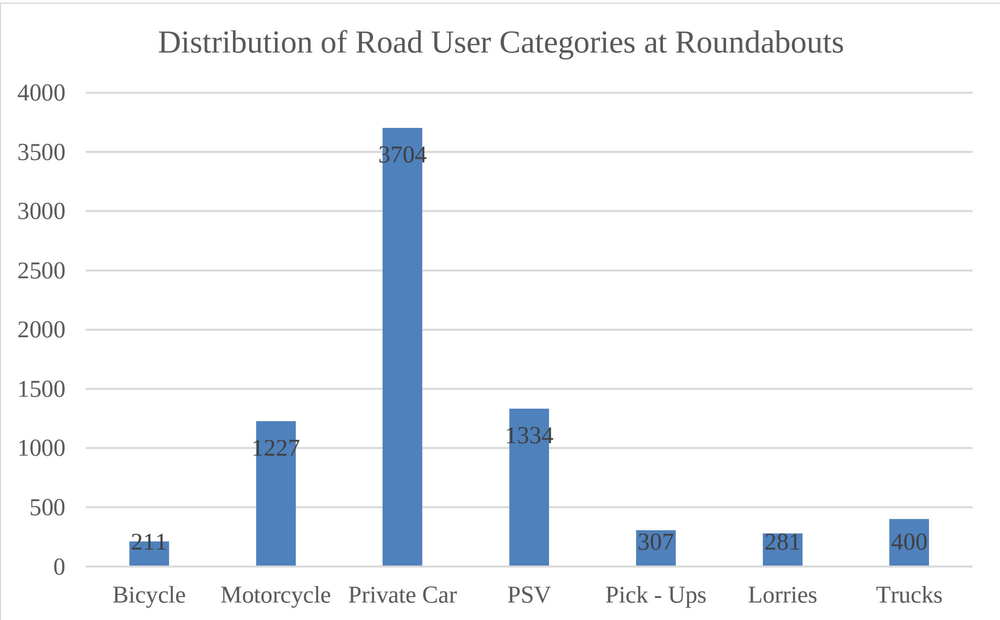


Figure II-14: Distribution of Road Users Crossing Roundabout, R3. Source: Author, 2023

Table II – 6: Pedestrian Crossing Behaviour at crossing near Haile Selassie Roundabout, R3

Single	366
Group	53
Right Angle	246
Skew	116
Holding Hands	41
Talking to Each Other	73
Talkning on phone	17
Observing oncoming traffic	194
Not observing oncoming traffic	70
Police hand signal	282
Mixed traffic	138

Source: Author, 2023

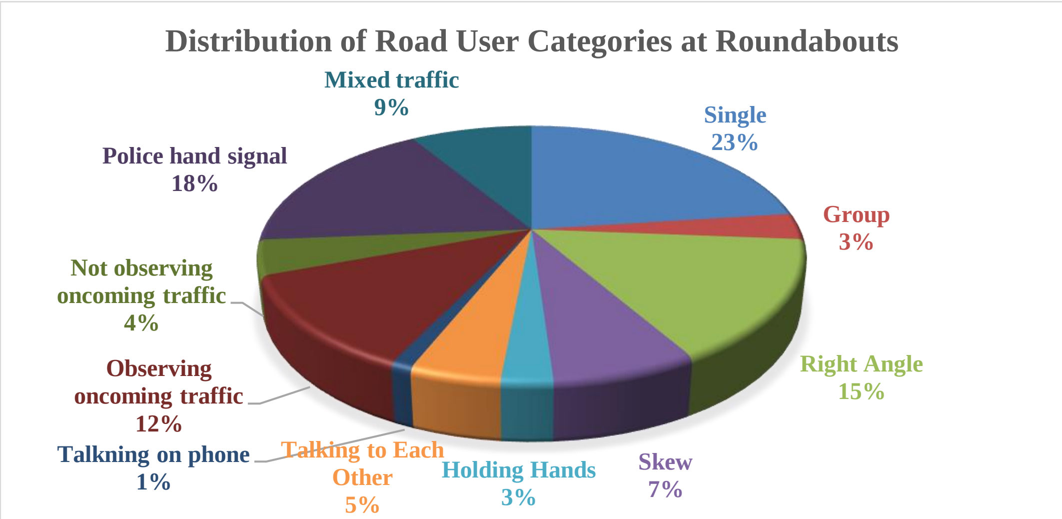


Figure II-15: Pedestrian Crossing Behaviour at crossings near Haile Selassie Roundabout, R3
Source: Author, 2023

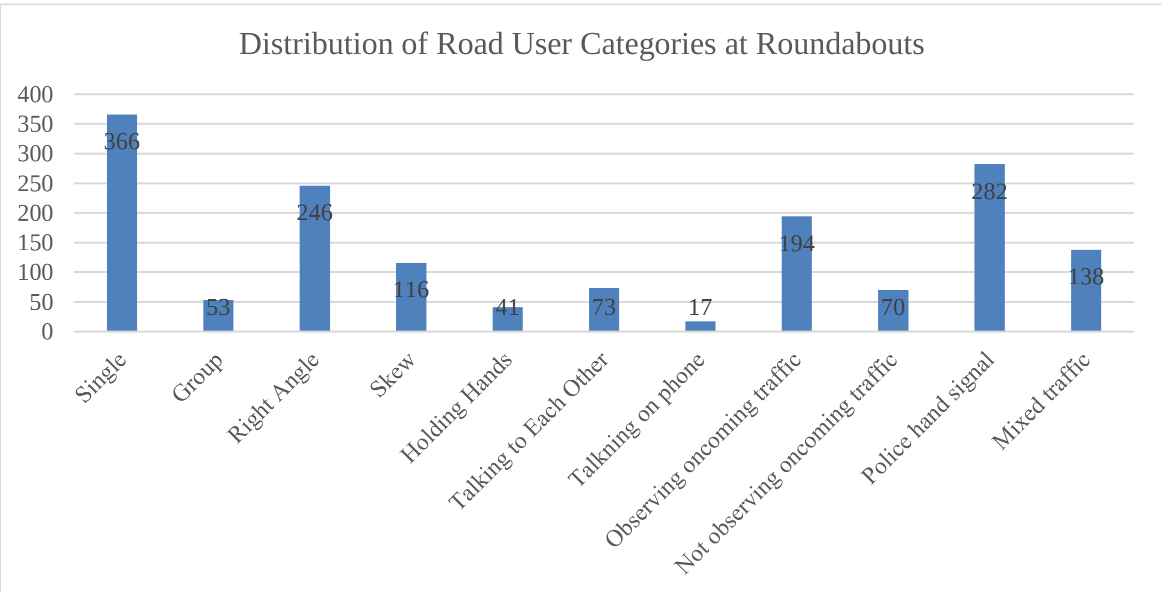


Figure II-16: Pedestrian Crossing Behaviour at Crossing near Haile Selassie Roundabout. Source: Author, 2023

Table II – 7: Pedestrian Crossing Behaviour at Midblock M1

Single	1958
Group	574
Right Angle	1233
Skew	454
Holding Hands	207
Talking to Each Other	259
Talkning on phone	34
Observing oncoming traffic	915
Not observing oncoming traffic	464
Police hand signal	1317
Mixed traffic	335

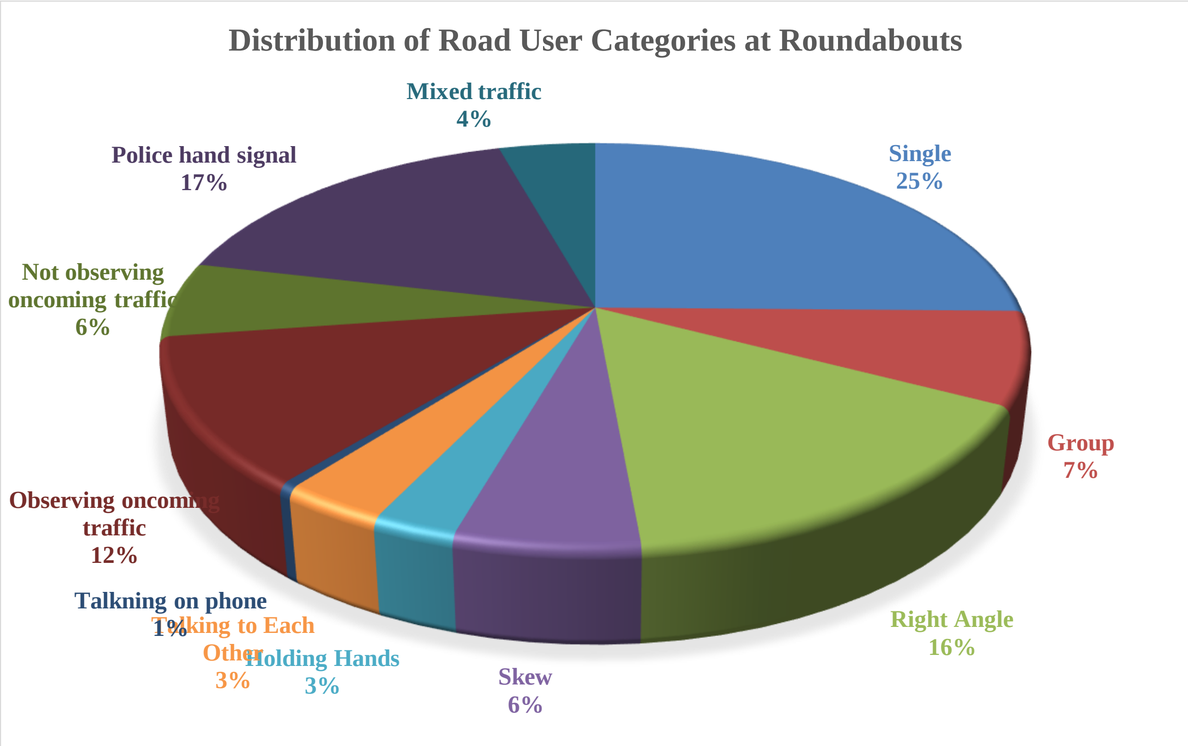


Figure II-17: Pedestrian Crossing Behaviour at Midblock M2. Source: Author, 2023

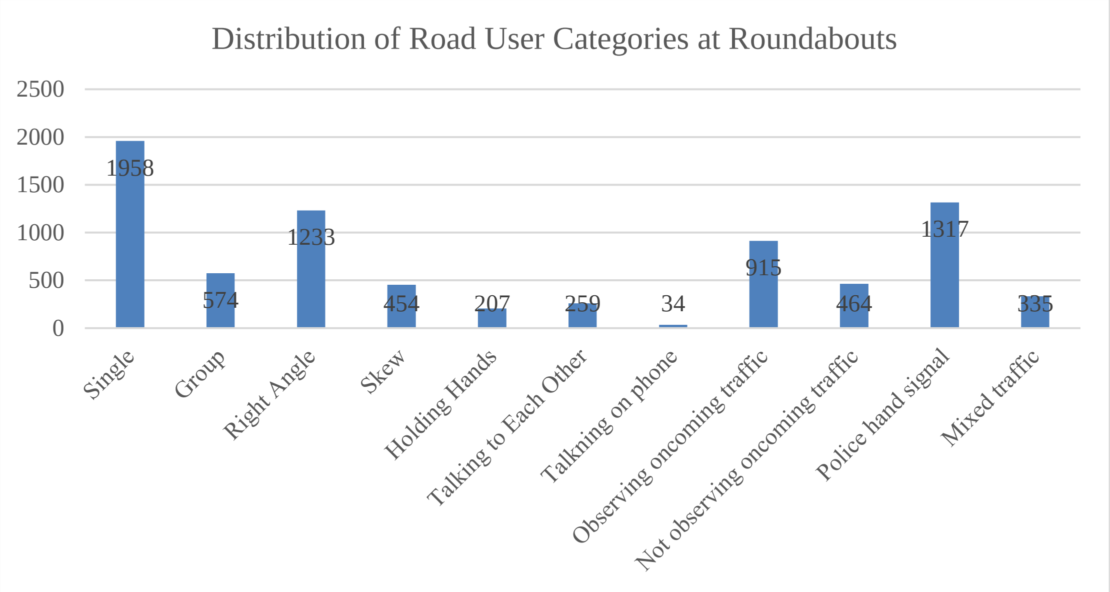


Figure II-18: Pedestrian crossing behaviour at Midblock M2. Source: Author, 2023

Table II – 8: Vehicle Volumes at Roundabout, R3

Bicycles	37
Motorcycles	673
Private Car	845
PSV	716
Pick-ups	416
Lorries	417
Trucks	293

