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School of Transportation Sciences

Master of Transportation Sciences

Master's thesis

An Assessment of the Crossing Behavior and Conditions for Vulnerable Road users on a Highway Setting in Harare, Zimbabwe

Kudakwashe Chaweka

Thesis presented in fulfillment of the requirements for the degree of Master of Transportation Sciences, specialization Traffic Safety

SUPERVISOR :
Prof. dr. Tom BRIJS

CO-SUPERVISOR :
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2020

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Acknowledgements

I would like to express my humble gratitude to the Almighty God who gave me the courage, intellect and opportunity to conduct this Master Thesis Part 1, and am hopeful such grace can be sufficiently granted for the second part of the thesis. Without the grace from above, I would not manage much in my own efforts.

Much appreciation and gratitude also go to my Mentor (Dr Wouter Van Haperen) and Local supervisor (Dr Smart Dumba) who took time to correct and edit my work and advised me at each and every step of the way. Without your regular feedback I would not have managed to pull this out and am really grateful for your time and commitment in seeing this becomes a success. I also acknowledge and am grateful to my Promoter Professor Dr. Tom Brijs whose published works I regularly consulted and referred to in drafting my Master Thesis Part 1 without which this could not have been a success.

I would also like to thank my sponsors for the Master's program VLIR UOS who awarded me this amazing opportunity to study in Belgium from my country. The experience has been life changing and to be able to go as far as conduct this thesis thus far, it's been their support which has been consistent sufficient.

Lastly, I would like to acknowledge my family though miles away they have been supportive throughout my study here in Belgium. Their moral support and prayers have been so vital in allowing me to continuously work hard and focus on this Thesis, without which I would not have pulled through.

Abstract

The following study bridges the Urban Land use Planning and Transport planning interface where poor coordination of these two results in road safety challenges for Vulnerable Road Users. The study explores how urban sprawl in the form of linear settlement development patterns have a significant impact on highway road classification and function (mobility and accessibility). As settlements like Kuwadzana extension (High density) and Glaudina (medium density) continue to develop along Harare-Bulawayo highway, its function has been altered and confused. This has seen high speed traffic (Fast moving vehicles) interact with low speed traffic (VRUs crossing the junction) under mixed traffic conditions which has serious implications on the safety of the latter road users. Hence, pedestrians of all age groups particularly the young, elderly and physically challenged, cyclists, and motorcyclist bear the greatest burden. This is further worsened by the fact that much of the transport planning in the country has focused on automobile infrastructure and facilities and is largely piecemeal and uncoordinated making VRUs worse off. Thus, as these continue to grow in size and population, so too will the demand volumes on the junction and if no action is taken more and more VRUs will be exposed to the risk of collision on the Junction.

Therefore, given the above, the main focus of the study is to observe and analyse the crossing behaviour of VRUs on the two-way, four lane highway junction looking at various indicators that may allude to the safety or unsafety of the junction and its implications to the exposure risk of collision. The indicators will be explored in a systems approach looking at infrastructural, distraction, traffic safety aids, driver characteristics and VRU characteristics. Some of the specific indicators that fall in these categories include crossing distance, crossing path, crossing speed, yielding behaviour, looking behaviour and the age and gender of both drivers and VRUs which are explored in detail in the study. The study adopted a quantitative and qualitative approach to data collection where both primary data sources and secondary data sources were be consulted. Video image technique (in the form of a high resolution canon digital camera) and human observers were utilised in the data collection period. The Ministry of Transport and The City of Harare were consulted for permission and some secondary sources of data needed in the study. Data collection was done on a six day schedule making hourly recordings of the peak morning , off peak afternoon and evening peak period. Some of the data collection instruments utilised were a tap measure , stop watch and a complementary form which was used to gather more evidence by human observers.

At least 3205 Vulnerable Road Users were captured and analysed in the six day period. Males constituted at least 67% of the people that crossed the junction while 33% were female. The greater number of the people that crossed the junction especially morning peak period was headed towards Glaudina end. In the afternoon and evening the volumes of people crossing towards the other direction Kuwadzana Extension increased and these were people returning from work, school and some business endeavours. The study confirmed that the road classification and functionality has altered over time due to developments of linear settlements. The study also realised that ownership and management of different road segments is largely sectoral and as such issues to do with growth of these settlements and balancing of form , usage and functionality have been left unattended to. As a matter of consequence no infrastructure or measures have been put in place to ensure that the growing numbers of people crossing the junction do so with ease and their safety guaranteed. As confirmed by other previous studies of this nature, males adopted more risky crossing behaviour(14%) than females (5%) witnessed by them taking smaller gaps as well as taking some evasive action(jogging) especially in peak periods. 71% of those that crossed did so in staged crossing completing the first two lanes then wait on the midblock section before completing the other two lanes compared to 29% that did single crossing. Again males

engaged more in single crossing than females and they were willing to take smaller gaps and take some evasive action (jogging) to complete their crossing.

The study also discovered that the mean crossing speeds for this current study are much higher than those given in the HCM and witnessed in other studies. The average crossing speed was 1.29m/sec which is higher than the 1.25m/sec given in the HCM and males(1.32m/sec) had a higher average speed than that of females (1.27m/sec). The study also confirmed that in such a highway setting the mean accepted gaps and rejected gaps in crossing are higher than witnessed in some studies. Binomial Logit model was incorporated to verify some for the factors that determined accepting or rejecting a certain gap in traffic. Gender , vehicle speed and waiting time at the kerb were the significant aspects in determining if one accepted or rejected a gap from the model results. However , contrary to some studies , smaller waiting time at the kerb was significant which is usually not the case . VRUs are likely to take smaller gaps and risk crossing if they have waited for more than 30 seconds as they become more impatient.

There is therefore need for reviewing the road classification and functionality in light of the growing linear settlement dynamics along many highways in the country. The design speed limit of 120km/hr for highways is still relatively higher than global standards which enhances the risk element when considering such high volumes of people crossing it on a daily basis. The speed limit hence also needs to be reviewed as average speeds gathered prove that in the event of a collision some serious casualties and injuries can be witnessed. Improvements in public transport provisions can also address some of these challenges, some speed reduction measures like speed humps and long term overpass infrastructure. Witnessing an accident occur during data collection demonstrated that there are indeed some risk elements worth noting and coming up with some measures to improve the safety conditions for VRUs. There are signs of compliance in crossing behaviour in the manner people crossed in groups and following another in accepting or rejecting a gap. The study however due to some constraints could not fully explore behavioural aspects and some demographic aspects like age which could have improved the quality of the outcome. Lack of some data aspects also limited the study in addressing the objective on intensity and nature of linear settlement patterns over time. Thus, future studies could probe more on these aspects with improved technical resources, more time and other methods to actually get people’s concerns over the crossing conditions and their behaviour in the highway junction.

Key terms: Vulnerable Road Users, Road Classification and Function

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Abbreviations

CUTR- Centre for Urban Transportation Research

GIS- Geographic Information Systems

IRAP- International Road Assessment Program

M2W- Motorised Two-Wheeler

M3W- Motorised Three-Wheeler

OECD- Organisation for Economic Corporation and Development

RTMC- Road Traffic Management Corporation South Africa

TSCZ- Traffic Safety Council of Zimbabwe

SPSS- Statistical Package for Social Sciences

VRU - Vulnerable Road Users

1. Introduction

Among a myriad of challenges confronting experts in urban development lies the challenge of rapid urban development which has seen a lot of uncoordinated land use and transport planning. As some citizens have been finding it tough to cope with the demands of the life in the city centres, they have resorted to occupying land and building along major highways resulting in linear settlement structures. The resultant linear settlements have had a multiplier effect in further creating other challenges such as congestion and traffic crashes. It is the poor and vulnerable road users that have taken a huge blow from the latter, and as such planning for the safety of these VRUs has become an integral part of traffic safety experts in both developing and developed countries. The scope of this study is thus to examine some of the traffic safety concerns created by such developments on VRUs on a typical four lane urban highway, and an unsignalized T junction which feeds into two adjacent neighbourhoods in Harare, Zimbabwe. The first part of this study presents some definition of key terms that will be used in the study. The following section provides an overview of crash trends involving vulnerable road users with some definitions of key terms of the study. The problem statement is presented followed by the research objectives and research questions for the study. The scope of the study area will then follow after which a justification of the study is presented.

Definition of Key Terms

- **Vulnerable road users**: The term Vulnerable Road Users (VRU's) may be generally defined as the road users who are most at risk for serious injury or death when they are involved in a motor-vehicle-related collision (Zeeger et al, 2010, Hoque et al undated, Jovanov et al, 2017). These include pedestrians of all ages, types and abilities, particularly older pedestrians and people with disabilities, cyclists, motorcyclists, physically impaired and elderly road users (Hoque et al, undated). They are called vulnerable for they do not have much covering on them to protect them in case of a collision like airbags and seatbelts and they are smaller and less visible to other road users (Jovanov et al, 2017). For instance, a pedestrian is 284 times more likely to be injured or killed in a car-pedestrian collision than the motorist. A cyclist is 150 times more likely to be injured or killed in a car-bicycle collision than the motorist and a motorcycle driver is 50 times more likely to be injured or killed in a car-motorcycle collision than the driver of the car (Jovanov et al 2017).
- **Road Classification and Function**: Functional classification is the process by which the roads are grouped into classes by the service they are intended to provide. Basic to this process is the recognition that a trip involves movement through a network of roads (Talvitie, 1996). This classification however differs from country to country given the level of economic development and mixed traffic conditions however, regardless of such the basics are applicable to all countries. Allied to the idea of channelling traffic is the dual role the road network plays in providing access to property and in travel mobility (Talvitie, 1996) (IRAP, undated). Access is a fixed requirement, necessary at both ends of any trip. Mobility along the path of such trips is defined in terms of "level of service." It can incorporate a wide range of indicators: road condition, travel speed, degree of congestion, and so forth.

1.2 Background of the study

According to WHO (2016), 50 % of the 1,25 million people that perish annually from road traffic crashes are VRUs that is pedestrians, cyclists and motorcyclists. Most of these crashes are recorded in low to middle income countries which constitute 90% of the world's fatalities from road traffic. Among the total road traffic deaths in the world, half are motorcyclists (23%), pedestrians (22%) and cyclists (5%) (Mahmud et al 2018). From a European perspective, of the above figure of fatalities recorded annually around the globe, 23 500 people died in 2017 which is the safest across the entire globe (European commission fact sheet 2018). Vulnerable road users accounted for almost half of the road victims that is 21% of all people killed on roads were pedestrians, 25% two-wheelers (14% were motorcyclists, 8% were cyclists and 3% mopeds riders) (European Commission fact sheet 2018). Compared to other regions, the numbers recorded in Europe are the lowest with the Sub -Saharan Africa and Asia having a figure of up to 70% fatalities recorded for VRUs annually (Wisman et al, 2016). This figure however can be in reality more than what is presented in the above latter regions, given the fact that there are issues of accident underreporting and poor accident data collection and management in these regions.

At national levels the number of accident victims for Vulnerable road users is quite high even in regions with the lowest accident fatalities for instance in Europe. At least 50% of the recorded crashes in Romania are pedestrians particularly children who are overwhelmed by the traffic streams and in the process fail to calculate their critical time gaps (Jovanov et al, 2017). Elsewhere in other countries like Bangladesh, (VRUs) that is pedestrians, bicyclists, cycle rickshaw occupants and motorcyclists constitute by a margin the biggest share (around 80%) of urban travel and they account for nearly 80 percent of road traffic accidents fatalities in urban areas (Hoque et al undated). In India at least 47 % of the annual fatalities recorded involve VRUs in the form of motorised two-wheeler (M2W), Pedestrian, and Bicyclist and, motorised-three-wheeler (M3W) (Shaikh and Freidrikson ,2016). A study conducted by Shaikh and Freidrikson (2016) in India, of the recorded 407 accidents, 37% (151) recorded VRU involvement and of all fatalities (N=199), 40% were accounted by VRUs. These statistics in the above two cases of Bangladesh and India, provide a typical scenario of the present study whereby VRUs are faced with mixed traffic conditions and share the same road space with fast moving vehicles especially in sub urban and rural areas (Hoque et al undated, Shaikh & Freidrikson, 2016). Bringing matters closer home, in South Africa of the 14,071 deaths recorded in 2016, 5410 of these were pedestrians which accounts for 38% of the total accident recorded this year (RTMC, 2017). Although not well documented and detailed statistics are available, in Zimbabwe at least 2000 pedestrians died after being hit by a car with more than 30 000 being injured in the same period (Traffic Safety Council of Zimbabwe undated).

Therefore, the above statistics present an overview of the challenges traffic safety experts are confronted with in as far as the safety of VRUs is concerned. This is especially in the context of mixed traffic conditions and on highways both in developed and developing countries. This therefore warrants for studies of this nature, to understand the safety risk and vulnerability of these road users in the context of an unsignalized junction along the highway, where there are growing linear settlements on either side of the road.

1.3 Problem Statement

Uncoordinated land use and transport planning has created numerous challenges for many cities in both developed and developing countries, one of which being increased exposure to collision and injury risk to VRUs. Linear settlement development along major highways in South Eastern Europe for instance, has created more demand for traffic that is mixed road function (usage of the road as fast distributors for fast longer distance motorized traffic and as a route for slow local traffic) creating major road safety problems especially to VRUs (Jovanov et al 2017). In the context of the developing world countries such as India, Bangladesh and Zimbabwe, the mixed road function is worsened by mixed traffic conditions where fast moving vehicles (up to 120km/hr) have to share the same road space with road users (VRUs) travelling at a very diverse low speed (at least 5km/hr). This creates a dangerous crossing zone for the latter users whose exposure to collision risk becomes higher under the mixed traffic and speed conditions. According to a scoping review for studies on VRUs published in English, many have been conducted in the USA and Europe (Van Haperen et al, 2016). At country level most, studies were conducted in USA (38%), Canada (8%), China (8%), the UK (4%) and Israel (4%) (Van Haperen et al, 2016). Most of these studies were behavioural observation studies that mainly focused on locations where interaction between road users is required. Mainly signalized intersections (39%) and pedestrian crossings (31%) have been extensively researched (Van Haperen et al, 2016). In the developing context such studies can be witnessed in India and Bangladesh, (IRAP undated, Hoque et al undated). Other studies in the developing context were also conducted in Ghana, Kenya and Tanzania and some of these focused on the impact of roadside developments on road function and classification (Muriithi, 2008).