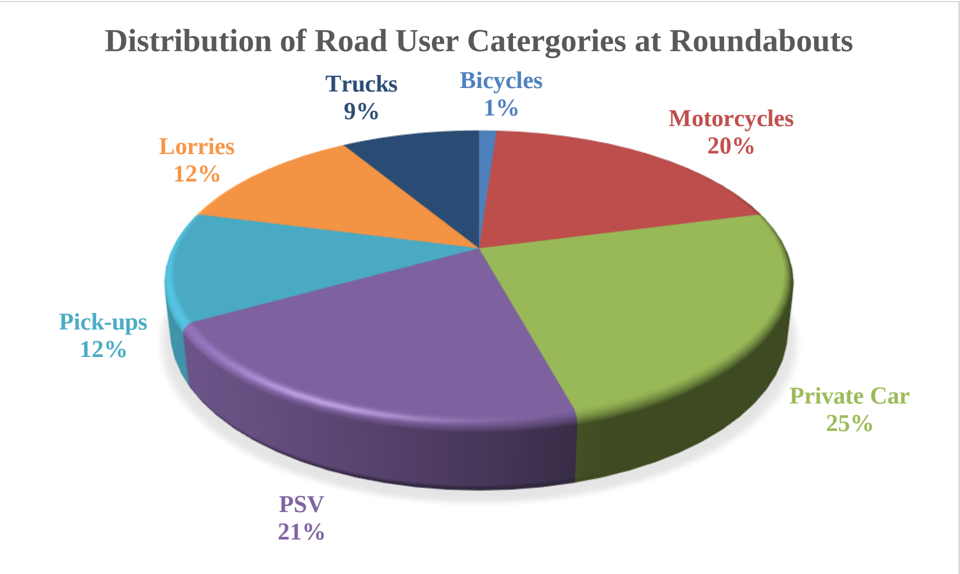


Figure II-19: Distribution of Road Users Crossing Roundabout, R3. Source: Author, 2023

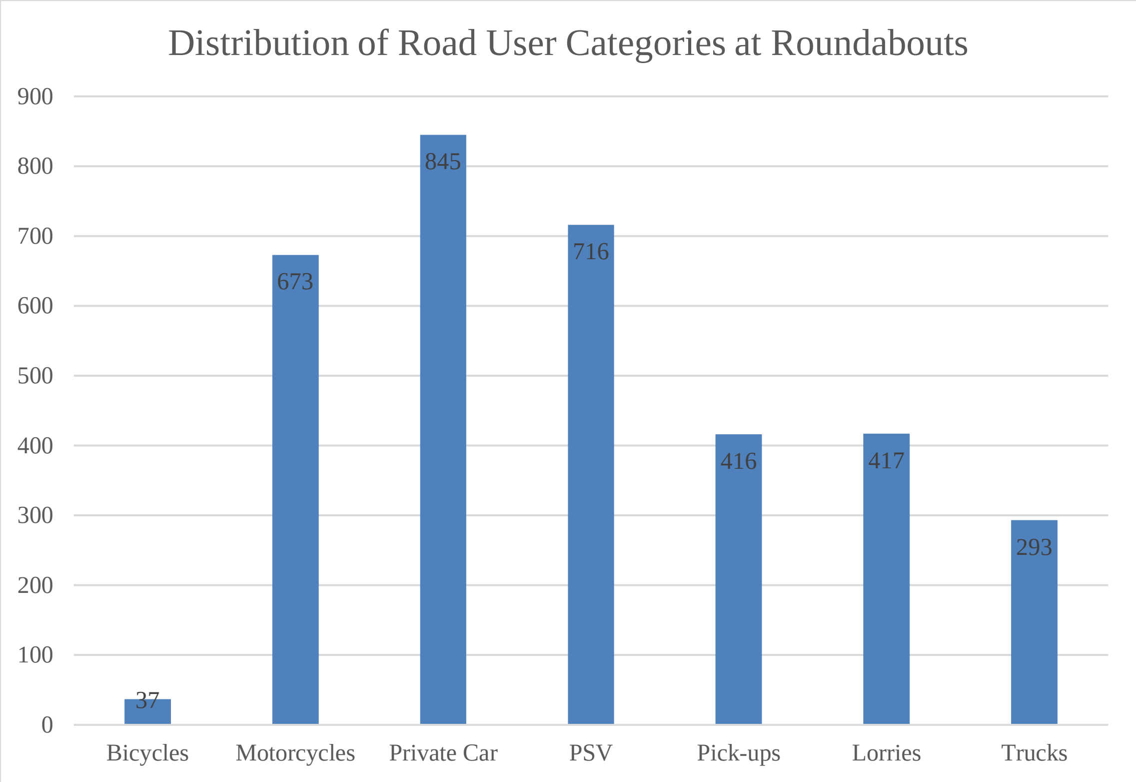


Figure II-20: Distribution of Road Users Crossing Roundabout, R3. Source: Author, 2023

Table II – 9: Vehicle Volumes at Roundabout, R3

Bicycles	66
Motorcycles	622
Private Car	2517
PSV	696
Pick-ups	127
Lorries	97
Trucks	85

Source: Author, 2023

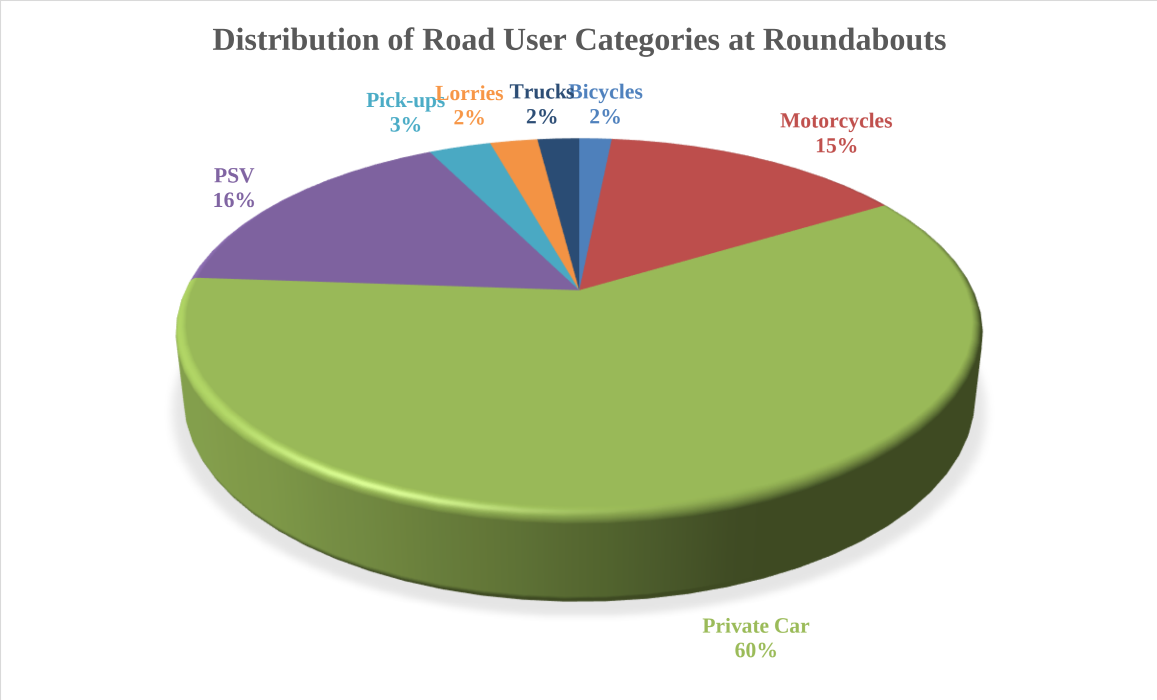


Figure II-21: Distribution of Road Users Crossing Roundabout, R3. Source: Author, 2023

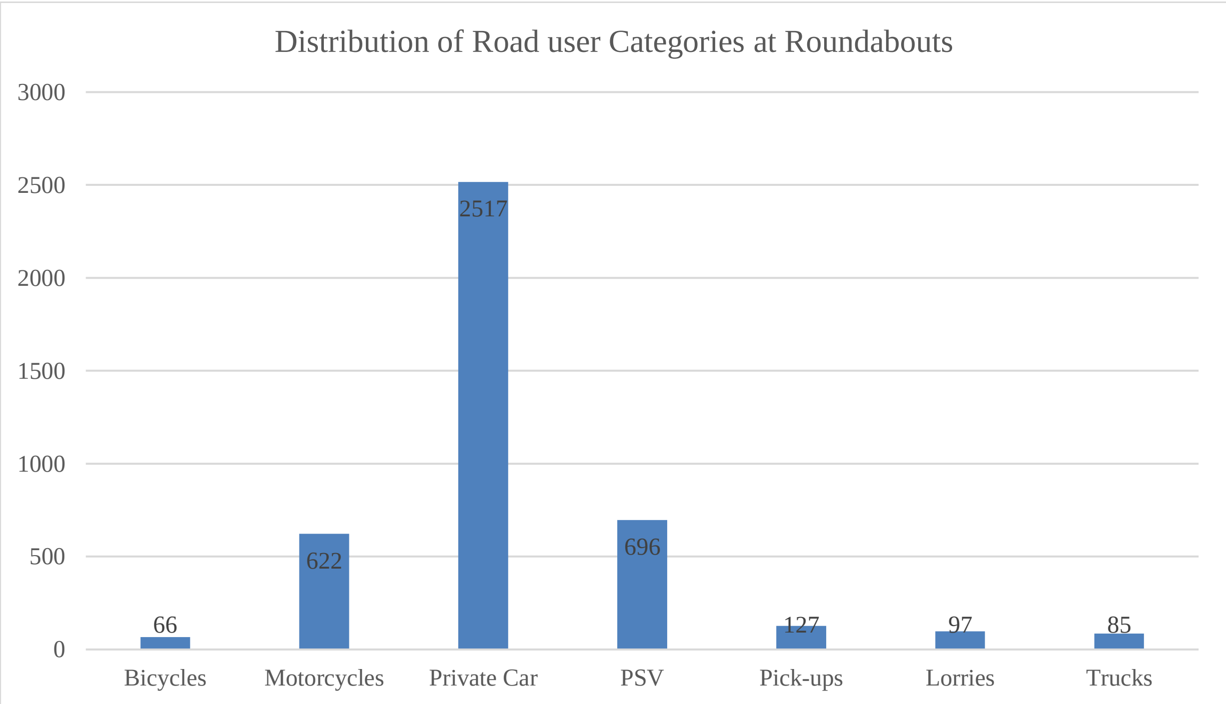


Figure II-22: Distribution of Road Users Crossing Roundabout, R3. Source: Author, 2023

Table II – 10: Vehicle Volumes at Roundabout, R3

Bicycles	86
Motorcycles	1179
Private Car	3082
PSV	345
Pick-ups	179
Lorries	275
Trucks	310

Source: Author, 2023

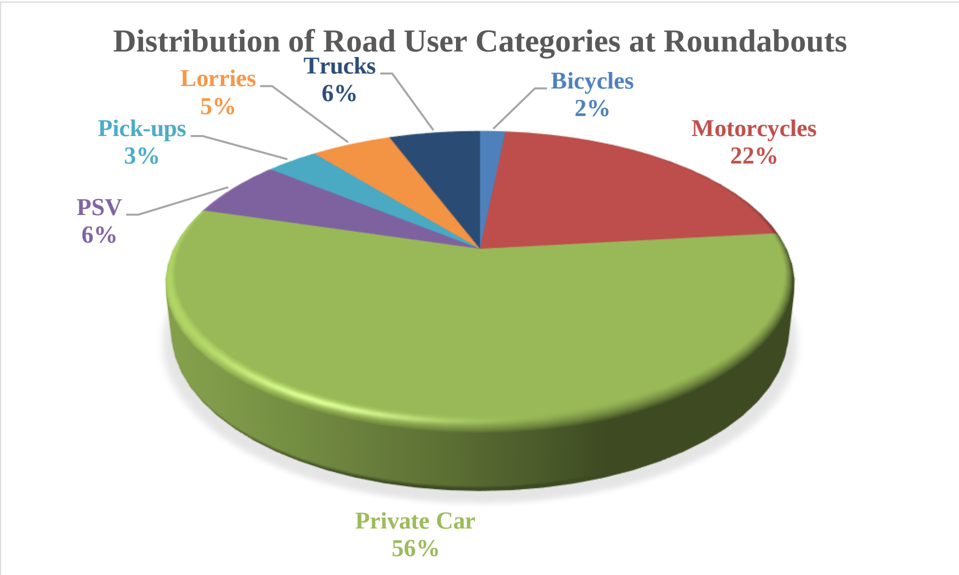


Figure II-23: Distribution of Road Users Crossing Roundabout, R3. Source: Author, 2023

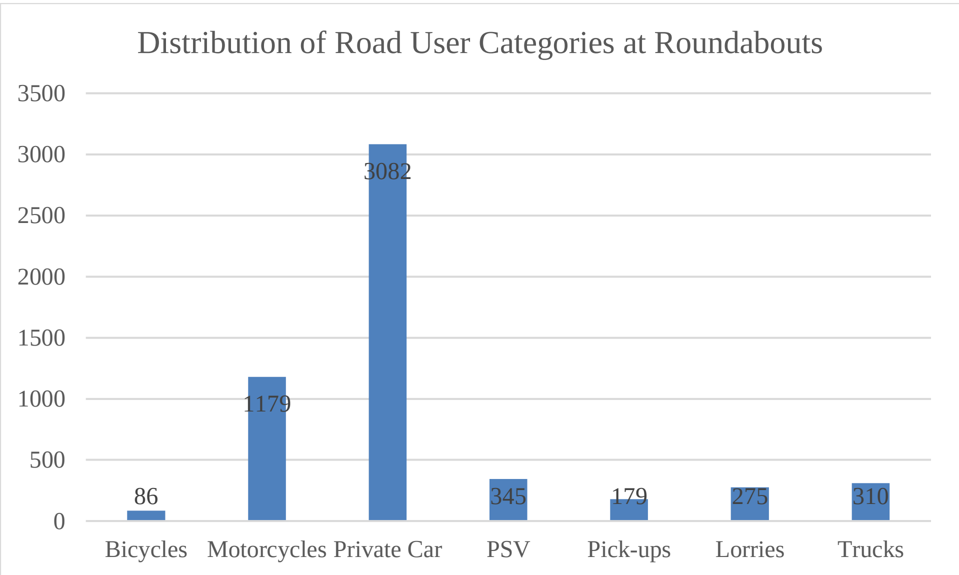


Figure II-24: Distribution of Road Users Crossing Roundabout, R3. Source: Author, 2023

Table II -11: Vehicle Volumes at crossing near Haile Selassie Roundabout, R3

Bicycles	68
Motorcycles	806
Private Car	2800
PSV	1045
Pick-ups	147
Lorries	53
Trucks	43

Source: Author, 2023

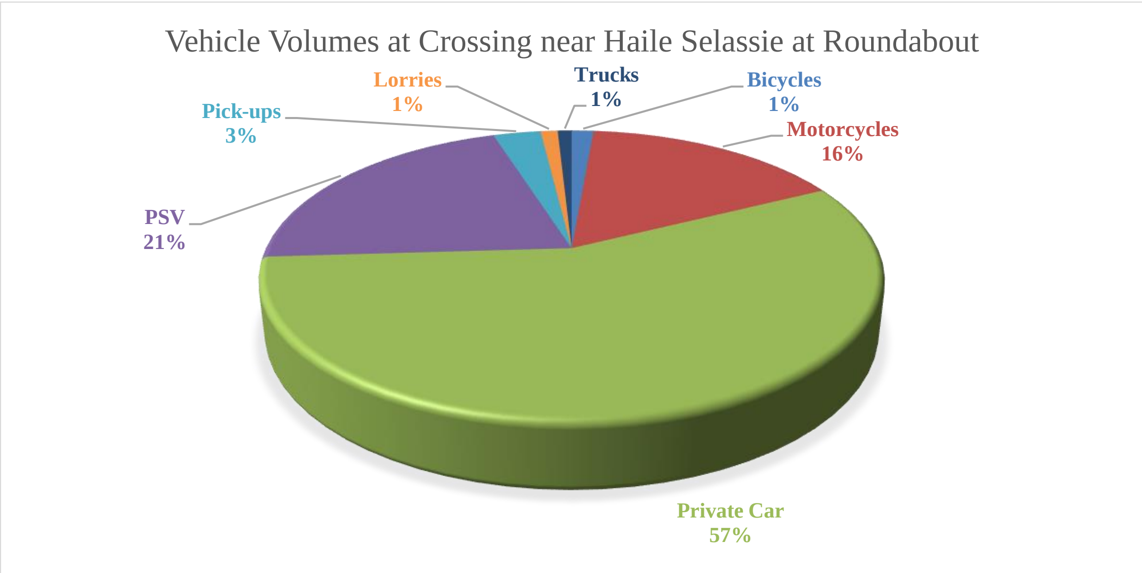


Figure II-25: Vehicle Volumes at Crossing near Haile Selassie Roundabout, R3. Source: Author, 2023

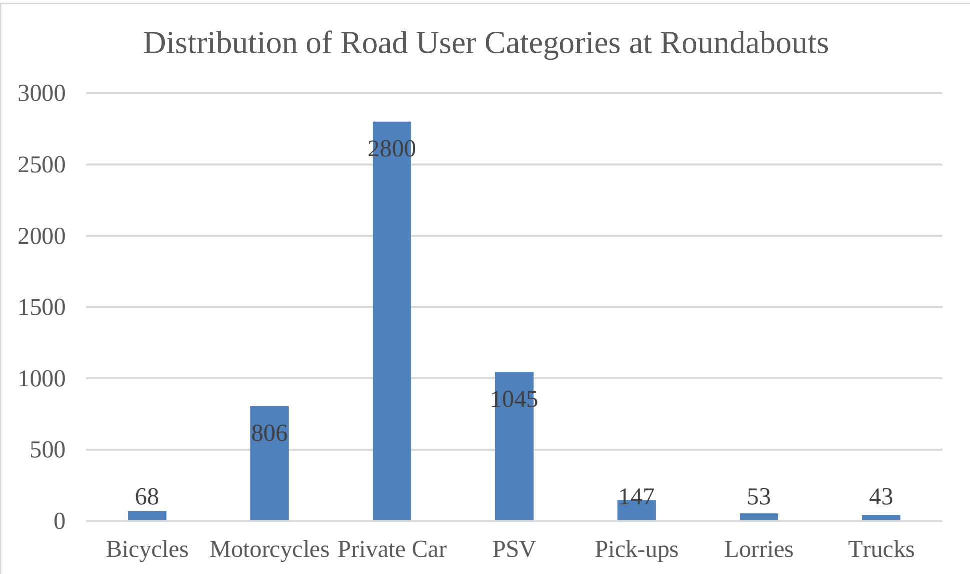


Figure II-26: Vehicle Volumes at Crossing near Haile Selassie Roundabout, R3. Source: Author, 2023

Table II – 12: Pedestrian Crossing Behaviour near University Way Roundabout, R1

Single	2507
Group	8417
Right Angle	10049
Skew	941
Holding Hands	275
Talking to Each Other	1186
Talkning on phone	47
Observing oncoming traffic	10310
Not observing oncoming traffic	697
Police hand signal	1837
Mixed traffic	1893

Source: Author, 2023

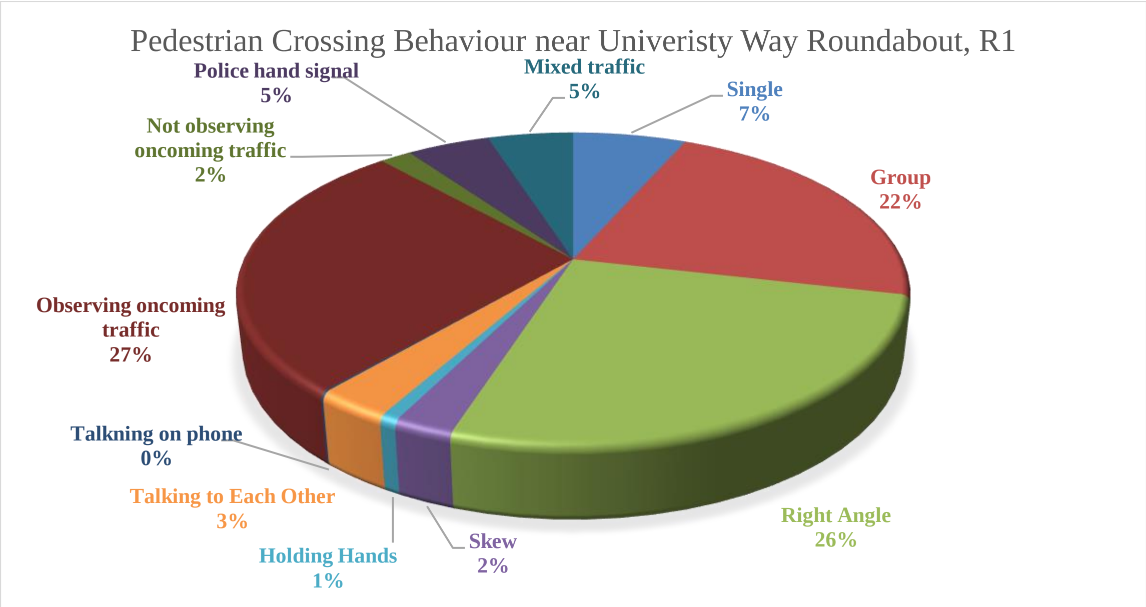


Figure II-27: Pedestrian Crossing Behaviour near University Way Roundabout, R1. Source: Author, 2023

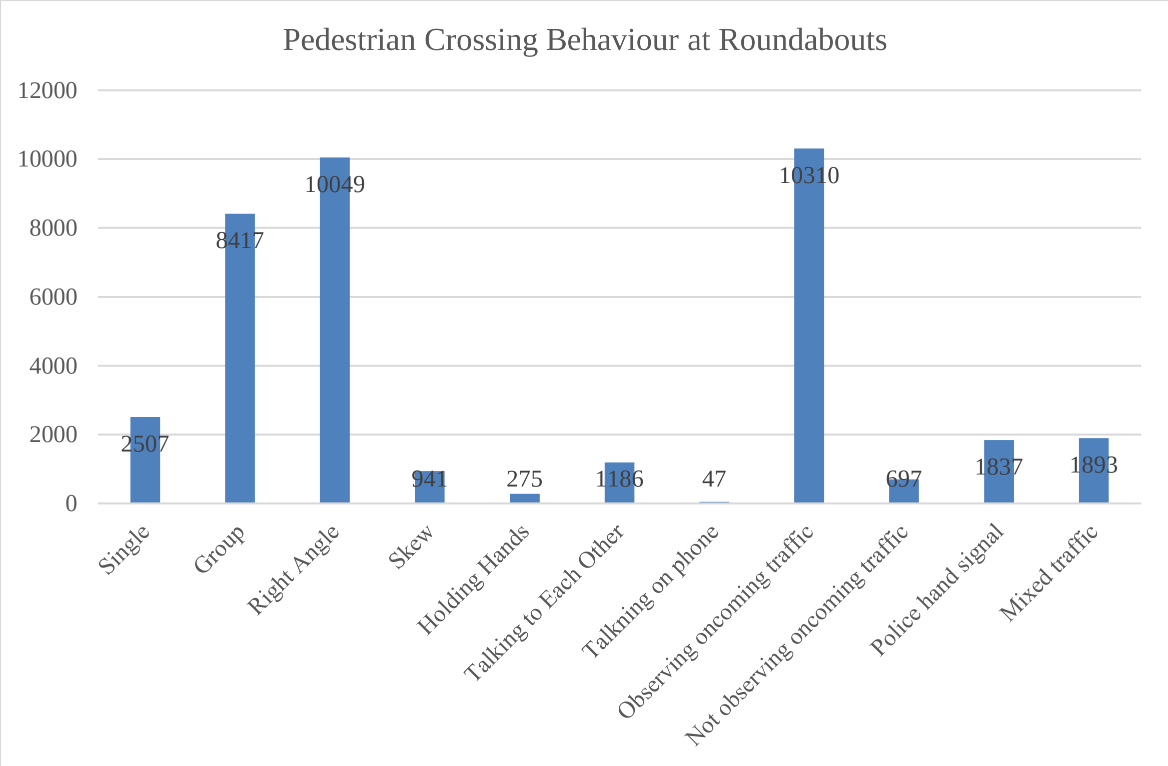


Figure II-28: Pedestrian Crossing Behaviour near University Way Roundabout, R1. Source: Author, 2023