There is a growing influx of such linear settlement developments along major highways in Zimbabwe, altering road function and classification as well as enhancing the exposure to collision and Injury risk for VRUs. The exposure is also worsened by the fact that pedestrians are always willing to shorten distances when crossing, reduce waiting times, violate the traffic regulations and disregard the risks that are associated with doing such. Furthermore, there are limited accident statistics in developing countries, Zimbabwe included which makes it difficult to quantify the traffic safety problems for VRUs (Jovanovic et, 2017). As such studies remain scarce, and as the rate of these linear settlement developments continue to intensify, the safety concerns of VRUs will remain unattended. Thus, as an attempt to add to the body of knowledge, this study seeks to analyse the crossing behaviour of VRUs and factors that expose them to collision and injury risk on the junction Kuwadzana extension turn off along Harare-Bulawayo highway.

1.3 Aim of the Study

The study seeks to analyse the crossing behaviour of VRUs and factors that expose to collision and injury risk on the junction Kuwadzana Extension turn off along Bulawayo Road.

1.3.1 Objectives of the Study

1. To understand in detail the current and previous road function and classification of the highway prior to increased growth in linear settlement patterns along it
2. To understand the nature, intensity and growth trends of linear settlements and the implications of such to the safety of VRUs residing in these
3. To observe the interaction of VRUs with other road users on the junction
4. To review previous accident data involving VRUs on the junction and compare those with the observed indicators
5. To proffer possible solutions and recommendations on what could be done to improve the safety of VRUs given findings from the previous steps.

Table 1 Research Questions and Methodological Approach

Research questions	Methodological approach
1. How has the national highway been altered in terms of classification and function given linear settlement developments • What is the nature of these residential developments, their intensity and anticipated future growth patterns? • What are the vehicular and VRU demand volumes given increase in land use activities around the area?	GIS based mapping techniques and analysis Video image techniques
2. How do VRUs interact with other road users on the junction given the current state of infrastructure and facilities? • What is the current state of infrastructure and facilities for VRUS on the Junction? • How do VRUs cross the junction-critical look at indicators such as gap acceptance, looking behaviour, crossing speed, path, time? • What do these indicators reflect of the safety of the junction to VRUs	Video image techniques And human observers Descriptive analysis and use of statistical methods
3. What possible measures can be adopted to improve the safety of VRUs on the junction	Literature review

Source : Self ,Constructed , 2019

1.4 Scope of the study Area

The study site is located in the capital city of Harare, Zimbabwe along one of the major arterial roads that is Harare-Bulawayo road. The highway is a four-lane road with double lanes separated by a mid-section that is an island and it has bidirectional flow of traffic. Directly connected to the highway, is a local distributor which forms a T junction with the highway and this feeds into Kuwadzana Extension high density suburb. On the other side of the road is a medium density suburb, Glaudina which is a recent development and there is an unpaved approach leg that has since been created which feeds into the highway making it a four-legged junction. The mid-section part on the junction is slightly raised and cars moving from Kuwadzana extension have to yield to those moving in either direction along the highway. The junction is not signalized or stop controlled and motorists use intuition to give way to one another on the junction. There is constant interaction of inhabitants from the two adjacent neighbourhoods which generates traffic both vehicular and VRU towards fulfilling day to day obligations. The study site may be illustrated in the following figure:

Figure 1: Google Images of The Study Area

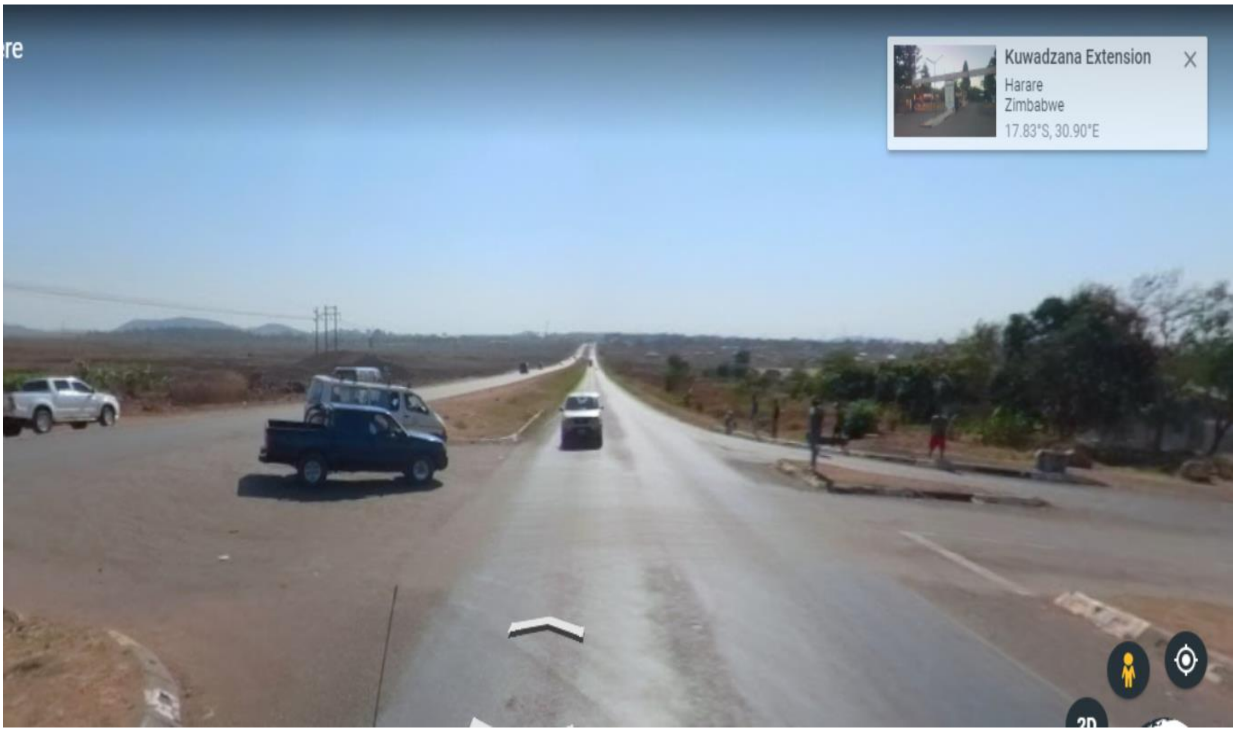


Figure 2 Google Image of the Study Area . *Source: Google Earth Images, 2019*

1.5 Justification of the study

Planning for the needs of VRU road users is key to the development of any city for almost all journeys either start or end with walking or cycling mode. Thus, as everyone becomes a pedestrian at one point or the other, it makes everyone an interested stakeholder in as far as ensuring that VRU safety is upheld especially in areas where low income citizens dwell. Realising that there is rapid urbanization taking place in Zimbabwe, development of linear settlements along major highways has taken centre stage with the side effects of such overlooked by the planning authorities. There are a lot of incidents both reported and not reported where pedestrians or cyclist have been hit by fast moving vehicles along these highways when they attempt to cross the road. Some of those victims of such crashes involve school going children who because of their age fail to calculate the critical gap needed to successfully cross the road leading to crashes. As these settlement patterns continue to grow and develop, so too will the need to cross the highway which increases the exposure of VRU to collision and crash risk. Thus, conducting studies that examines VRU's safety on crossing such highway junctions are of critical importance both in the present and for forward planning to device proactive measures to ensure that the majority of citizens who rely on cycling or walking in this part of the world are safe when crossing the roads.

2.0 Literature Review

2.1 Introduction

Based on crash statistics involving Vulnerable Road Users (VRUs) across the globe, the need for conducting vast research has been embraced by scholars and practitioners in the domain of Traffic safety. This is evidenced by the growing number of publications on the subject, and some of those will be reviewed in this discussion, in the context of current study. The next section tackles issues of linear settlement developments along highways and what it implies for road hierarchy and functionality, as well as the consequences of such to the safety of VRUs. A review of behavioural observation studies on VRUs is presented next, with a detailed analysis of the indicators that were investigated in the studies and how they relate to safety risk for these users. These indicators include infrastructural indicators, distraction, traffic safety aids, personal characteristics of VRUs, driver characteristics and vehicle characteristics. The following section will also explore theories of pedestrian crossing and these include gap acceptance theory and multi lane crossing. Typical behaviours in observation studies such as informal communication, yielding behaviours, crossing behaviours, looking behaviours, and speeding are also reviewed from already conducted behavioural observation studies. The last section of the review will provide a detailed analysis of the methodological approaches to VRU studies that have been and are in use in literature which also then paves way for the next chapter that is the methodology. These methodologies include use of GIS in analysing settlement development patterns, use of video image techniques and human observers in VRU studies. A conclusion of the chapter is then given at the end.

2.2 Consequences of Disjointed Land Use and Transport Planning (Linear settlements) on Road Safety.

The incidents of VRU crashes along highways can better be analysed and understood from a land use planning and transport planning spectrum. Due to the fact that the road network system provides the nerve system upon which urban development (land uses) shape up, poor coordination of these two aspects has seen a number of challenges emerging one of them being road traffic crashes. In both developed and developing countries, settlement patterns have been allowed to crop along major highways which has had serious consequences on road classification and functionality (Jovanov et al, 2017). By default, a highway is originally designed as a major arterial or primary distributor of fast-moving traffic, just as the major arteries in the human body channel and pump blood to the veins throughout the entire human body (Vollpracht, 2013). Thus, an understanding of how and where to erect different land uses has a significant effect on increasing or lessening road traffic crashes. According to International Roads Assessment Program (IRAP, undated), it took a period of 50 years for developed countries to understand how infrastructure can mitigate road traffic crashes and then device principles on tackling it. One such developed country where linear settlement developments has had a significant impact on traffic Safety for VRUs is Romania (Jovanov et al, 2017). As in South Eastern Europe, and other areas across the globe, the rate of expansion (sprawling) of isolated communities along a highway has been rapidly reducing the effectiveness of nationally or regionally intended routes (Jovanov et al, 2017). By default, these roads are intended for fast moving traffic and their function is altered and confused by slow moving local traffic from these settlements which enhances risk for VRUs crossing these roads.

The challenge of linear settlements and road function on highways can also be witnessed in developing countries such as India, Ethiopia and Ghana. In a study conducted in Ghana, pedestrians who live or work close to the highway are exposed to the risk of being knocked down by vehicular traffic by 25% (Noora et al, 2016). Of those interviewed and at risk, 80% of the pedestrians expressed no fear to cross the highway randomly, and this random and disorderly way of crossing poses a great threat to public health along the N1 highway in Accra Ghana (Noora et al, 2016). There is also evidence from this study which suggest that despite provisions of footbridges to cross, about 20% still found them too high to climb and hence a proportion of 90% of pedestrians cross on unapproved sites (Noora et al, 2016). Thus, the study concluded that what also enhances the risk factor is the behaviour and attitude of VRUs themselves given their reluctance to make use of approved sites for crossing. However, this is one scenario whereby there are designated infrastructure or approved sites for crossing. What could be the circumstances of such on highways without such provisions in place, is one of the objectives for investigation in this study.

2.3 Understanding functional Classification of Roads

Countries define their roads based on two important aspects that is the administrative and functional classification (Talvitie, 1996). By administrative, countries organize their roads into hierarchical networks according to their main purposes, such as national roads for roads linking the capital to provincial centres, principal cities and other centres of national importance; urban roads for roads and streets serving transport demands within cities and towns; and, rural roads for local transport demands in rural areas (ibid). Functional classification looks at grouping roads in accordance to the services they are intended to render (IRAP undated, Talvitie ,1996). A functionally classified road network, assigns each road link a task that channels trips through a network efficiently. The basic concepts of road functionality are universally applicable despite varying economic, level and nature of development and mixture of traffic from one country to the other (Talvitie, 1996). The following schematic diagram illustrates of this concept and what it implies for traffic volumes, traffic speeds and hence traffic safety.