Table II – 13: Pedestrian Crossing Behaviour at Midblock M1 between University Way (R1) and Kenyatta Avenue (R2) Roundabouts

Single	1750
Group	467
Right Angle	1263
Skew	275
Holding Hands	93
Talking to Each Other	378
Talkning on phone	19
Observing oncoming traffic	1099
Not observing oncoming traffic	346
Police hand signal	1012
Mixed traffic	387

Source: Author, 2023

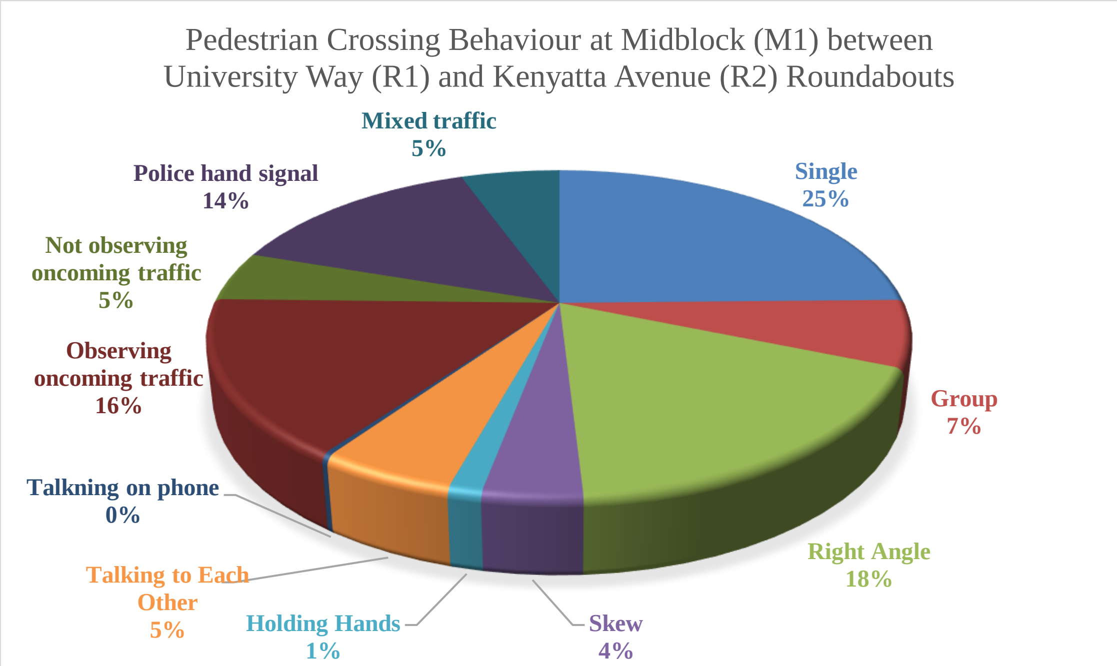


Figure II-29: Pedestrian Crossing Behaviour at Midblock (M1) between University Way (R1) and Kenyatta Avenue (R2) Roundabout. Source: Author, 2023

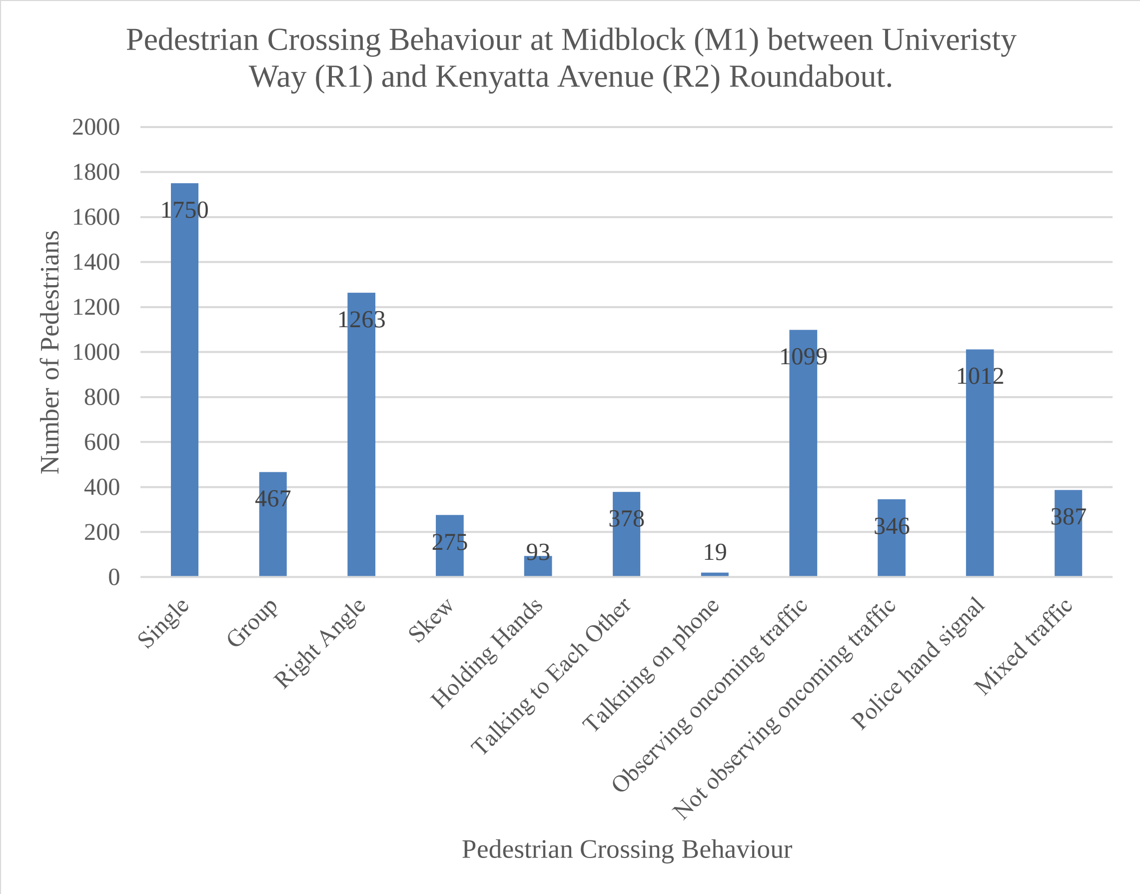


Figure II-30: Pedestrian Crossing Behaviour near Kenyatta Avenue Roundabout, R2. Source: Author, 2023

Table II – 14: Pedestrian Crossing Behaviour near Kenyatta Avenue Roundabout, R2

Single	2489
Group	8356
Right Angle	9756
Skew	1003
Holding Hands	277
Talking to Each Other	611
Talkning on phone	54
Observing oncoming traffic	9982
Not observing oncoming traffic	833
Police hand signal	722
Mixed traffic	1434

Source: Author, 2023

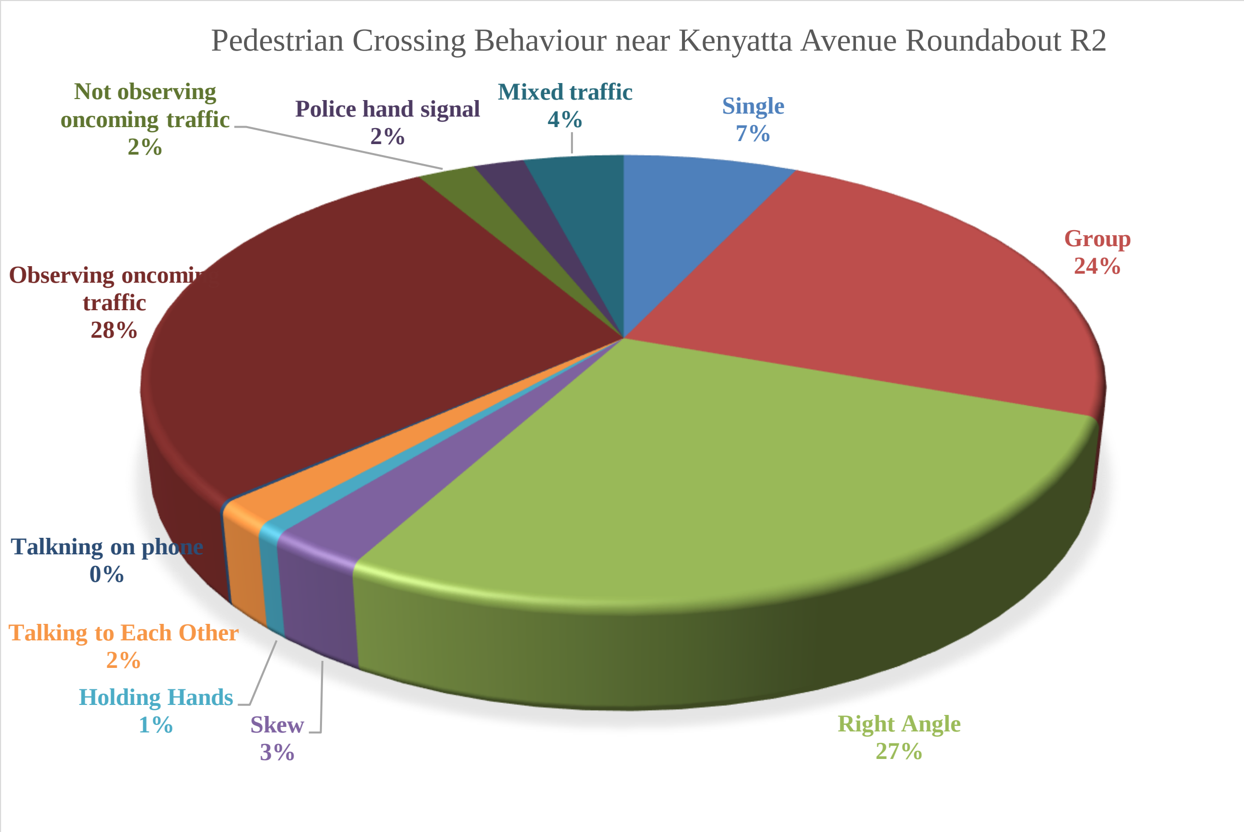


Figure II-31: Pedestrian Crossing Behaviour near Kenyatta Avenue Roundabout, R2. Source: Author, 2023

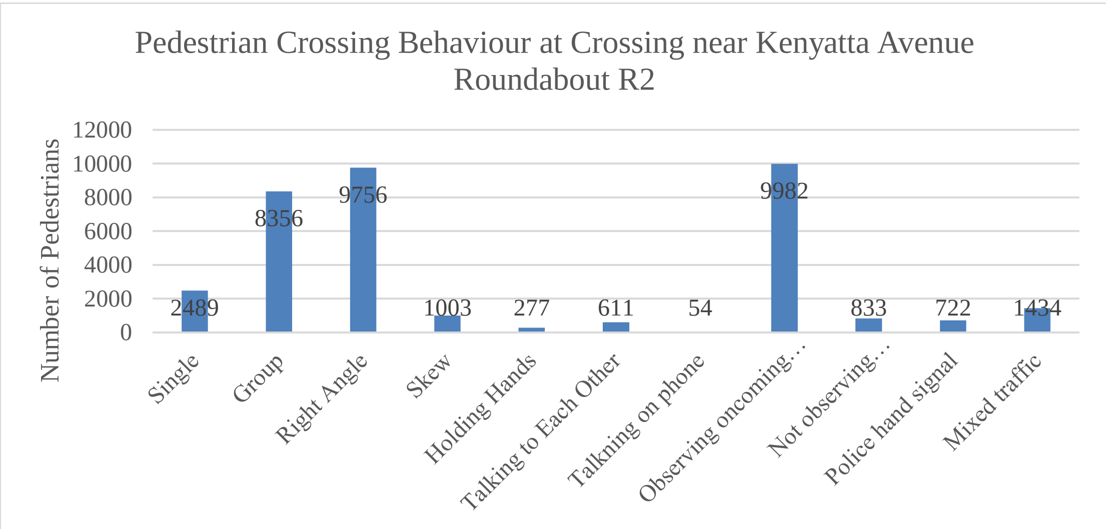


Figure II-32: Pedestrian Crossing Behaviour near Kenyatta Avenue Roundabout, R2. Source: Author, 2023