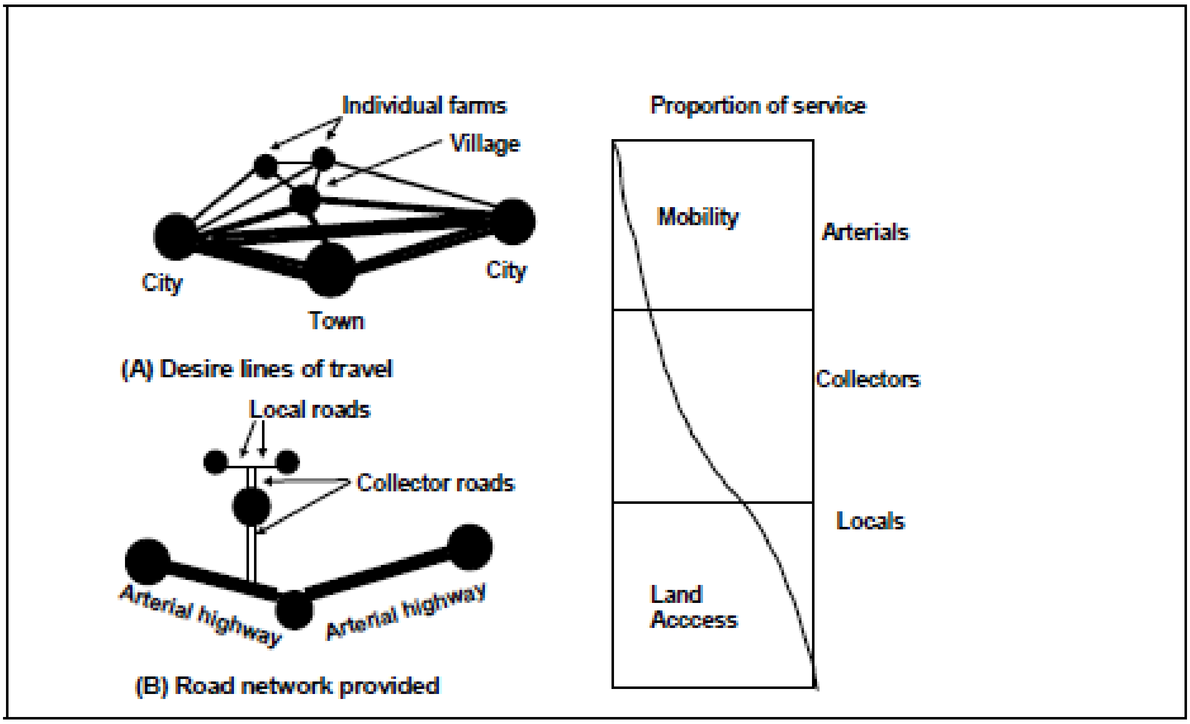


Figure 3 Road Classification and function In Terms of Accessibility and Mobility *Source: Talvitie 1996*

The basic concept behind this scheme is an illustration that a road provides the function of accessibility or mobility. The lines in the upper left part show paths of travel desires, connect trips and destinations. Line width indicates amount of travel and circle size the trip generating power of settlements (Talvitie, 1996). According to the design in the figure above, local roads ideally should emphasize the land access function, arterials the mobility function and collectors a compromise between the two functions. In other words, arterials ought to have the highest traffic volumes of high-speed vehicles, the greatest amount of commercial traffic and the longest average trip lengths (Talvitie et al, 1996). However, in reality as evidenced by the case studies in the above section and in other developing countries, main arterials like highways are now facilitating both the accessibility and mobility function catering for both commercial and residential traffic as well as fast- and slow-moving traffic. These are the typical road sections VRUs are confronted with crossing to and from along the highways, which exposes them to greater risks of collision.

2.4 Understanding factors In VRU safety Through A Systems Approach

To understand factors associated with VRU crashes and safety risk, there is need to adopt a systems approach where internal and external factors are holistically exploited towards devising measures to improve their safety. A system is made up of two components that is the internal and external environment. The internal risk factors originate from the internal operation of the system itself. For instance, a transportation system comprises the road users, vehicles, and the road environment. Interaction among any or all of these elements may result in unwanted events such as crashes. Some of the causes are related to road users and others may be associated with the vehicles and the road environment. On the other hand, the transportation system may also interact with the external environment or with other systems. External factors may arise from outside the systems, which also may have adverse effects on the operation of the system. The system can operate against any background and within any given operating environment ranging across the spectrum of socioeconomic, demographic, technological, cultural, political, and legal environments. Of keen interest in this study are pedestrians which is the predominant mode for VRUs in the context of Zimbabwe. Below is a figure which illustrates of the system variables important when dealing with pedestrian safety:

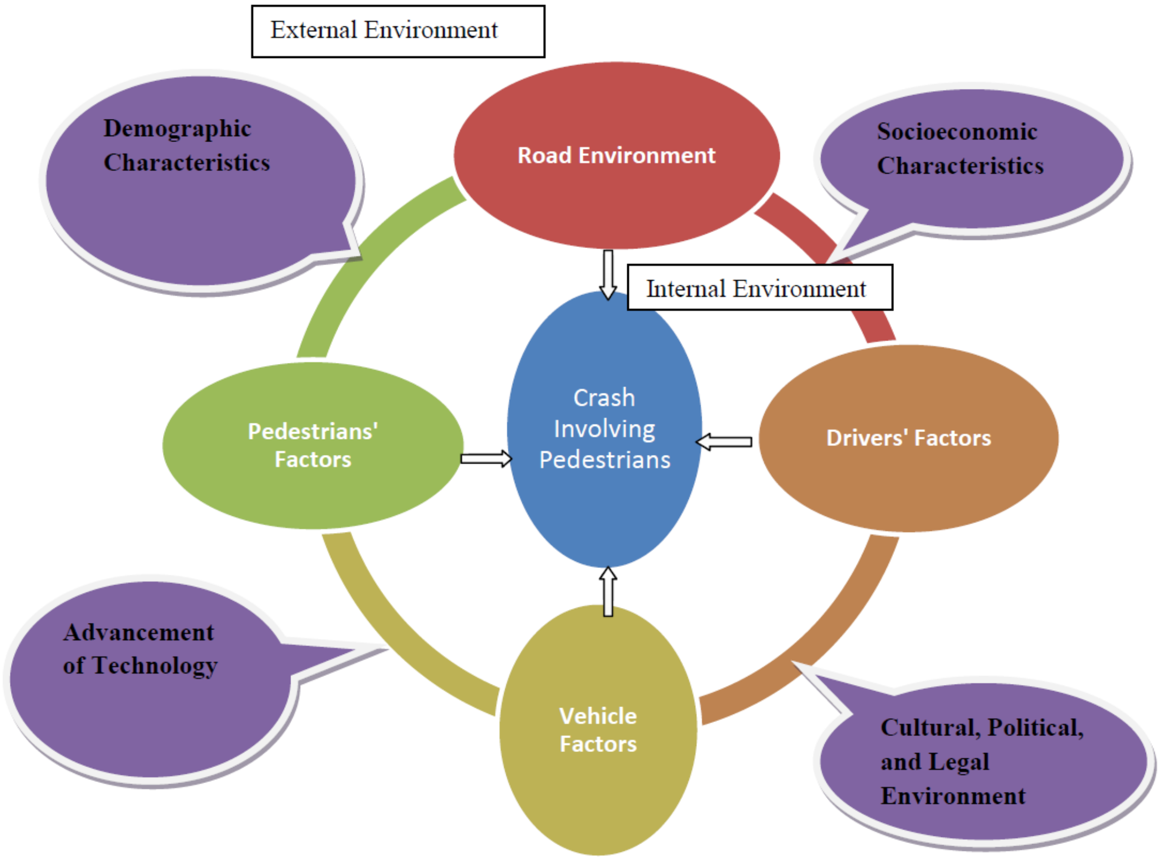


Figure 4 : A Systems Approach to Pedestrian Safety Analyses . *Source: (Tulu, 2015)*

The parties involved within any pedestrian safety systems approach in internal environments are: the drivers themselves, any pedestrians, the vehicles, and the road environment (Zegeer & Bushell, 2012). Each of the elements can make either a positive or a negative contribution to pedestrian safety, or have a fixed negative and positive effect on various aspects of any crash event. Thus, when analysing factors that involve VRUs it is not objective to apportion blame on one aspect or one road user for aspects that may lead to a crash may be attributed to a number of factors. The external environment consists of various factors and areas that influence pedestrian safety and these variables affect a pedestrian's exposure to involvement in a crash. The most common variables are political, legal, cultural, technological, social, economic, and demographic factors. Zegeer and Bushell (2012) revealed that crashes involving pedestrians are a complex interplay of conditions, which are in play not only during the crash, but also leading up to the crash. For instance, there is evidence from past studies which shows that, Sub-Saharan African countries had a higher road traffic risk as a result of driver perceptions, attitudes and behaviours when compared to the rest of the countries in the study (Nordfjærn, et al., 2011). Thus, to understand VRU safety risk and exposure, there is need to explore all factors both internal and external that is looking at all indicators that may point at safe or unsafe crossing conditions which may ultimately result in crashes, which is what this study aims to assess.

2.5 Behavioural Observation studies for VRUS Across the Globe

One of the leading factors in road traffic crashes is road user behaviour which accounts for 94% of the accidents that happen in the entire world, with road environment and the vehicle contributing 18% and 8 % of all accidents respectively (Polders & Brijs, 2018, Van Haperen et al, 2016). Behavioural observation studies may be defined as studies that emphasise on analysing the actions of road users in their natural setting (Polders & Brijs, 2018). They provide a chance to better understand the contributing factors influencing the occurrence of road crashes. Many behavioural observation studies that have been conducted thus far on VRUs have been primarily on monitoring how these road users interact with other road users and what makes the interaction safe or unsafe (Van Haperen et al,2016). Among these studies, pedestrians are included in 65% which is way higher than the 25% for cyclists (Van Haperen et al, 2016). The majority of these studies on behaviour for VRUS have mainly been focusing on crossing behaviour (40%), yielding behaviour (23%) and red light running (10%) (Van Haperen et al, 2016). Furthermore, in all these studies about 47 indicators have been identified and these consists of behavioural and situational indicators and road user characteristics (Van Haperen et al, 2016). These can be categorised as infrastructural indicators, distraction, interaction configuration, VRU characteristics and driver characteristics. Some of these indicators found in behavioural observations for VRUs include informal communication, yielding behaviour, crossing behaviour, looking behaviour, red-light running, interaction type, approaching behaviour, speeding, priority behaviour, and distraction while they interact with other road users (Polders & Brijs ,2018, Van Haperen et al ,2016 & Eby, 2011). The diagram below shows the proportion of behavioural observation studies and the main focus under investigation in the studies.

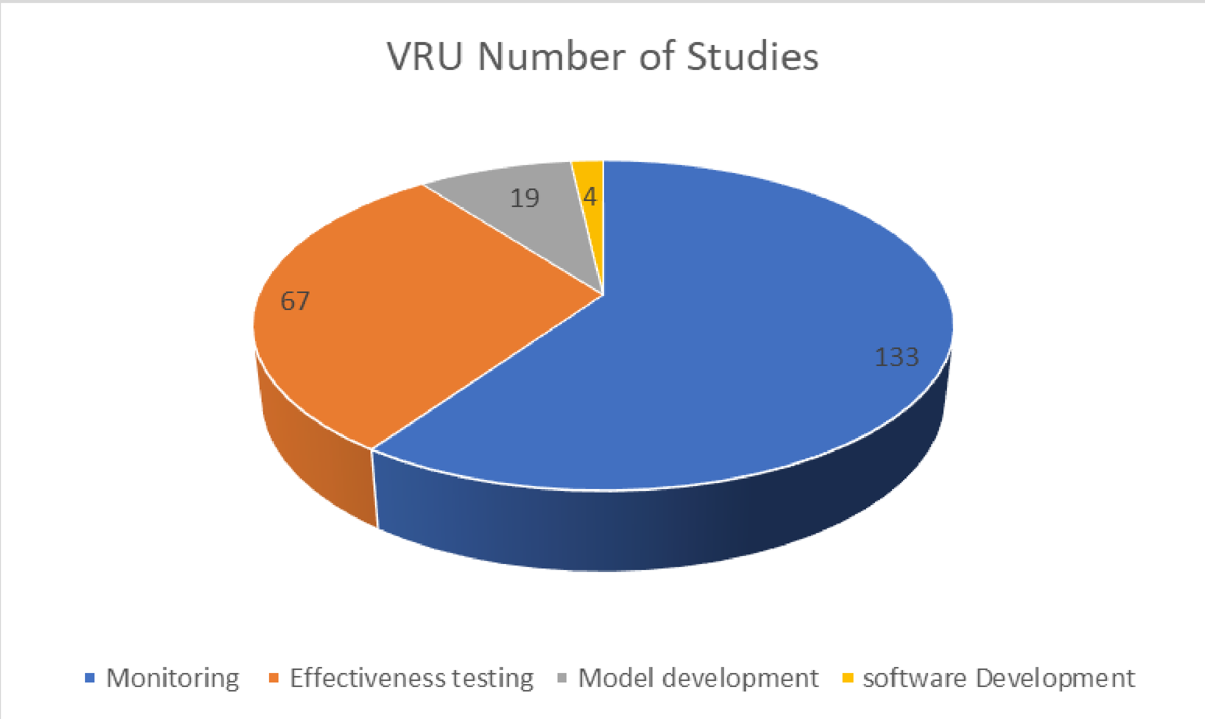


Figure 5: Pie Chart Diagram Showing The Distribution of VRU observational Study focus Scope *Source: Van Haperen et al, 2016*

There are a number of factors that make behavioural observation studies quite viable in as far as VRU studies are concerned. These include the fact that they allow for quick diagnosis of potential safety concerns, they are practice ready and suitable to learn and apply with limited amount of time for training observers (Polders & Brijs, 2018). They are furthermore, relatively cheaper than other safety diagnostic methods, they allow for deriving of location specific solutions and can be used in conjunction with other techniques. They can also be used in combination with traffic violation data, accident data analysis, self-reports, traffic conflict techniques and traffic intensity measurements (Lotter, 2001). On-site behavioural observation studies can be adopted for diverse purposes and are especially relevant when assessing road safety situations where there is no available accident data, or when the available accident data is not so detailed (OECD, 1998). Thus, the current study will also adopt behavioural observations of VRUs crossing an unsignalized junction on a four-lane highway along Harare-Bulawayo road and Kuwadzana extension turn off.