Table II – 15: Pedestrian Crossing Behaviour at Midblock M2 located between Kenyatta Avenue and Haile Selassie Roundabouts

Single	409
Group	185
Right Angle	254
Skew	241
Holding Hands	36
Talking to Each Other	204
Talkning on phone	9
Observing oncoming traffic	250
Not observing oncoming traffic	148
Police hand signal	260
Mixed traffic	182

Source: Author, 2023

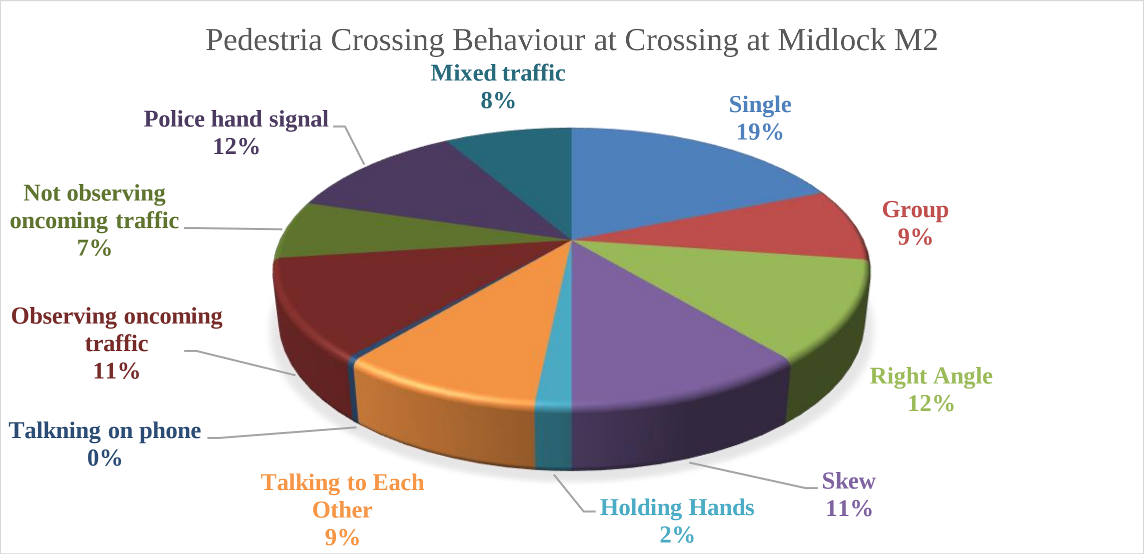


Figure II-33: Pedestrian Crossing Behaviour near Midblock, M2. Source: Author, 2023

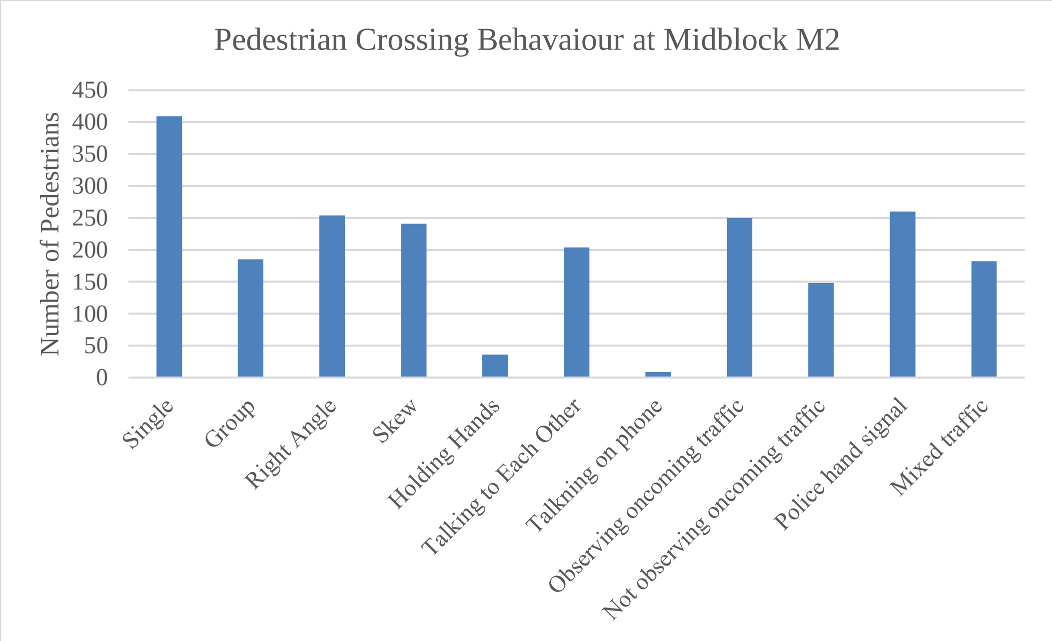


Figure II-34: Pedestrian Crossing Behaviour at Midblock (M2) between Kenyatta Avenue and Haile Selassie Roundabouts. Source: Author, 2023

Table II – 16: Pedestrian Crossing Behaviour at Crossing near Haile Selassie Roundabout, R3

Single	807
Group	1007
Right Angle	531
Skew	166
Holding Hands	99
Talking to Each Other	320
Talkning on phone	158
Observing oncoming traffic	619
Not observing oncoming traffic	279
Police hand signal	4
Mixed traffic	382

Source: Author, 2023

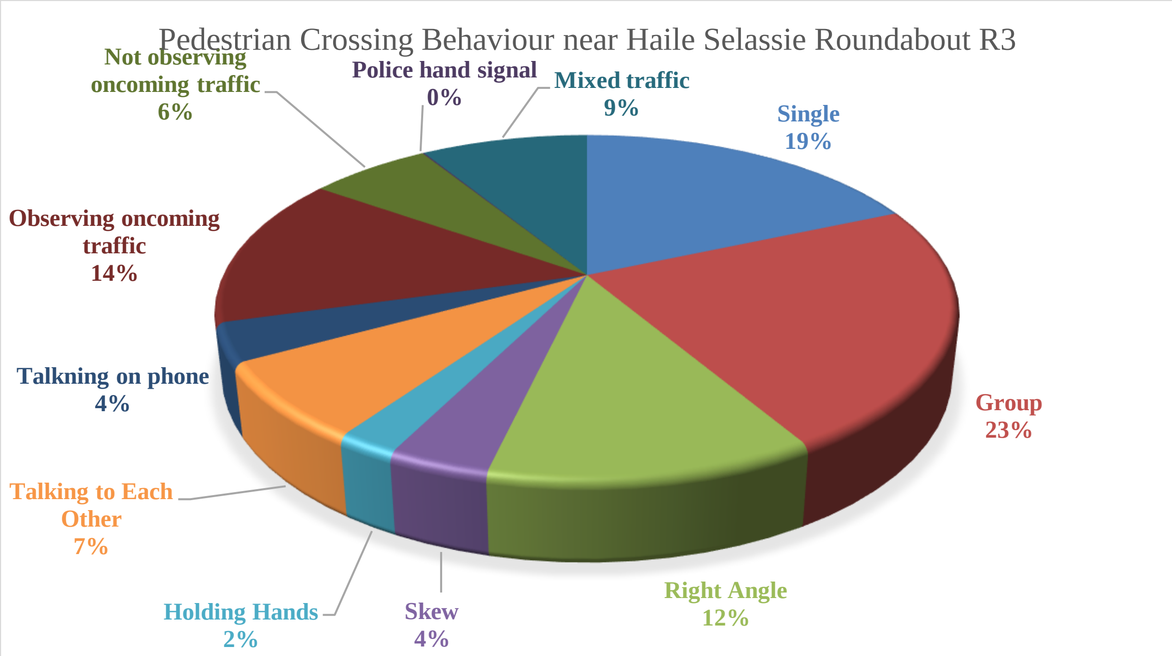


Figure II-35: Pedestrian Crossing Behaviour at Crossing near Haile Selassie Roundabout, R3

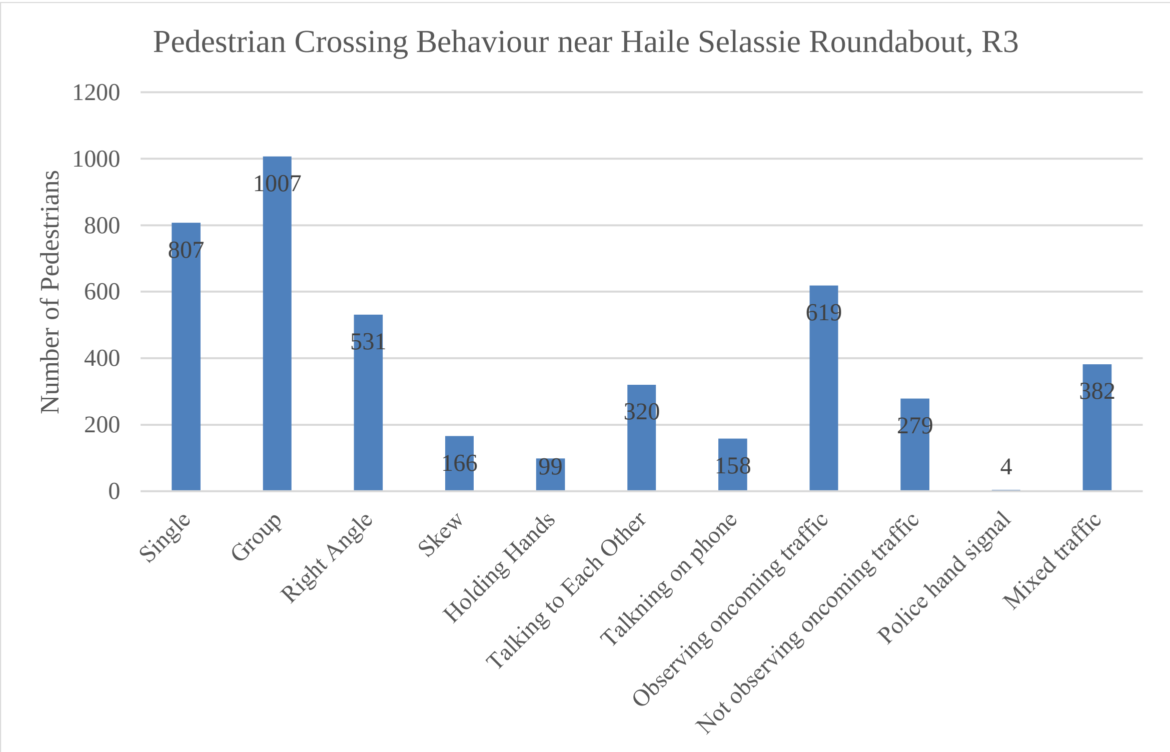


Figure II-36: Pedestrian Crossing Behaviour at Crossing near Haile Selassie Roundabout, R3