2.6 Infrastructural Indicators

Junction configuration in terms of the type of junction, number of lanes, type of infrastructure present like crosswalk markings, information signs, midblock sections or pedestrian lines and other infrastructural elements are important attributes when analysing indicators for VRUs safety (Zeeger and Bushwell, 2012)Ideally, the needs for VRU safety and mobility should be considered at the initial phases of the design of the road infrastructure, but however in practise engineers have had more focus on motorised traffic (OECD, 1998). As such the necessary infrastructure needed for pedestrians are usually not provided for or where provided they are do not take full cognisance of the diversity of the put in place for four basic reasons that is:

- **Level of Service-** facilities and infrastructure is put in place given that the crossing opportunities available to pedestrians are not up to the desired LOS and there is adequate demand including suppressed demand on a roadway.
- **Safety-** when historical records of crashes at or in the vicinity of the site signal a significant number of crashes that may potentially be minimised by provision of crossing assistance infrastructure and facilities
- **Specific Access Provision-** this takes into account vulnerable groups seeking to cross the roadway and these include young children, school crossing, the visually impaired and the physically challenged members of society.
- **Integration-** this is done when there is need to integrate and reinforce a wider traffic management plan for an area for instance a local area.

In order to protect pedestrians crossing wide roads; kerb extensions and staggered pedestrian crossings such as mid-block crossing and refuge islands were implemented in the Netherlands (Rodriguez 2017). Availability or unavailability of the necessary facilities determine how VRUs cross a certain junction reflected by the yielding behaviour, the crossing behaviour in terms of path, distance and time as well as the manner with which they cross. To illustrate the significance of infrastructural indicators, (Houten et al, 2001) assessed the significance of yield markings and a symbol sign prompting motorists to yield to pedestrians at a multi lane crosswalk with pedestrian-activated yellow flashing beacons. The study concluded that the introduction of yield markings and the sign 10m and 15m before the crosswalk enhanced the distance ahead of the crosswalk that motorist yielded to pedestrians. This in turn significantly reduced the percentage of pedestrian and motor vehicle conflicts, thus a better indication on safety for VRU on the intersection.

There are instances when there are no stop/yield signs, pedestrian crossover, or half or full traffic control signals on a junction or particular intersection. In such circumstances VRUs are expected to wait at a kerb until an available critical gap presents itself in the traffic stream and this is regarded as uncontrolled crossing (Akbar, 2017). Other road users like motor vehicle drivers are not expected to wait but rather it is the VRUs that are supposed to calculate some available gaps within the traffic stream upon which they can cross with due care and attention (OECD, 1998). Furthermore, if there are no crossing path provided at these junctions (due to low vehicular and/or pedestrian traffic volume or physical constraints), VRUs are expected to locate a safe place to cross that will enable them to see clearly and reach the other side of the road or midblock or pedestrian Ireland, in the event of multi lane crossing.

Given such circumstances, the safety of the VRUs largely depends on their ability to make an effective judgement on the gap that is presented in the traffic stream. This comes down to VRU individual characteristics which differ according to gender and age groups as shall be explained in detail in the below sections. Therefore, infrastructural indicators on the particular junction in this study will be analysed in the light of the above framework assessing those facilities present or absent and their resultant effect on VRU's crossing and hence safety

Table 2:Distraction Indicators

Personal attributes	Situational attributes
➢ **Mobile phone use -texting, chatting and internet (Lenon et al, 2016) influenced by age & gender** ➢ **Carrying heavy stuff when crossing- may negatively impact crossing speed** ➢ **Smoking, drinking or drug influence** ➢ **Psychological factors- stress, depression, anxiety, confusion**	➢ Road side features such as billboards, physical impediments along the crossing platform ➢ Crossing in platoons and its effect on speed as well as crossing behaviour - negative effect on rolling gap (Pele et al, 2018) ➢ Lighting conditions on the roadway (Uttley & Fortios , 2017) ➢ Weather conditions -rain,snow and fog has a positive effect on crash levels (Li et al , 2016)

Source: Self-Created, 2018

2.7 Interaction Configuration

Understanding the interaction of motor vehicles and VRUs on crossing points is key in as far as observing indicators that point at how safe or unsafe an intersection is for the latter. This involves indicator s like the yielding behaviour, yielding distance and who makes the evasive action in the event of a conflict. In studies conducted in Britain and France, Mobileye systems were installed on the cars to detect pedestrians when they come in close contact with cars (Jansen et al, 2017). It could be concluded that the real dangerous interactions (real or expected conflicts) were associated with higher car speeds than less dangerous interactions, and required more severe braking (Jansen et al, 2017). Himanen and Kulmala (1988) found that the most crucial explanatory variables influencing driver's behaviour included pedestrians' distance from the curb, the size of the city, the number of pedestrians crossing simultaneously, vehicle speed, and vehicle platoon size. Thus, on a typical four-way highway where there are fast moving cars and some slow-moving vehicles, how vehicles interact with VRUs can reflect a lot on how safe or not the junction is for VRUs. This is usually confirmed through traffic conflict techniques like Swedish Traffic Conflict technique which however will not be conducted in this particular study.

2.8 Traffic Safety Aids

Although many traffic safety aids have been explored in studies for drivers or motor vehicles the only notable ones for pedestrians and cyclists are reflective clothing and push buttons on signalised intersections. There are other safety aids such as Accessible pedestrian signals (APS) which are auxiliary devices that communicate information about the WALK and DON'T WALK intervals at signalized intersections in non-visual formats (audible tones and vibrotactile surfaces) to pedestrians who are blind or have low vision (Akbar, 2017). Traffic safety aids help in easing the crossing task for pedestrians and cyclists especially in busy intersections or junctions which may not have high priority for VRUs. Thus, their availability or unavailability can have a significant impact on the safety of a junction for VRUs. These are however mostly found on signalized intersections and not used on unsignalized junctions which is the context setting of this particular study

2.9 Driver Characteristics

The manner in which drivers interact with VRUs on both signalized and unsignalized largely determine of critical indicators which may signify how safe or unsafe the junction is for the latter road users. The age, gender and risk perception of the driver plays a significant role in the manner drivers behave towards the crossing point. This behaviour includes their approach, yielding behaviour, their speed as well as braking, and how they respond to pedestrian non-verbal cues for instance a smile or gaze from the pedestrian as well as driver awareness of the presence of a pedestrian (CUTR 2015, Bourquin et al ,2016, Rasouli et al, 2017). Young male drivers are well documented for their speeding and risky driving manoeuvres and such may pose a threat to VRUs on crossing points especially on junctions along the highway with vehicles moving at high speeds.

2.10 VRU Characteristics

There is evidence in literature that supports that demographic factors of VRUs especially pedestrians, in the form of gender and age plays a critical in determining the resultant crossing behaviour. Women are prepared to wait for longer times to cross than males and are of a higher perception to risk than the males (Hamed, 2001, Tiwari et al, 2007 & Holland & Hill, 2007). In a study conducted by Ferenchak, (2016), the average waiting time of female pedestrians is 34.4 s, which is 88.0% longer than the average waiting time of male pedestrian of 18.3s. Other studies also suggest that women aged between the age of 25-29 are less likely to cross Highways in risky situations than males (Noora et al 2016, Holland et al 2007, & Amo T et al, 2014). This relationship between males and higher rate of risky behaviour has even been shown in young children aged 5-8 years old (Barton and Schwebel, 2007). Furthermore, studies also indicate that males have a significantly higher crossing speed than that of women which probably explains why they are more less patient in their waiting times (Tiwari et al, 2007). Given the above, it is inevitable that males constitute 80% of the pedestrian fatalities. Although these studies have a more bearing on pedestrians, the gender and age dimension is quite representative of VRUs characteristics when crossing the road.

Also complimented by the gender aspect, age also plays a critical role in the manner in which VRUs cross the road. Studies have also shown that higher pedestrian age correlates with decreased risk perception, larger minimum gap acceptance, and longer waiting times when crossing a street (Hamed, 2001; Holland and Hill, 2007, Ferenchak, 2016). Furthermore, the age of the VRUs also determines their crossing speed as for pedestrians this speed is fastest around the age group 21-30 years and decreases as a person grows older (Tarawneh, 2001). However, there is seems to be some unclear relationship between pedestrian age group and actual risk and conflict (Ferenchak 2016). Although young pedestrians are more willing to take crossing violations, it is the elderly ones that make more unsafe decisions (Diaz 2002, Holland & Hill, 2010).

The challenge for the latter road users comes from the fact that they usually find it difficult to interpret the situations which exposes them to more risk. However, this must not be over-elaborated for in other studies done by (Lobjois et al., 2013; Lobjois and Cavallo, 2007; Sun et al., 2003) conflictingly found that older pedestrians were more conservative in their crossing behaviours, further compounding to the lack of clarity and gap in the current literature. Thus, given the above picture, an understanding of the relationship between these aspects will help in assessing the behaviour and challenges VRUs encounter when crossing a four-lane highway along linear settlement development patterns in the context of the developing world. The following section will now explore some of the common indicators found in previous VRU studies in detail and these are the yielding behaviour, use of non-verbal communication and crossing behaviour.

2.11 Yielding Behaviour of Drivers and VRUs

This kind of behaviour is essentially analysed to see whether drivers or VRUs stops to give access to each other or not on a crossing platform. In a scoping review on VRU studies, a total of 67 studies looked at yielding behaviour of both drivers and VRUs at crossing points that were not part of an intersection or priority-controlled intersection (Van Haperen et al, 2016). In many of these studies, it was assessed more as a (yes /no) variable and only in a few was there some detail to the nature of yielding that is differentiating between soft and hard yield (Samuel et al, 2013 & Schroeder et al, 2009). Another Yielding related aspect assessed in earlier studies was if a road user took some evasive action that is (hard braking or swerving) to avoid collision (Van Houten et al, 2001). It is also important to assess the yielding distance, the attitude displayed by those road users taking evasive action or allowing others to have a right of way and the communication that happens between both road users. Many variables that affect drivers' yielding behaviours, such as vehicle speed, intersection geometry, sightlines, expectation of pedestrians, and others, might not be within the control of pedestrians (Bourquin et al, 2016). This together with the next indicator that is use of non-verbal communication are crucial in the assessment of VRU's safety concerns on highway setting as in the context of this study. The road user culture is important in as far as yielding behaviour is concerned and this varies from one region to the other. In developed countries like Belgium and other EU countries motorists are usually keen to yield and offer VRUs right of way when crossing and they are more responsive to VRU's approach on the crossing point than one witnesses in the developing context. For instance in developing countries like Ethopia , more or less the same picture in Zimbabwe, more priority is given to vehicular traffic which entails more waiting times for VRUs who are largely forced to yield to vehicular traffic than the other way round. The figure below illustrates the typical scenario of yielding patterns in developed (a) and developing country context (b).

(a) Developed context (b) Developing country context. Figure 6: Contrast of Driver Yielding Behavior in Developed and In Developing Countries. *Source: (Adkins, 2011 & Tulu et al, 2013)*

2.11 Crossing Behaviour

Some of the commonly explored indicators in the crossing behaviour of VRUs are the crossing path, crossing speed, the type of movement which includes crossing straight or j walking, and demographic factors like age and gender. VRUs are required to follow traffic rules and only cross on pedestrian designated facilities especially Illegal crossing behaviour has been explored in some studies in developed countries towards explaining the high rates of crashes (Tulu et al, 2013). In a study conducted in China, 65.7% of the pedestrians did not check the oncoming and departing vehicles when they crossed unmarked roadways (Zhuang & Wu, 2011). Another study conducted in Chile revealed that pedestrians have a positive attitude towards illegal midblock crossing.

From a developing country context. A number of underlying factors for illegal crossing behaviour are raised in a study conducted in Ethiopia (Tulu et al, 2013). These include:

- Psychological attributes and complexity of the road environment
- Drivers not yielding to pedestrian crossing
- Infrastructural factors- few legal crossing points, median sections which are difficult to negotiate and poor lighting
- VRUs in the form of pedestrians being reluctant to use pedestrian overpasses

Although these kind of illegal crossing behaviours are widespread in developing countries, there is limited information on what really influences the above factors and this could be explained by the levels of knowledge about road rules, enforcement levels and relative opportunities to cross illegally (Tulu et al, 2013).

2.12 Theories of VRU Crossing Behaviour

Although this study is covering all road users which fall under the category of VRUs, the most common type of road users in the context of the current study are pedestrians hence theories on crossing behaviour largely focus on pedestrians as the VRUs.

2.12.1 Gap Acceptance Theory

Pedestrian crossing behaviour can be understood with the help of the gap acceptance theory (Oxley et al 2005). The theory stipulates that each pedestrian or group of pedestrians, has a critical or minimum gap they accept within the traffic stream upon which they decide to cross and will reject this gap provided it goes below the critical gap. This vehicular gap can be defined as the time difference between the leader and follower vehicle with reference to the pedestrian path (Kadali & Vedhagiri, 2013). On arriving at the intersection, the pedestrian would check whether the available gap is greater than the critical gap and decide to either take or decline the gap. If the gap is declined, the next gap is considered. This sequential process of decision making continues until the pedestrian finds a sufficient gap to cross the entire roadway or when a right of way is presented on change of phase on a signalized intersection. The critical gap is an intrinsic value which differs from one individual depending on age, gender and personal attributes (Himanen, & Kulmala, 1988). As highlighted in the above section males are less patient than females hence, they are likely to take up the risks associated with lower critical gaps. Furthermore, critical gaps also decrease with increasing waiting times which makes the VRUs more impatient given the fact pedestrians particularly males, are not willing to wait for more than 30 seconds before they can cross the road on signalized intersections (Mckernan, 2012). Thus, in the context of a T junction along a four-lane highway with no traffic signals, this study will assess of these factors looking at indicators like waiting times, type of vehicle and critical gap, vehicular speeds, VRU crossing speed and gestures among other important indicators.