Table II –17: Mode Choice at Crossing near University Way Roundabout, R1

T	2
B	4
MB	16
M	5
W	1

Source: Author, 2023

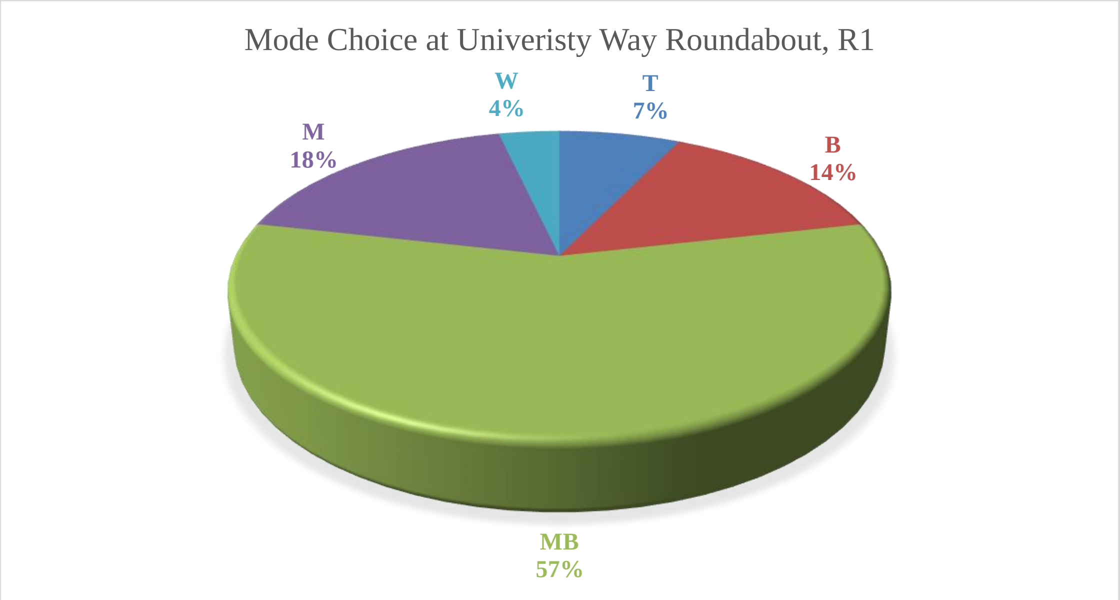


Figure II-37: Mode Choice at Crossing near University Way Roundabout, R1

Table II – 18: Mode Choice at Crossing near Kenyatta Avenue Roundabout, R2

T	2
B	1
W	8
M/B	12
M	5

Source: Author, 2023

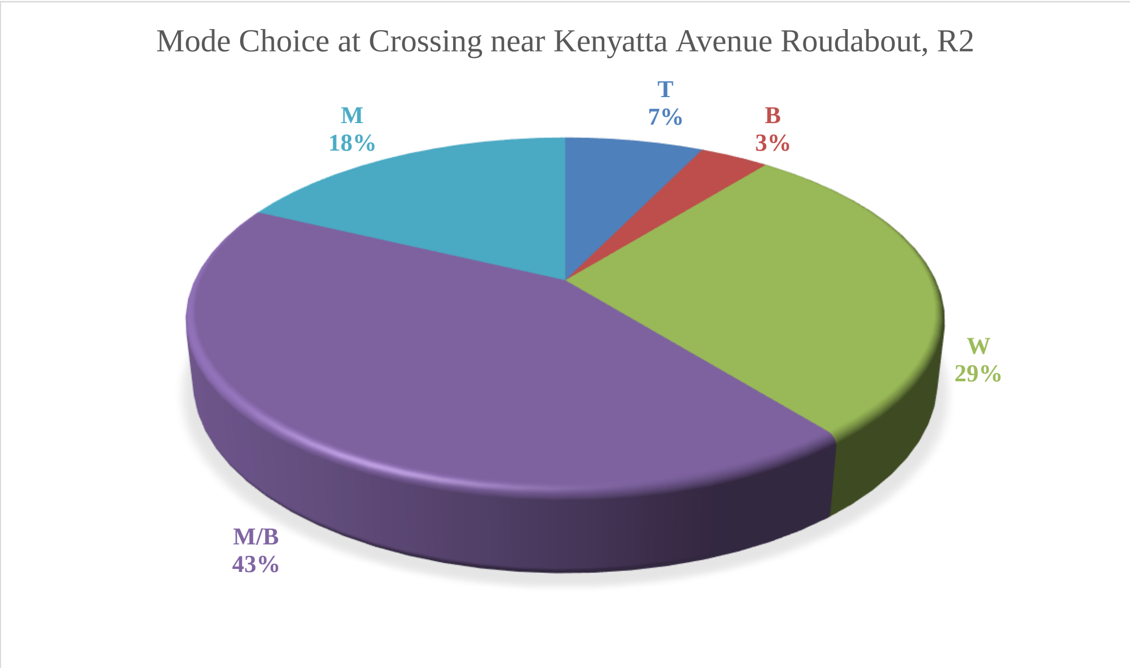


Figure II-38: Mode Choice at Crossing near Kenyatta Avenue Roundabout, R2

Table II – 19: Mode Choice at Crossing near Haile Selassie Avenue Roundabout, R3

T	2
M	8
B	1
M/B	16
W	1

Source: Author, 2023

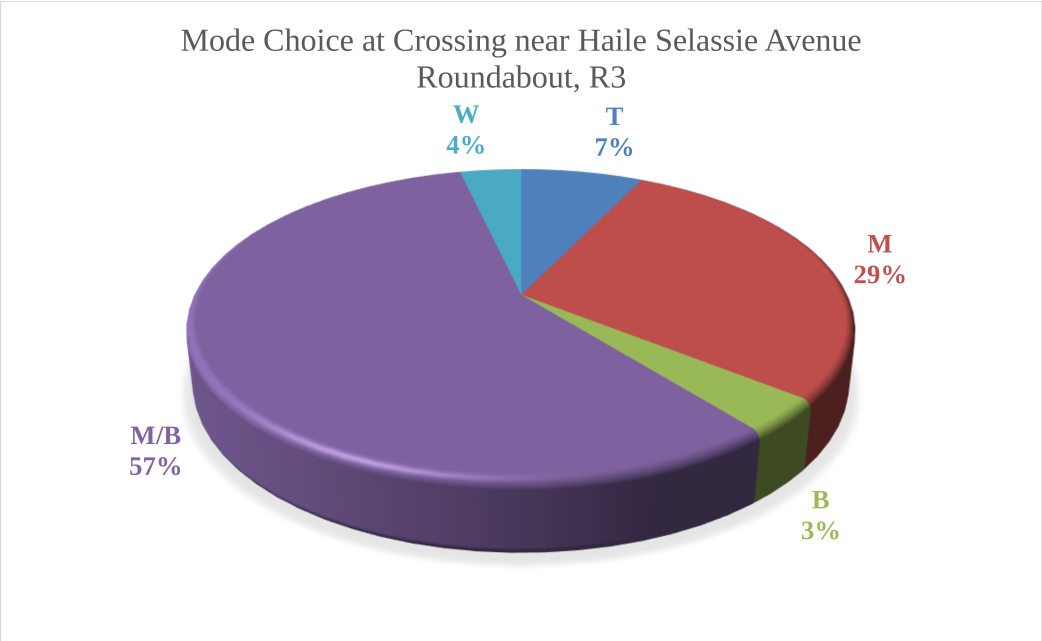


Figure II-39: Mode Choice at Haile Selassie Avenue Roundabout, R3

Table II – 20: Mode Choice at Midblock M1 between University Way and Kenyatta Avenue Roundabouts

Preferred Mode	No. of Persons
Walking	1
Mini-Bus	20
Bus	0
Matatu	7
Tuk-tuk	0

Source: Author, 2023

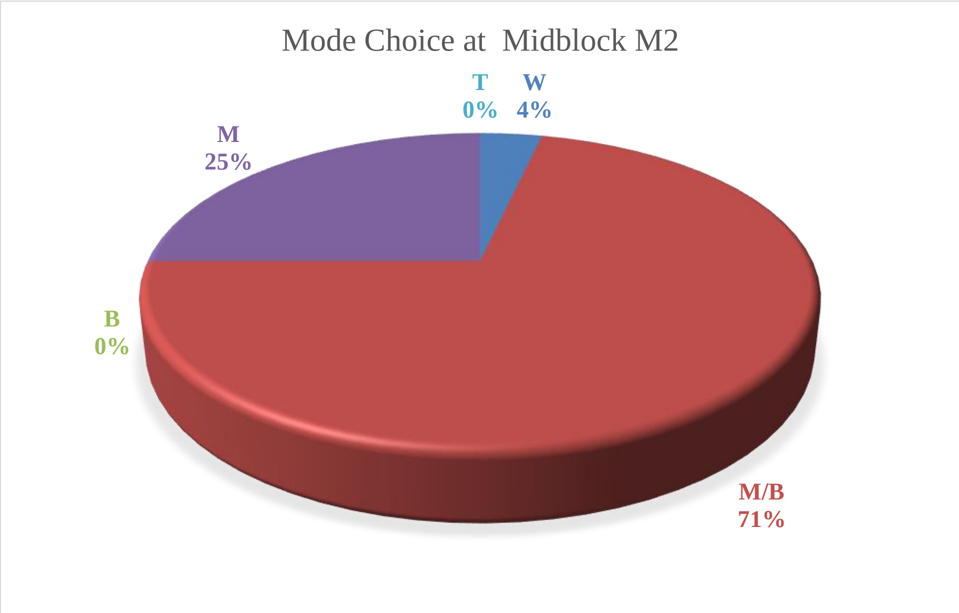


Figure II-21: Mode Choice at Midblock M1 between University Way and Kenyatta Avenue Roundabouts

Appendix III: Analysis on Crash Data from the National Police, Nairobi Central Division (2016-2021)

Table III-1: Crash Distribution by Road Segment Type

Crash Distribution by Road Segment Type	
Junction	36
Section	57
Total:	93

Source: Author, 2023

Table III-2: Pedestrian Vs Non-Pedestrian Injury Collisions

Pedestrians Vs Non-pedestrian Injuries	
Pedestrians	45
Non-pedestrians	48
Total:	93

Source: Author, 2023

Table III-3: Pedestrian Crash Distribution at Roundabouts along Uhuru Highway

Pedestrian Crashes along Uhuru Highway	
University Way Roundabout	15
Kenyatta Avenue Roundabout	9
Haile Selassie Roundabout	12
Midblock Section	**57**

Source: Author, 2023

Table III-4: Pedestrian Crash Distribution by Road Section Type on Uhuru Highway

Distribution of Pedestrian Crashes	
Roundabouts	11
Section	34
Total	**45**

Source: Author, 2023

Table III-5: Pedestrian Crashes Crash Frequency in Nairobi Central Business District

Central Police Database	
Uhuru Highway	93
Other Areas	925
Total:	**1,018**

Source: Author, 2023

Table III-6: No. of Pedestrian Crashes by Time of Day

No. of Pedestrian Crashes By Time of Day	
Day	**62**
Night	**33**
Total:	**99**

Source: Author, 2023

Table III-7: Number of Pedestrian Crashes involved in Serious Injury Collisions by Gender

Serious Injury	**Number of Pedestrians Involved**
Male	25
Female	11
Total	**36**

Source: Author, 2023

Table III-8: Male Pedestrians involved in Serious Injury Collisions at Section Vs Roundabout

Male Serious Injury At Section Vs Roundabout	
Section	14
Roundabout	11
Total	**25**

Source: Author, 2023

Table III-9: Female Pedestrians Involved in Serious Injuries Collisions at Sections Vs Roundabouts

Female Pedestrian Serious Injuries At Roundabout	
Section	9
Roundabout	2
Total	**11**

Source: Author, 2023

Table III-10: Male Pedestrians Involved in Serious Injuries Collision by Age (Nairobi)

Male Pedestrians Involved in Serious Injuries Collision- General	
0 -19	21
20 - 30	86
31 - 40	76
41 - 50	35
51 - 60	13
Above 60	54
Age Not Known	17
Total	**302**

Source: Author, 2023

Figure III-1: Male pedestrians involved in serious injuries collisions by Age (NTSA, 2021)

Table III-11: Female Pedestrians Involved in Serious Injuries Collisions

Female Pedestrian Involved In Serious Injuries Collisions	
0 - 19	7
20 - 30	38
31 - 40	32
41 - 50	64
51 - 60	6
Above 60	2
Age Not Known	7
Total:	**354**

Source: Author, 2023

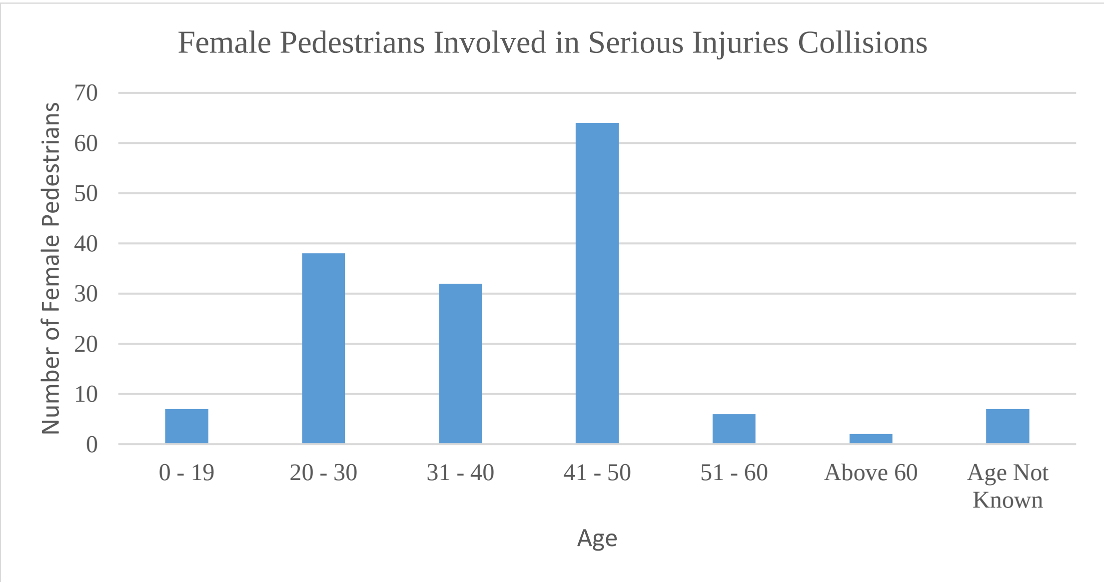


Figure III-2:Female Pedestrians Involved in Serious Injuries Collisions. Source: Author, 2023