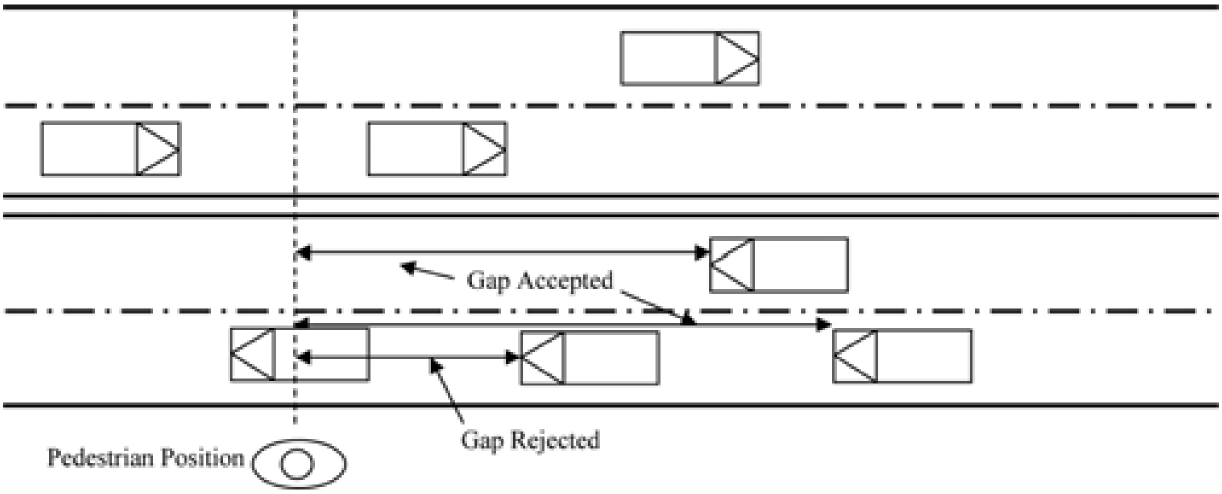


Figure 7: Diagrammatic illustration of accepted and rejected gap by pedestrians crossing multi lanes. *Source: Chandra et al, 2014*

2.12.2 Multi Lane Crossing

In the event of an approach with multi-lanes, pedestrians can adopt a number of crossing modes. The first mode could be to look for a combined gap in the entire approach and cross all in a single stage. Second one the pedestrian can look for gaps in the near and far (opposite) stream, and cross in a single stage (Palarmathy et al, 1994). The third option involves the pedestrian looking for a gap in the near stream, cross, and then look for a gap in the far stream, i.e. a two-stage crossing. Lastly, the pedestrian may cross lane by lane using available gaps as per lane. The first three options are commonly observed on signalized intersections while the last one is common on mid-block crossing sections.

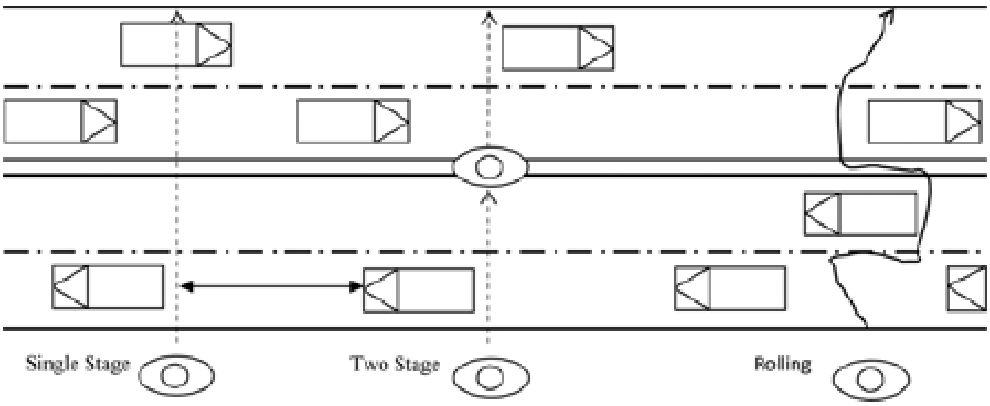


Figure 8: Crossing Patterns Adopted by Pedestrians (VRUs) on a Multi Lane Crossing. *Source: Chandra et al, 2014*

2.12.3 Theory of Planned Behaviour in VRU crossing Studies

One of the commonly used psychological theory to explain how VRUs come to the decision-making process of when to cross or when not to cross is the theory of planned behaviour. Most of the studies that adopted this theory adopted three main attributes of the theory to explain crossing behaviour and these are attitude, subjective norms, perceived behavioural control will predict the intention to engage in a certain behaviour (Norman & Evans, 1998, Francis et al 2004). Results from previous studies show that there is significant a significant correlation between the model's components and pedestrians' behaviours (Diaz, 2002). Although this theory is significant in predicting and determining the decision-making process by VRUs when crossing the road, the study will not assess these psychological aspects in the data collection process.

2.13 Types of Crossing Facilities for VRUs (more emphasis on pedestrians)

There are essentially two categories of pedestrian crossing and these are controlled and uncontrolled crossing. An uncontrolled crossing is a crossing that does not have any traffic control measure to provide a dedicated pedestrian right-of-way (Akbar 2017). In such a circumstance, pedestrians must wait for a safe gap sufficient to fully cross the roadway or for vehicles to stop before crossing. The following table shows typical conditions for controlled and uncontrolled pedestrian crossing facilities.

Table 3: Controlled and Uncontrolled Crossing Facility Types

Controlled crossing	Uncontrolled Crossing
➢ **Traffic control signals** ➢ **Intersection pedestrian signals** ➢ **Pedestrian crossover** ➢ **Stop signal** ➢ **Yield signal** ➢ **Designated school crossing with crossing guard**	➢ Midblock crossing (in the absence of traffic control signals, intersection pedestrian signals or pedestrian crossover) ➢ Designated school crossing (in the absence of a crossing guard and without other forms of control such as traffic signals, intersection pedestrian signals, pedestrian crossover, STOP signs or YIELD signs) ➢ Marked crossing (at intersection in the absence of stop or yield signs

Source: Adopted from Akbar, 2017

When pedestrians cross the carriage way at the same level and platform vehicles are passing through, this is regarded as at -grade crossing. The following section shall now review some of the best practise crossing facilities for VRUs in the developed countries which will be compared with those common in developing countries, for instance Zimbabwean facilities which is the scope of the study.

2.13.1 Zebra Crossing

This crossing facility type is a common feature used across the world in both developed and developing countries. A zebra crossing is simply an unsignalized portion of the carriageway where the pedestrian has legal priority over the motor vehicle. The cross strip is outlined by parallel lines of studs and marked with alternate black and white thermoplastic strips parallel to the centreline of the road (Ibrahim et al, 2005). These strips resemble the coat of a zebra and the distinctive black and white paint are usually complimented by flashing orange belisha beacons (Akbar, 2017). Although they are a proven safe crossing facility for VRUs in the developed countries, in some developing countries these are not always the safest for pedestrians and cyclists. In a study conducted in Malaysia, it was discovered that the willingness of drivers to give way to pedestrians is very low and that the waiting times for most crossing pedestrians was also very low (Ibrahim et al, 2005). These crossing facilities also pose a risk to pedestrians and cyclists in the capital of Zimbabwe, Harare CBD, where pedestrians cross at their own risk as drivers are reluctant to yield to pedestrians on the crossing point. These can be illustrated in the figure below:

Figure 9:Images of Zebra Crossing Facilities Both in Animation and Real World Setting. *Source: (Ministry of Transportation, Ontario, 2011 & Njikizana @izimphoto1 twitter.com)*

Thus, in an environment of poor driver, pedestrian and cyclist behaviour as well as weak regulation and enforcement, Zebra crossing points may be riskier than their intended goal of enhancing safety for VRUs especially in the developing world context for instance in Zimbabwe. This facility is the most common in Zimbabwe and the coming facilities are reviewed from a developed country context as best practises.

2.13.2 Pelican Crossing

This is a type of crossing which is controlled and features a pair of poles each with a standard set of traffic lights facing oncoming traffic, a push button and two illuminated, coloured pictograms facing the VRUs (pedestrians) from across the road (Akbar 2017). Within these are aa red, stationary person to indicate that is it not safe to cross, and a green moving person to illustrate that it is safe to cross. It also comes with non-visual indication that it is safe to cross in the form of a beep, vibrating button or tactile rotating cone in order to assist visually impaired VRUs. When a VRU presses the button on the crossing, the traffic light will switch from green to amber and then red. After some time, the traffic lights will then turn to a flashing amber light (meaning one can go as long as the VRUs are off crossing) then green to go. It is the only crossing platform with a flashing amber light in its sequence and provides clear instructions to drivers and VRUs on when to stop as well as take-off. These are used in developed countries such as Belgium and the UK and in some developing countries such as Indonesia. The challenge however, is that often times the VRU will press this and not wait on signal change but then proceed to cross using a critical gap in the traffic stream or just continue walking down the road. This crossing type can be diagrammatically shown in the below:

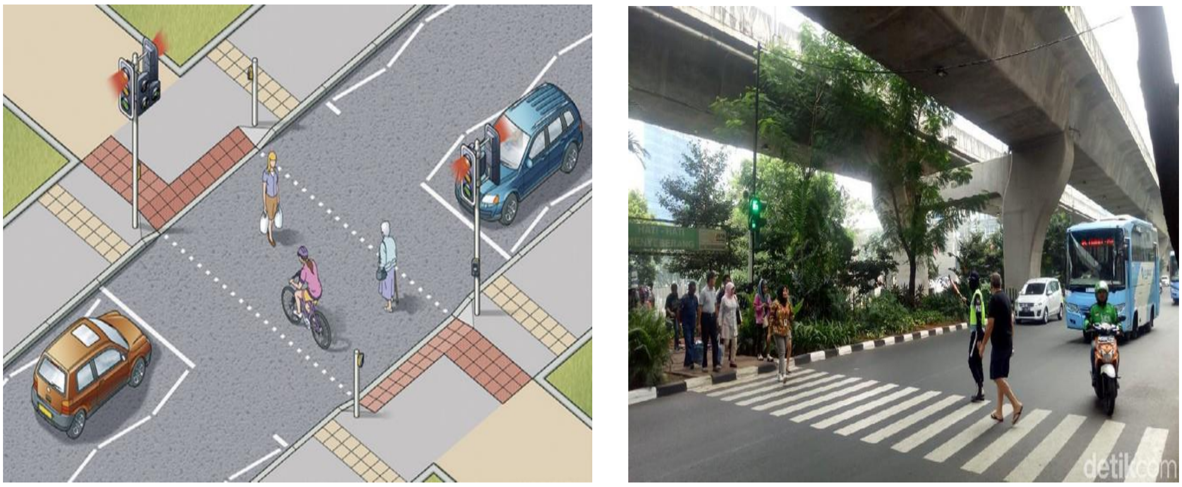


Figure 10: Images of Pelican Crossing Both in Animation and In Real World Setting. *Source: The highway Code, UK, 2018 & Lho Ini ,2018*

2.13.3 Puffin Crossing

Puffin crossing is a pedestrian user-friendly intelligent crossing. It improved the inadequate crossing time for slow pedestrians such as seniors and children to cross, which was the limitation of Pelican crossing (Hunsanon et al, 2017). It processes sensors along a crosswalk and adjusts the crossing time instantaneously, and they will prolong the red traffic light to enable the road user to complete their crossing (Akbar, 2017). They also unlike the pelican crossing, do not have the flashing green man and flashing amber signal. In this crossing type, the red and green man signal are located just above the push button on the same side as the VRU. This encourages VRUs to face the oncoming traffic while waiting for the green man to show. These are VRU user-friendly intelligent crossing facilities.

Figure 11: Images of Puffin Crossing both in Animation and Real-World Setting

. *Source: City of Bristols Uk, 2018*

2.13.4 Toucan Crossing

The toucan (two can cross) crossing is a shared signal-controlled crossing designed for use by pedestrians and cyclists (VRUs). Although quite similar to puffin crossings, these are wider and consist of a red and green cycle as well as the red and green man (Akbar ,2017). Both cyclists and pedestrians will both have the same green signal all at once and cyclist have the same access to crossing as pedestrians on this green time. They do not have flashing amber phase for vehicles on the road. At such a crossing platform the red pedestrian and cycle signals are advisory and if it is safe one can get access despite the signal being red (walking or riding a bike).

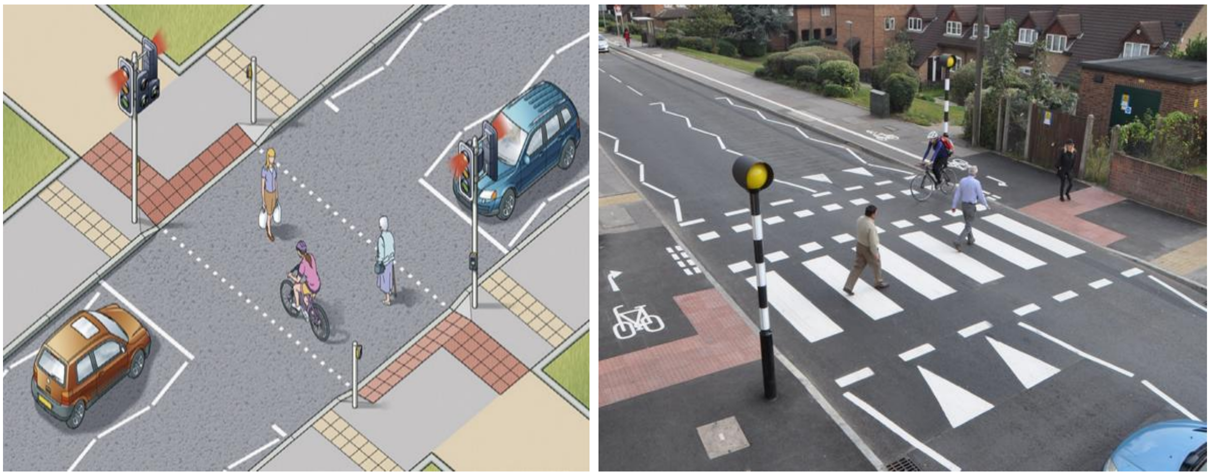


Figure 12: Images of Toucan Crossing Both in Animation and Real-World Setting. *Source: The Highway Code, UK, 2018 & City of Bristols, Uk, 2018*

2.13.5 Midblock Crossing

Typically, in most developing countries, uncontrolled mid-block crossing is a very common facility used for VRUs in urban areas as well as on highways. A midblock pedestrian crossing is one of the most hazardous locations where the police or crossing guards are commonly responsible for separating vehicular and pedestrian flow. The police or crossing guards' control vehicular and pedestrian traffic based on their experience, perception, and personal judgment, which are intuitively based on linguistic information (Hunsanon et al, 2017). For instance, in a study conducted in Dhaka Bangladesh, individuals struggle to cross at midblock crossing points and as such often forms group to exert pressure on the moving traffic stream. This is given there are no control or police to help in crossing as drivers disregard giving priority to VRU crossing. In the below are images of garment workers forming groups to exert pressure on motorists to give them way on a midblock crossing facility that is not controlled in Dhaka. The same can be witnessed in Zimbabwean urban areas where VRUs team up to cross on midblock crossings along highways which are not controlled by the police or by crossing guards.

Figure 13: Image of Mid-Block Crossing in A Typical Developing Country Context in Bangladesh *Source: Hoque et al, 2007*

2.13.6 Marked crossings (Unsignalized Areas)

There is evidence in literature to suggest VRUs prefer crossing on locations with crosswalk markings than those without (Fitzpatrick, 2006). Furthermore, to be more precise, the presence of a marked crosswalk is more influential at an intersection than at a midblock location. However, in some studies also conducted by Herms, 1972, it was discovered an increased incidence of pedestrian collisions in marked crosswalks, compared to unmarked crosswalks, at 400 uncontrolled intersections in San Diego, California. Another late 1990s study on crosswalk pavement markings found that as traffic volumes, speeds, and street widths increase, greater crash frequency was present when only crosswalk markings (no signs or beacons) were used as compared with no crosswalk markings (SACT, 2009). The study did not entail marked crosswalks are not sufficient but that they on their own are not sufficient on multilane streets with high traffic volumes and speeds. It should be noted however, that marked crosswalks, on their own, do not slow traffic or reduce pedestrian crashes. In most cases, marked crosswalks should be used in conjunction with other pedestrian safety devices such as pedestrian signals or signage to increase visibility and driver awareness (RBA, 2014). This however can be given from the fact that marked crosswalks are interpreted in the wrong manner by VRUs in many instances. Marked crosswalks with painted pavement markings are not recommended at uncontrolled crossings as they create a false sense of security on the part of pedestrians, particularly children, who may enter the crossing expecting that approaching drivers will see them and stop (Akbhar, 2017) These views include but are not limited to:

- Many pedestrians (VRUs) consider marked crosswalks as a tool to enhance pedestrian safety and mobility
- They view the markings as proof that they have a right to share the roadway, and in their opinion, the more the better.
- Many pedestrians (VRUs) do not understand the legal definition of a crosswalk and think that there is no crosswalk unless it is marked.
- They may also think that the driver will be able to see the crosswalk markings as well as they do,
- they assume that it will be safer to cross where drivers can see the white crosswalk lines (US Department of Transportation, 2002)

Thus, given the above perceptions on the VRUs, marked crosswalks may actually pose more safety threats than benefits especially in an environmental context of poor road user behaviour and poor enforcement of road rules and regulations typical of most developing countries. A typical example found in both developed and developing countries of a marked crosswalk is that of zebra crossing which has been already been touched on in the sections above.

Figure 14 Images of Marked Crossings at Unsignalized Intersections: . *Source: Asaithambie et al, 2016*

2.13.7 Designated School Crossings

These are facilities put in place in a school zone area for both kids and adults to help them cross without facing so many challenges by foot or cycling (Nemeth, 2014). They are typically designed to address specific problems or needs that have been identified and can range from simple sidewalk replacement/repair to more complex traffic calming devices, such as roundabouts or speed humps. A municipality may choose to designate crossings as school crossings where special emphasis is needed due to a combination of the number of crossing school children, geometry of the approaching roadways, approach speed, and traffic volumes. Special emphasis could include placement of an adult school crossing guard, installing signage, pavement markings or a signal (Nemeth, 2014). In many developing countries like Zimbabwe, the use of an adult crossing guard or the police is the common feature and these are usually there to help students cross during the morning period (when they report for school) and afternoon (on their way back home). Given the traffic volumes and history of crashes involving students crossing to school, these adult crossing guards are put in place by the school itself or the municipality in question. Thus, in the context of the current study, it is of interest to discover the volumes of students who cross the highway and junction for the purposes of schooling given there are schools across the two neighbourhoods.

Figure 15: Images of Designated School Crossing Zones. *Source: (Nemeth, 2014 & Billingsley, 2018).*

2.14 Constraints in Determining and putting in place of VRU Crossing Facilities

- Practical spacing requirements
- Cost and cost effectiveness of implementation
- operation / maintenance requirements of crossings,
- the possibility of decreased safety for vehicle occupants and decreased air quality

These limitations are taken into considerations together with VRU demand volumes which helps engineers and planners to pro-actively design crossing facilities for VRUs and these are more critical to take into con sideration in developing countries given resource constraints as in the context of the current study.

2.15VRU Responsibilities and Rights

2.15.1 Responsibilities

VRUs are expected to observe certain responsibilities when they cross a roadway at a marked or unmarked crossing, when there is not traffic signals or stated rules. The following responsibilities are universally applicable responsibilities adopted from a study that was conducted in India (Akhbar , 2017):

- Try to catch a driver's eye, if they are able to so they get them to yield for them to cross
- To cross only at intersections
- They have to stand clear of buses, hedges, parked cars, or other obstacles before crossing so they can be easily noticed by the drivers
- They are to look /listen left right and left again before crossing the roadway
- When crossing multiple lanes, they have to be sure traffic has stopped in each lane before crossing the street
- Yield to vehicles when crossing roads where no marked crosswalks are present
- Not to suddenly enter the street if a vehicle is so close that it is difficult for the driver to yield to the pedestrian
- They are to ensure the vehicle is far enough away from the crosswalk, given the speed limit and roadway conditions for the driver to be able to yield the right of way to the pedestrian

2.15.2 Rights

On a general note, unless otherwise specified, VRUs have the right to travel anywhere upon the public roads and highways and most restrictions are usually placed on the conduct of them crossing, walking along or using public ways (Akbhar, 2017). Some of these rights include:

- Cross on crosswalks that are marked and to do so safely
- Move along roadways and highways where no sidewalks are present. they are expected to exercise caution and walk as near as practically possible to an outside edge of the roadway and, if on a two-way roadway, they are to move only on the left or right side of the roadway depending on the context
- The drivers of vehicles are expected to yield the right of way to any pedestrian and all other traffic on the sidewalk.

Thus, given the above, the current study also aims at assessing if these have any bearing on the manner VRUs and drivers interact on the junction given mixed traffic and mixed speed conditions, and from such ignorance by any road user can be determined be it the VRUs or the drivers themselves. There are some claims of pedestrian ignorance leading to increased traffic crashes in Zimbabwe according to the Traffic Safety Council of Zimbabwe (TSCZ).

2.16 Factors Influencing VRUs Decision to Cross A roadway

To understand the reasons why VRUs end up crossing where they cross, it is critical to first understand the generators or attractors of traffic which creates the demand for crossing on the roadway. These generators or attractors include such facilities as transit stops, schools, malls, buildings, trail links, and sidewalk connections (Akbhar, 2017).

- **The frequency and nature of gaps in streams of vehicles**: this focuses on the level of traffic volume, speed of traffic and the overall platoon effect. At crossing locations without traffic control, the higher the traffic volume and speed, the higher the exposure and the more difficult it is to find a vehicle gap to cross (Akbhar, 2017). High vehicular volumes and speeds can also inhibit a perception of safety.
- **VRU physical ability**: Persons with a disability, seniors or young children will normally cross at a slower speed and therefore will take longer to complete a crossing.
- **VRU behaviour and comfort level**: In terms of their perception of safety, the pleasantness of where they are walking, and their understanding of the rules of the road.
- **Availability, proximity and quality of nearby pedestrian facilities**: VRUs are more likely to cross where there are easily accessible, visibly marked crosswalks or controlled intersections where they feel much safer than areas without such facilities.

2.17 Methodological Approach to Behavioural Observation Studies for VRUs in Literature.

Evidence from literature on VRU behavioural observation studies show that the video image technique and the manual human observer approach are commonly used (or a combination of the two) (Van Haperen et al, 2019). There is however no standardised observation protocol for all study situations, thus researchers come up with individual protocols tailored to their particular study (Polders & Brijs, 2018). This is also given by the fact that researchers do not uniformly describe the study characteristics at the same level, hence this limits the transparency and transferability of study approaches (Van Haperen et al, 2018). What also governed as well as governs the study approach chosen depends on the variables of interest to be generated from the study (Behavioural indicators) as well as the purpose of the study which was briefly touched on in the section on behavioural observation studies above. Both video image technique present advantages and disadvantages when used separately as well as when used in combination and all these will be given in detail in the next section.

2.18 Use of GIS tools in Traffic safety Studies

The use of GIS techniques in assessing urban settlement development patterns along highways is also documented in literature. In study conducted by Sudhira et al, (2003), in India on two highways. Two important highways in Karnataka, South India, viz., Bangalore - Mysore highway and the Mangalore - Udupi highway, in Karnataka and the Tiruchirapalli - Tanjavore - Kumbakonam triangular road network in Tamil Nadu, South India, were considered in this investigation. Geographic information systems (GIS) and remote sensing enabled them to quantify the increase in the built-up areas for nearly three decades (Sudhira et al, 2003). GIS based technologies can provide traffic safety experts with some critical crash analysis tools for roadways known for many accident occurrence or black spot treatment

(Sarkar et al, 2016). In a study conducted in Bangladesh, detailed Geographic Information System (GIS) based database was created including various attributes particularly locational attributes to identify and visualize high risk road locations using police reported accident records collected from Accident Research Institute (ARI) in the period of 2008 to 2011 in that particular corridor and then analysis was done by using the GIS software ArcGIS 10.1(Sarkar et al, 2016). The technology was able to represents some promising findings and experiences of the high-risk road assessment and highlighted the direction towards devising affordable cost-effective countermeasures for road safety improvements. They can also be used for traffic accident information management (Ahmadi, 2017). Thus, given its relevance and contribution to traffic safety studies, the tool shall also be adopted in the context of this study to map land use developments and their impacts on VRU safety along a highway junction in Harare, Zimbabwe.

2.19 Conclusion

The current chapter has given a detailed assessment of behavioural observation studies on VRUs highlighting the past and present picture in light of the context of the current study. The chapter raised some of the important indicators that are assessed in VRU behavioural observation studies as well as different types of crossing facilities for VRUs and the conditions under which a crossing decision is reached. The section closed by an overview of the commonly used methodological techniques and approaches in behavioural observation studies for VRU which paves way for the following chapter that is the methodological approach of the study.

3.0 Methodological Approach to the study

3.1 Introduction

In this section, the overall research design, research protocol, data needs, instruments and data collection methods are explored. The chapter also presents the data analysis tools used for the current study. The data sources for the primary and secondary data are also be presented. The chapter also presents some of the encountered challenges and limitations to the study as well as issues of ethical considerations to taken note of in the study. The chapter ends with a conclusion which paves way for the next section that is on the results interpretation, analysis and discussion.

3.2 Research Design

The research design of a behavioural observation study is linked to the purpose of the study (Polders & Brijs, 2018). In this context, the purpose of the study was to monitor VRUs crossing behaviour on an unsignalized junction on a four-lane highway along linear settlement patterns in Harare, Zimbabwe. The following figure shows an overview of the research design for the current study.

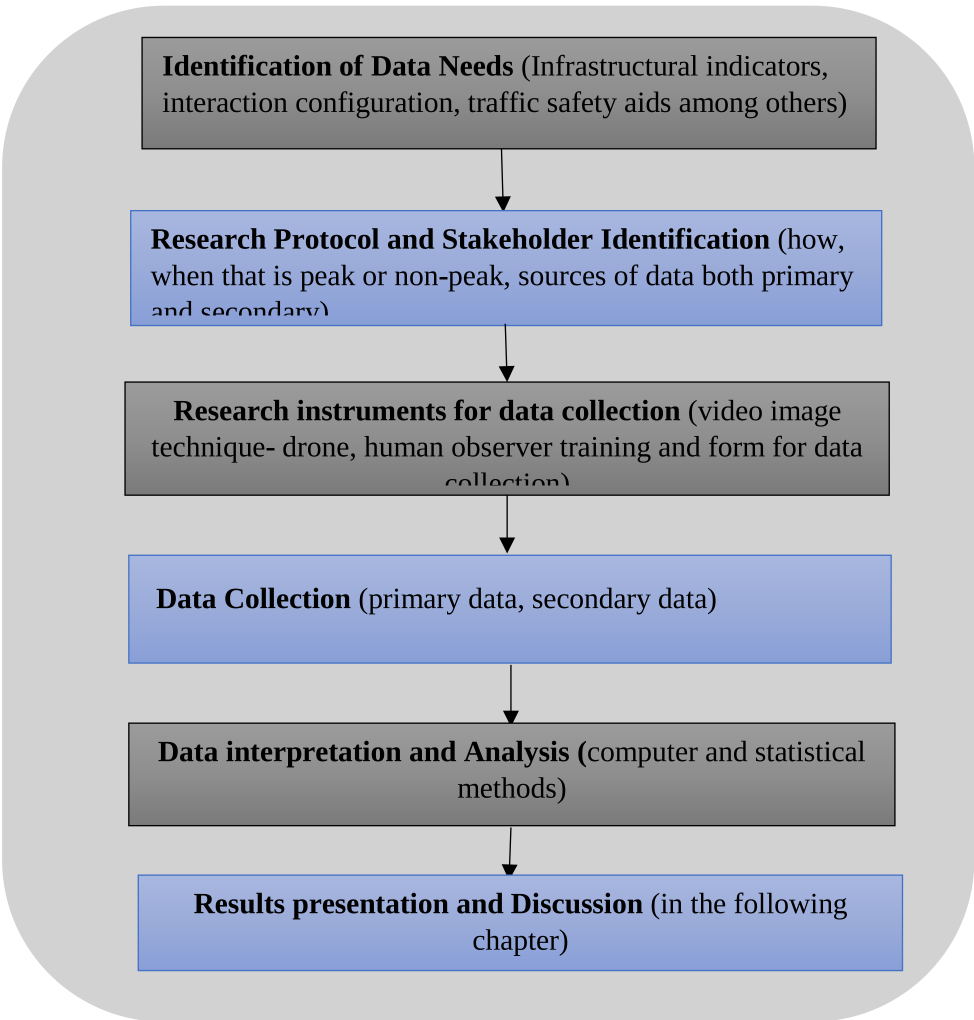


Figure 16: Research Design for The Study . *Source: Self, Constructed, 2019*

3.3 Data Needs

The data needs in this present study can be analysed in a table as summarised in the below. The table has categories of type of indicators, their measurement unit, their description and the source from which the data will be gathered in the study.