Table III-: Male Pedestrians Involved in Fatal Collisions

Male Pedestrians Involved in Fatal Collisions	
0 - 19	3
20 -30	25
31 -40	19
41 -50	8
51 - 60	3
Above 60	4
Age Not Known	12
Total	**74**

Source: Author, 2023

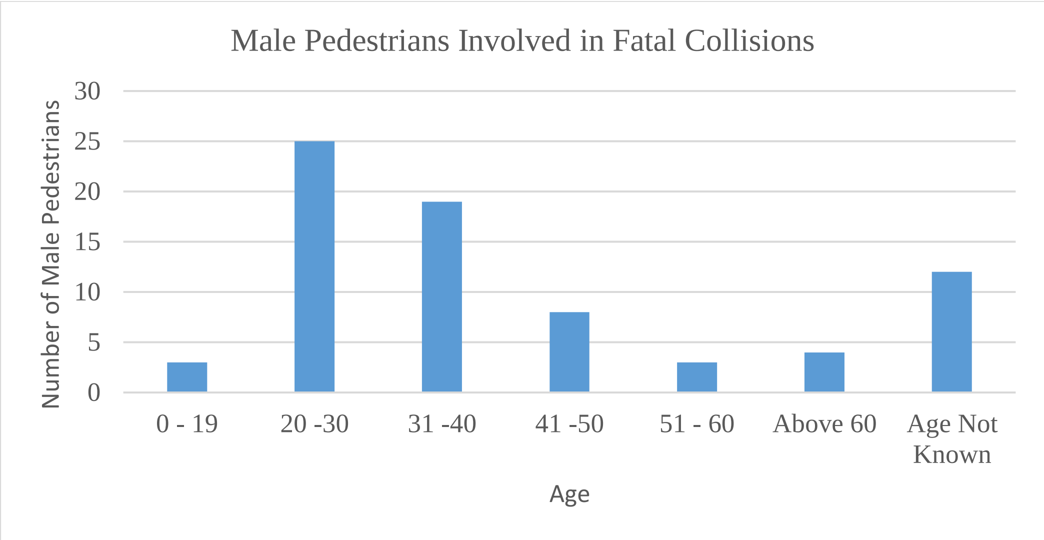


Figure III-3: Male Pedestrians Involved in Fatal Collisions. Source: Author, 2023

Table III-13: Female Pedestrians Involved in Fatal Collisions

Female Pedestrians Involved in Fatal Collisions	
0 - 19	1
20 - 30	1
31 - 40	5
41 - 50	0
51 - 60	4
Above 60	0
Age Not Known	1
Total	**12**

Source: Author, 2023

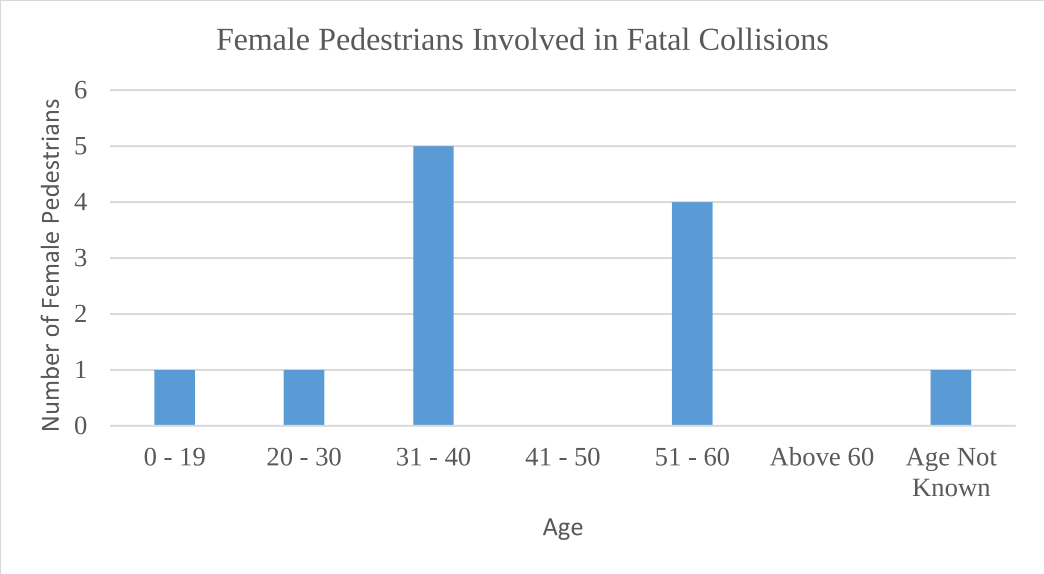


Figure III-4: Male Pedestrians Involved in Fatal Collisions, Source: Author, 2023

Table III-14: Male Pedestrians Involved in Slight Injuries Collisions

Male Pedestrians Involved Slightly Injuries Collisions	
0-19	4
20-30	11
31-40	7
41-50	0
51-60	5
Above 60	1
Age Not Known	17
Total	**45**

Source: Author, 2023

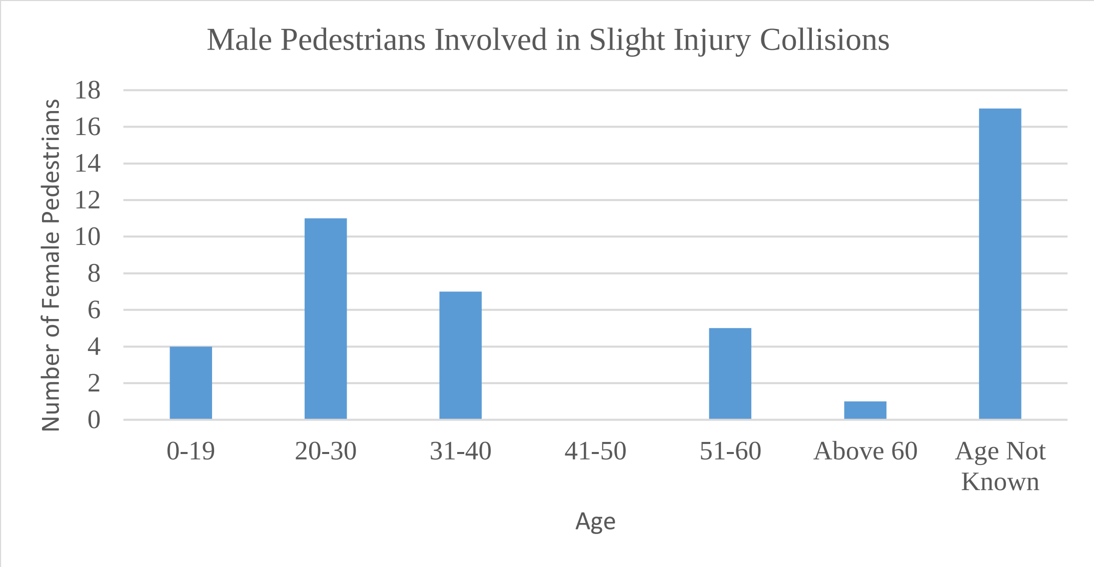


Figure III-5: Male Pedestrians Involved in Fatal Collisions, Source: Author, 2023

Table III-15: Male Pedestrians Involved in Slight Injuries Collisions

Age Profile	No. Female Pedestrians Involved in Slight Injuries Collisions
0-19	1
20-30	5
31-40	8
41-50	3
51-60	0
Above 60	0
Age Not Known	7
Total	**24**

Source: Author, 2023

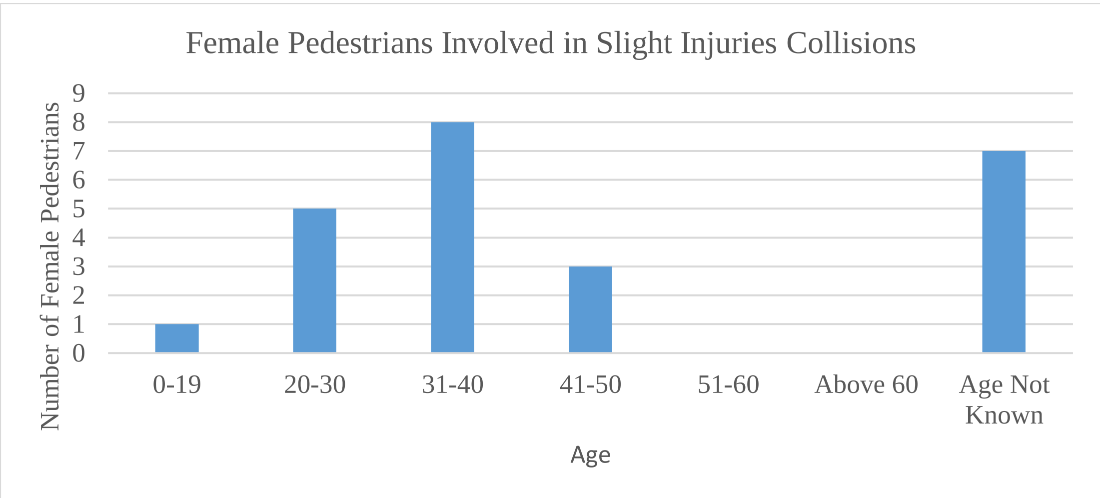


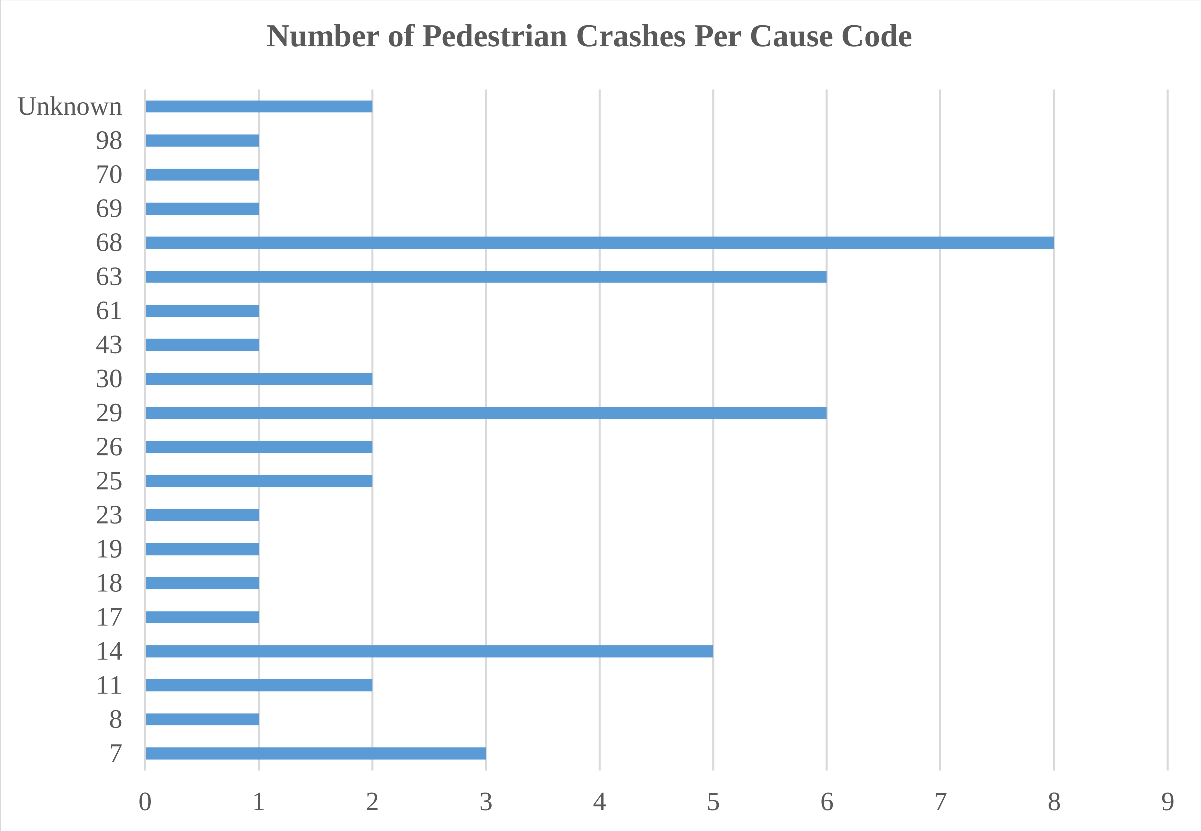
Figure III-5: Male Pedestrians Involved in Fatal Collisions, Source: Author, 2023

Table III-16: Male Pedestrians Involved in Slight Injuries Collisions

Accident Cause Code	**No. of Pedestrian Crashes**
7	3
8	1
11	2
14	5
17	1
18	1
19	1
23	1
25	2
26	2
29	6
30	2
43	1
61	1
63	6
68	8
69	1
70	1
98	1
Unknown Cause	2
Total	**48**

Source: Author, 2023

Figure III-3: Male Pedestrians Involved in Fatal Collisions



Appendix IV: Data Collection Questionnaire

The following data collection questionnaire was developed and used during the study.