Table 4: Type of Indicators and Variables to Be Investigated

Type of Indicators	Variables
Infrastructural Indicators	Cross section of the junction, crossing distance, type of crossing, waiting positions, crosswalks (marked or unmarked), pedestrian island, signals, signs, surrounding developments (residential, industrial, institutional or commercial)
	Yielding distance, driver speeds, evasive action, VRU speeds, evasive action, Gap size, critical gap, use of hand gestures, smile, nodding of the head by both road users
Distraction	Smartphone use (texting, call or internet), crossing in platoons (size and direction single or bi), luggage and position, roadside features (boards, trees and signs)
Traffic safety Aids	VRU push buttons, markings and signs to assist in crossing, reflective devices (clothes, reflectors)
Driver Characteristics	Gender, attitude towards crossing VRUs
VRU Characteristics	Age, gender, crossing violations (jaywalking), crossing path, crossing speed, non-verbal cues (hand gestures, head movements, smile)

Source: Self-Created Table, 2019

3.4 Research Protocol and Definition of Key Indicators

The current VRU monitoring survey was done on a six-day period staggered over a period of two weeks covering morning peak, afternoon off peak and evening peal period. The days for the first week were on a Tuesday, Thursday and Saturday. The second week will see data collection on a Wednesday, Friday and Sunday. Monday was omitted from the data collection due to the fact that the traffic volumes on Mondays are usually affected by additional traffic of people travelling over the weekend period. Traffic volumes for public holidays will also be omitted in the survey for they carry the same distorted effect as that of Mondays. These were not helpful in as far as getting the actual traffic picture on the junction. Data was collected in hourly intervals with the first recordings from the morning being conducted from 7am to 8am. The afternoon off peak hourly recording was be from 12pm to 1pm. This period was favourable as it also marks the hour upon which primary school going children cross the junction especially those in the lower grades. The evening peak hourly recording was from 4:30pm to 5:30pm . This was essentially to accommodate high school and working-class residents returning from work after the day’s endeavours.

Table 5:Location Kuwadzana Extension Turn off Along Harare-Bulawayo Road Data Collection Schedule

Date	Morning peak Period	Afternoon off-peak	Evening Peak Period
Tuesday	7am-8am	12noon-1pm	4:30pm-5:30pm
Wednesday	7am-8am	12noon-1pm	4:30pm -5:30pm
Thursday	7am-8am	12noon-1pm	4:30pm-5:30pm
Friday	7am-8am	12noon-1pm	4:30pm -5:30pm
Saturday	9am-10am	1pm-2pm	5pm-6pm
Sunday	9am-10am	1pm-2pm	5pm-6pm

Source: Self Constructed, 2019

Vehicle speed- The estimated speed in m/s then km/hr of each vehicle as it passed through the junction. This was gathered through measuring a distance of 400m before and after the junction and use of a stop watch to gather the time in seconds the car took to complete this distance. The distance was measured by a tape measure. The speeds were gathered as estimate values and averaged over different times of the day. The speeds were gathered averaged for both Light Motor Vehicles (LMVs) and Heavy Goods Vehicles(HGVs) for different times of the day.

VRU waiting times – The time taken by pedestrians and cyclists on the kerb or on the median section of the road as they wait for suitable gaps in traffic upon which to proceed with their crossing. These were gathered from the video footage which was cut into smaller frames through VLC media player with replay and record option. The smaller frames were then played several times with a stop watch used to gather the waiting times at kerb as well as on the midblock section.

VRU crossing time- The time taken by pedestrians and cyclists to complete their crossing of the first and last two lanes. These were gathered by use of video frames and a stop watch with the same software as the above indicator. These were taken for both genders and for all times of the day .

VRU speed- this was generated through computing the distance of the two lanes and last two lanes together with the shoulders then dividing it with the crossing times for both the first two lanes and last two lanes. The distance measurements were gathered from the department of Civil Works under the Ministry of Transport.

Gap size- Gap can be defined as the time difference between leader vehicle and lag vehicle and it is an important term in pedestrian road crossing behaviour (Kadali & Vedagiri, 2013). The accepted game (Critical gap) was measured in time (Seconds) using a stop watch and on the video footages some demarcations were put on the point of crossing. A perpendicular line was drawn to mark the crossing points or positions and the gap was calculated from the moment a vehicle entered the frame of the video footage until the crossing point. On rejected gaps, this measured the time difference of the leader vehicle and the following vehicle as they passed the crossing point on instances the VRU remained waiting on the crossing kerb. These were computed using a stop watch as well as time measurements from the small video frames.

VRU and Vehicle volumes- The number of cyclist and pedestrians who crossed the junction. The number of vehicles that passed through the junction. These were generated through video footages and computed using tally sheet method. The characteristics of the VRUs with regards to gender were also gathered from the video footages.

VRU looking on Behavior- the manner in which pedestrians and cyclists looked at traffic in either direction right or left in their sequence of crossing in both ends and directions on the road junction. This was observed from the video footages .

VRU crossing manoeuvre/action (Evasive action)**-** This is the resultant crossing manner a pedestrian decided to use to avoid any threat of collision with the oncoming traffic. This could either be walking action or a jogging action which in most cases was taken to increase the crossing speed when crossing on smaller gaps in traffic. This was also observable from the video footages.

3.5 Data Collection Instruments

3.5.1 Video Image Technique

This approach was be adopted in the data collection for it offers more objective and accurate results than other approaches (Polders & Brijs ,2018). It also allow for continuous data collection of road user behaviour with an option to play it repeatedly when analysing the data thus detail is restored in the study, The video image technique is also very efficient in communicating research findings to other researchers and the public (Polders & Brijs ,2018). A high resolution Canon digital camera was mounted at an elevated angle towards the junction in the six day period making recordings of one hour per session three times a day. However , a closer bird's eye view angle could not be obtained given physical constraints on the data collection site. The image below provides the best angle that could be obtained in the data collection process.

Figure 17: Camera View of the Site *Source : Self Image, 2019*

3.5.2 Human Observers

Human observers have been adopted in the study to ensure wide area coverage of the data collection process especially on areas the video cannot cover and indicators the video footage will not cover. There were at least two human observers, that were incorporated in the data collection process. They made use instruments such as a form to record variables, stop watches , a tape measure for measuring some distance variables (Polders & Brijs, 2018). The observers stood on either side of the road and in strategic positions to the junction. These positions enabled them to capture estimated speeds with both of them standing on the pegged 400m mark with their stop watches and note pads ready to record. They also assisted one another in making these distance pegs using a tape measure and marked these areas with drawn lines on the ground and placed some landmarks . They also had some forms to note other interesting attributes to the study throughout the six day period. Some of these variables that were registered on the behavioural observation form are mostly 'yes/no' and 'single value' indicators. Furthermore, the data of interest can be gathered very promptly and efficiently (Van Haperen et al., 2018). This method was viable when collecting behavioural data at different types of locations (for instance roundabouts, intersections, part of an intersection) and for all types of road users (Polders & Brijs, 2018).

3.5.3 Data Analysis Instruments

The recorded video footages were analysed by use of VLC media player which allowed for the video to put into smaller frames with option of recording, rewinding, fast forwarding and capturing images as many times as possible. Data analyses was conducted using Microsoft Excel and SPSS 26 for the Binary Logit Model. The Binary Logit model was adopted to assess factors that were significant in VRUs either accepting or rejecting a particular gap in traffic. This will also be complemented by the human observer data sheet which will provide additional data. Computational software packages like SPSS was used to quantify and produce graphical illustrations of the results.

3.6 Conclusion

In a nutshell, the above chapter presented of how the current study was approached in as far as data collection, data analysis and what was to be the input to the next chapter, that is results interpretation and analysis. A framework of the research design was presented together with the research protocol and the data collection instruments that was used in the study.

4. Results , Discussion and Recommendations

4.0 Introduction

The study captured at least 3205 VRUS in the six day period, in terms of aspects like their gender, crossing position, crossing direction , crossing speed, waiting times and gap size. Also captured were the vehicular volumes and estimated vehicular speeds as they passed through the junction. Information on road classification, design standards and considerations were obtained from the Ministry of Transport. Microsoft Excel and SPSS were utilised in the analysis and interpretation of results .

4.1 Nature and Intensity of Linear Settlement Development Patterns Over Time

One of the main objectives of the study was to assess on the growth patterns of these linear settlement development patterns, hence its implications for demand volumes on the junction. However, due to limited data availability in the form of digital maps a detailed assessment of this could not be done using GIS mapping. There is nonetheless still some valuable maps that were generated on google maps for the year 2007, 2012 and 2018 which provides a picture of the growth patterns. These show that there has been rapid growth in residential blocks , some major landmarks like Kuwadzana 8 primary school , Kuwadzana extension clinic , Siffra shopping centre, Pinehood High school in Glaudina and some churches. There is evidence from the maps which shows that open green spaces have been converted to some residential blocks and some entrepreneurial projects the past two decades as the settlement has grown. The polygons dermacated by orange for 2007 in the fig below are much smaller in size than that of 2012 and 2018 demacated by a lighter shade of orange and lime green respectively. It can be observed that in 2007 the other neighbourhood Glaudina was more of a virgin land with some much green spaces on the polygon. Neighbourhood developments start to emerge more in the glaudina polygon in 2012 and they extensively grow and become more pronounced in 2018. In as far as Kuwadzana extension is concerned , the polygon for 2012 has some green spaces which are filled up by residential blocks in 2018 which is bigger and more filled up by residential blocks. Thus , the maps show a pattern of rapid growth over the three year spells which has huge implications to the growth in population across the two neighbourhoods. Development of landmarks like schools , shopping centers and churches implies increased interaction between the two neighbourhoods. This suggests of increased numbers of people crossing the highway junction on a day to day basis. This is notwithstanding the fact that volumes of VRUs crossing the junction in the given years could not be generated for comparisons with the current volumes.

The fig below shows the development patterns for year 2007,2012 and 2018 respectively . The smaller polygon on the upper part of each image represent Glaudina while the bigger one below represent Kuwadzana Extension suburb. In between the polygons is our main highway and the junction which is the main focus of the study.

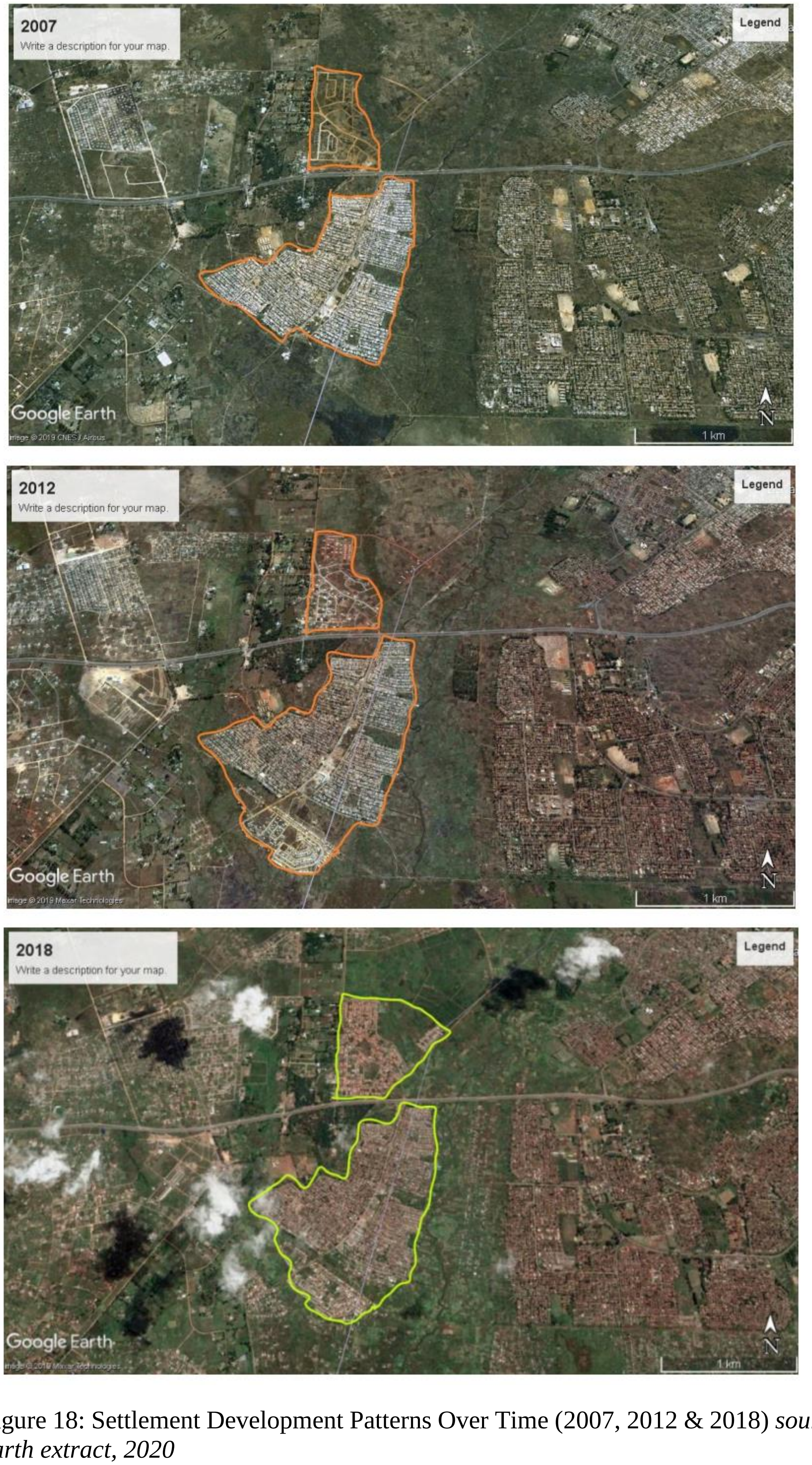


Figure 18: Settlement Development Patterns Over Time (2007, 2012 & 2018) *source : Google earth extract, 2020*