<u>Objective 1: To assess the risk of demographic factors in pedestrian safety at level crossings</u>

1. Does gender affect pedestrians at crossings near roundabouts?

1.1 Which amongst the following best describes your gender?

a. Male: …………… b. Female: ……………….

2. Does age affect pedestrian safety at crosswalks? (No. of pedestrians crossing by age)

2.1 What is your age?

0-10: …. 11-20: …. 21-30: …. 31-40: ……. 41-50: …. 51-60: … Above 60: ………..

2.2 What is your highest level of education?

Primary: …………… Secondary: ………….. Tertiary: …………. None: …………

2.3 What is your level of Knowledge of Traffic Rules and Regulations?

None: …………….Low: ………… Medium: … High: …. Excellent: ……………

2.4 As a pedestrian, do you feel safer while crossing the road with or without the following traffic control devices? (YES/NO)

Markings: ………….. Signs: ………….. Signals: … Police: … All: ……………..

2.5 How many often do you cross the road at this location?

Daily: ………… Weekly: …………. Monthly: ………………. Yearly: ………………..

Appendix V: Sample Traffic Data Collection Sheet for Haile Selassie Roundabout (R3)

Tables V-1 and Table V – 2 below shows sample traffic data collected during the study.

Table V – 1: Sample Traffic Data Collected at Haile Selassie Roundabout

Time	**Bicycles**	**Motorcycle**	**Private Car**	**PSV**	**Pick-Ups**	**Lorries**	**Trucks**
6.00-6.15 am	0	4	14	10	5	4	4
6.15-6.30	1	8	16	13	3	6	5
6.35-6.45	0	11	20	15	7	7	7
6.45-7.00	0	9	25	14	4	9	9
7.00-7.15	1	5	21	19	7	6	6
7.15-7.30	2	7	24	20	6	5	8
7.30-7.45	6	10	28	22	8	9	10
7.45-8.00	4	13	21	30	5	3	7
8.00-8.15	2	11	13	17	2	6	5
8.15-8.30	0	8	19	14	3	5	2
8.35-8.45	0	14	22	20	9	11	8
8.45-9.00	1	11	17	15	8	6	4
9.00-9.15	2	9	13	8	5	12	7
9.15-9.30	4	13	14	15	6	8	3
9.35-9.45	2	11	17	21	7	5	2
9.45-10.00	0	10	20	23	10	4	3
10.00-10.15	1	7	13	15	8	3	4
10.15-10.30	1	3	11	12	5	5	2
10.35-10.45	2	5	9	7	3	4	6
10.45-11.00	5	11	14	13	7	8	9
11.00-11.15	3	16	17	18	9	7	5
11.15-11.30	4	10	13	15	7	5	4
11.35-11.45	1	9	11	12	5	3	7
11.45-12.00	2	11	12	10	7	6	4

Time	Bicycles	Motorcycle	Private Car	PSV	Pick-Ups	Lorries	Trucks
12.00-12.15	1	7	10	8	5	3	4
12.15-12.30	2	5	8	10	4	6	3
12.35-12.45	0	6	11	13	3	2	5
12.45-1.00	0	3	9	15	6	4	2
1.00-1.15	1	4	7	8	5	6	3
1.15-1.30	1	5	10	15	7	5	4
1.35-1.45	0	9	13	18	4	7	6
1.45-2.00	1	12	22	17	6	8	9
2.00-2.15	2	15	30	16	8	6	5
2.15-2.30	3	13	21	14	5	4	3
2.35-2.45	5	11	19	12	8	2	4
2.45-3.00	2	9	22	10	7	5	2
3.00-3.15	4	10	14	13	6	3	7
3.15-3.30	1	8	11	18	4	1	2
3.35-3.45	0	5	17	9	8	5	3
3.45-4.00	2	9	22	15	5	8	6
4.00-4.15	3	8	20	19	3	5	4
4.15-4.30	4	7	18	21	6	8	7
4.35-4.45	2	14	16	18	4	7	6
4.45-5.00	1	15	19	24	2	5	9
5.00-5.15	3	16	22	27	5	9	6
5.15-5.30	6	21	28	34	9	8	7
5.35-5.45	5	27	32	36	11	5	4
5.45-6.00 pm	8	34	39	41	10	7	3

Table V - 2: Sample Data Collected at Haile Selassie Roundabout (R3)

Time	Single	Group	Right Angle	Skew	Holding Hands	Talking to each other	Talking on Phone	Observing oncoming Traffic	Not observing oncoming traffic	Police hand signal
6.00-6.15	12	4	12	4	0	2	2	14	2	1
6.15-6.30	10	11	21	0	2	6	1	21	0	4
6.35-6.45	9	3	10	2	0	0	0	10	2	2
6.45-7.00	10	0	8	2	2	8	0	10	0	5
7.00-7.15	11	5	16	0	0	0	0	14	2	0
7.15-7.30	14	0	14	0	6	10	3	10	4	7
7.30-7.45	20	6	23	3	0	0	2	26	0	0
7.45-8.00	13	7	18	2	4	8	0	20	0	9
8.00-8.15	20	10	25	5	0	10	0	27	3	11
8.15-8.30	19	8	27	0	0	13	2	24	3	7
8.35-8.45	15	4	16	3	2	4	0	17	2	4
8.45-9.00	28	30	54	4	8	0	2	48	10	13
9.00-9.15	24	28	47	5	0	15	0	44	8	9
9.15-9.30	30	21	42	9	2	18	4	48	3	11
9.35-9.45	29	38	49	18	4	21	0	61	5	2
9.45-10.00	29	60	76	5	12	28	0	69	12	14
10.00-10.15	32	68	84	16	16	36	0	100	0	25
10.15-10.30	18	45	58	5	0	14	2	59	4	17
10.35-10.45	29	54	73	10	4	19	1	80	3	20
10.45-11.00	41	38	66	13	2	22	2	71	8	19
11.00-11.15	30	29	56	9	0	14	1	57	2	11
11.15-11.30	47	50	89	8	8	26	2	95	2	17
11.35-11.45	41	38	61	18	0	32	0	71	8	20
11.45-12.00	41	37	65	13	2	31	0	70	8	13

Time	Single	Group	Right Angle	Skew	Holding Hands	Talking to each other	Talking on Phone	Observing oncoming Traffic	Not observing oncoming traffic	Police hand signal
12.00-12.15	29	48	57	20	4	18	1	68	9	19
12.15-12.30	37	46	71	12	0	38	0	76	7	21
12.35-12.45	48	36	54	30	0	28	0	72	12	8
12.45-1.00	41	39	60	20	2	36	0	65	15	28
1.00-1.15	39	47	56	30	4	28	0	72	14	30
1.15-1.30	23	56	56	23	0	14	0	70	9	11
1.35-1.45	27	54	60	21	0	20	1	65	16	21
1.45-2.00	33	40	53	20	10	0	0	67	6	19
2.00-2.15	37	37	56	18	0	0	3	50	24	20
2.15-2.30	28	45	43	30	0	0	0	47	26	28
2.35-2.45	30	42	54	18	2	0	0	60	12	11
2.45-3.00	48	58	90	16	8	8	0	100	6	10
3.00-3.15	36	38	54	20	0	12	2	59	15	19
3.15-3.30	58	64	112	12	6	14	0	96	18	9
3.35-3.45	42	70	56	56	0	20	1	80	32	21
3.45-4.00	38	45	58	15	2	14	0	60	13	24
4.00-4.15	44	60	88	16	0	2	0	90	14	30
4.15-4.30	56	75	120	19	2	18	0	100	31	19
4.35-4.45	64	68	102	30	8	30	0	111	21	28
4.45-5.00	56	72	98	30	0	28	0	102	26	30
5.00-5.15	64	71	100	35	2	32	4	102	33	18
5.15-5.30	47	84	91	40	0	36	0	105	26	14
5.35-5.45	71	95	130	36	80	20	2	144	22	40
5.45-6.00	64	87	130	21	4	34	0	128	23	24

Appendix VI: Pedestrian Safety Risk Factor Calculation, W

Risk index	Risk description	Roundabout R1 (University Way)				Roundabout R2 (Kenyatta Avenue)				Roundabout R3 (Haile Selassie Avenue)				Midblock/ Sections	
		R11	R12	R13	R14	R21	R22	R23	R24	R31	R32	R33	R34	M1	M2
m1	Road Width	10.5	10.5	14	14	14	10.4	14	14	10.5	10.5	10.5	14	10.5	10.5
m2	Number of Traffic Lanes	1.45	1.45	1.2	1.2	1.2	1.45	1.2	1.2	1.45	1.45	1.45	1.2	1.45	1.45
m3	Presence of Kerbs	1	1	1	1	1	1	1	1	1	1	1	1	1	1
m4	Presence of Bicycle Path	1	1	1	1	1	1	1	1	1	1	1	1	1	1
m5	Presence of Streetlights	1.4	1	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
m6	Angle of Crossing	1	1	1	1	1	1	1	1	1	1	1	1	1	1
m7	Presence of Bus Stops	1.1	1.1	1.1	1.1	1	1	1	1	1.1	1.1	1.1	1.1	1	1
m8	Neighbouring Crossings	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
m9	Horizontal Road Marking	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1	1
m10	Pedestrian Visibility due to vertical marking	1	1	1	1	1	1	1	1	1	1	1	1	1	1
m11	Pedestrian Visibility due to parked vehicles	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
m12	Road sign visibility	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
m13	Speed limit	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
m14	Presence of special pedestrian target (destination)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
m15	Raised crossings	1	1	1	1	1	1	1	1	1	1	1	1	1	1
m16	Road humps	1	1	1	1	1	1	1	1	1	1	1	1	1	1
m17	Coloured horizontal marking	1	1	1	1	1	1	1	1	1	1	1	1	1	1
m18	Safety island or marking	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6

Risk index	**Risk description**	**Roundabout R1 (University Way)**				**Roundabout R2 (Kenyatta Avenue)**				**Roundabout R3 (Haile Selassie Avenue)**				**Midblock/ Sections**	
		R11	R12	R13	R14	R21	R22	R23	R24	R31	R32	R33	R34	M1	M2
m19	Narrowing on the road	1	1	1	1	1	1	1	1	1	1	1	1	1	1
m20	Additional road signs	1	1	1	1	1	1	1	1	1	1	1	1	1	1
m21	Additional lighting	1	1	1	1	1	1	1	1	1	1	1	1	1	1
m22	Barriers	1	1	1	1	1	1	1	1	1	1	1	1	1	1
m23	Other factors	1	1	1	1	1	1	1	1	1	1	1	1	1.1	1.1
m24	Pedestrian Behaviour (Obeying Traffic)	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
m25	Actual vehicle speeds	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
m26	Previous accidents (3 years prior before)	1.375	1.375	1.375	1.375	1.225	1.225	1.225	1.225	1.3	1.3	1.3	1.3	2.425	2.425
	Total Risk Factor (W)	27.0	19.3	29.7	29.7	24.1	21.6	24.1	24.1	25.5	25.5	25.5	28.1	43.2	43.2