As more and more open spaces have been converted to some land uses for instance brick moulding and concrete works , this has also intensified interactions of the two neighbourhoods. There is one such project close to the junction and the data collection site whereby the group of workers laying bricks would cross the junction to the other end on several occasions to fetch water at a nearby river stream close to the neighbourhoods. There are other activities on open spaces which are generating traffic through-out the two neighbourhoods like gas refilling , tyre repairs and barber shops and vending stores across the two neighbourhoods. The following image shows the brick laying site close to the junction.

Figure 19: Brick Moulding site in the open space besides the Junction *source: Self, 2020*

4.2 Road Design Considerations

Harare-Plumtree road is regarded as a regional trunk road that connects Zimbabwe and Botswana. As such it is a road that is fulfilling both local and international duties which implies its multi-functional in terms of classification. According to the design specifications, the design speed is 120km/hr and each lane has a width of 3.7m with inner shoulders of 1m and outer 2m. The midblock section is 10m in width. Demand for road access changes with economic growth and increasing prosperity, with relocation of population, economic activities and trade routes, and with expansion of urban areas and concerns for the environment. The road was initially designed to be an arterial but over time due to linear developments along the highway it has been altered to become an arterial, collector and some cases stand access. This has been done legally and illegally. Some of the roads that connect into the highway were designed by the local authority. The other stand access and collectors that connect to the highway are informal dust roads that local residents decide to use to access the highway from their houses. It is important to understand that the highway in Zimbabwe is owned and managed by the Ministry of Transport. Local authorities own and manage all local access and collectors within their jurisdiction. Since the road in question is a highway it is owned by the Ministry of Transport. The other roads that connects with the highway are owned and managed by Harare City Council. There is no coordinated planning between these two entities. The ministry of Transport maintains that the road is still a highway and will remain so hence the speed limit has not been changed regardless of the road functioning as a collector and stand access.

The local authority on the other hand states that the road is not in their jurisdiction and cannot change the classification and function of the road. Since there is no coordinated road management system by these two entities no traffic calming measures can be implemented. The implication of linear development along both side of the highway is that pedestrians have to cross the highway. This is so because some of the services such as schools, clinics and shops are in Kuwadzana Ext because it is an older suburb than Glaudina. People from Glaudina have to cross the highway in order to access these facilities. Glaudina being a new suburb it has better water supply than Kuwadzana Ext and in turn Kuwadzana Ext residence cross the highway to access water form Glaudina.

4.3 Current state of Infrastructure and facilities for VRUs on the Junction.

It must be noted that there are no crosswalk points or a designated crossing point for pedestrians and as such they cross on multiple paths that shall be explored of more in the below. The planning on the junction is automobile centric and bears no consideration for the VRUs . This must have been planned without factoring that the road functionality would change at some point and hence there would be need for localised crossing by the people in the surrounding areas. The width of the shoulders is very wide and these allow vehicles to stops on undesignated areas in some cases blocking the view of VRUs from oncoming traffic as they want to cross. Wide shoulders also give drivers perceived safety as they feel that the road is wide enough to allow them to take corrective measures in case they lose control. Wider shoulders also entail that VRUs have to walk a long distance just to cross the traffic lanes. It was observed that the wide shoulders enable drivers to carry on dangerous overtaking manoeuvres even if it is a double carriage way. This happens when the two vehicles try to overtake a left turning vehicle at the same time even though there is no left turning lane. This is usually done by minibuses during peak periods. There are also no signals in place or stop signal signs for both sets of road users.

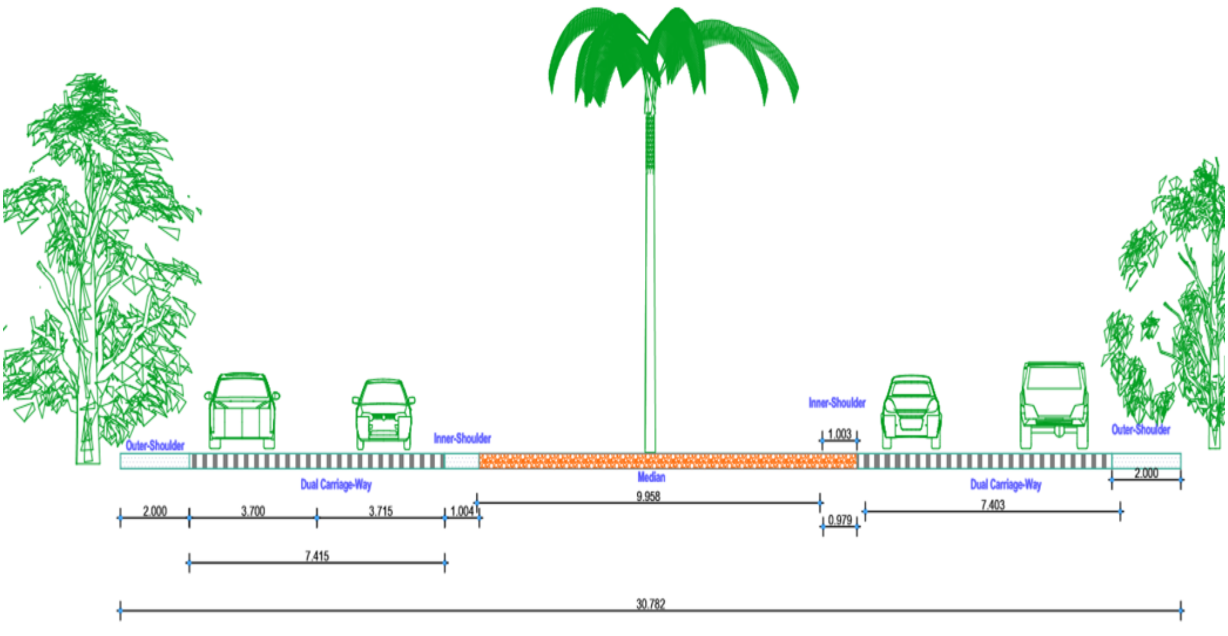


Figure 20: Cross Sectional Diagram of The Highway *Source: Self, 2019*

4.4 Changes to Road Classification and Functionality As A Result of Linear Settlement Developments

The design speed limit for the road section is 120km/hr for LMV and 80km/hr for HGVs, Minibus and Buses. Vehicular speed estimates gathered in the study reflect lower speeds for both LMVs and HGVs as they traversed through the intersection. Upon consultation with the Ministry of Transport responsible for the technical aspects of the road and the HCM , a LOS chart was designed for the speeds experienced in the data collection. These range from LOS A to F in accordance to the design speed of the two lane two way highway. This is shown in

Table 6: LOS and Speed Limit for Vehicles On A Highway By Local Standards

LOS	Quality	Speed km/hr	Description
A	Free flow	120	Operating at design speed efficiency
B	Reasonable free flow	100	Reasonable speed efficiency
C	Near free flow	80	Reduced speed efficiency beginning of some delays
D	Medium Flow	60	Delays become more pronounced with some blockages from turning movements
E	Near flow capacity	50	More delays and blockages in traffic
F	Congested flow	Below 45	Major delays and bottlenecks experienced

Source : Self , HCM 2010

This indicates some reduction in LOS on a scale of A to F for the motorist as they give way to crossing VRUs and turning movements. This is presented in the table below :

Table 7:Recorded Estimated Speeds for Different modes and LOS categories for the 6 Days

Vehicle Type	Time of the Day	Highest speed in km/hr	Lowest speed in km/hr	LOS Categories
LMVs	Morning hour	109.94	64.45	A & D
D	Morning hour	62.50	45	D& E
LMVs	Afternoon hour	93.74	61.34	B & D
HGVs	Afternoon hour	60	51.65	D & E
LMVs	Evening hour	104.65	52.45	A & E
HGVs	Evening hour	74.67	53.60	C & E

Source : Self , 2019

Furthermore, according to the hourly traffic flow rates in a multilane highway in the Highway Capacity Manual HCM 2000 and 2010, the volumes recorded in the six day study indicate that the junction is operating within capacity despite reduced LOS due to speed reductions. This further implies the multifunctional nature of the road as it now serves both mobility and accessibility for regional, local and access functions. As the linear settlements grow along the highway so too is its functionality and hence the need to update the speed limits and the classification on the planning , design and operational levels.

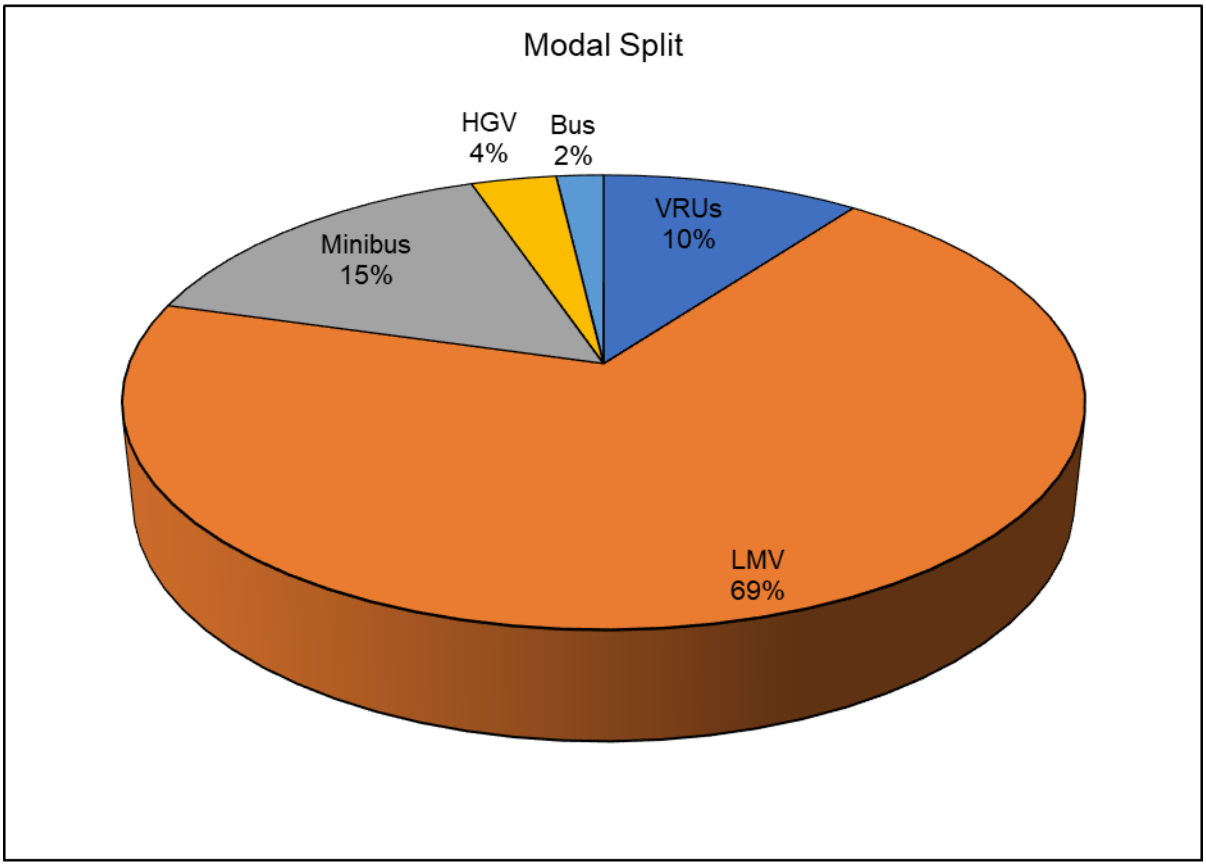


Figure 21: Modal Split of the Volumes recorded on the Junction *Source: self, 2019*

The modal split was extracted from total volumes during the research period. The VRUs constitute 10% of the total volumes while the Light motor vehicles (LMV) constitute 69% of the total volumes. LMVs have the highest average speeds as well and this makes it difficult for pedestrians to cross the road. Also of significant is the high number of minibuses. The minibuses are known for poor driver behaviour and in most cases they cause more pedestrians accidents than LMV. They also drive above speed limits and stop on undesignated stopping points.

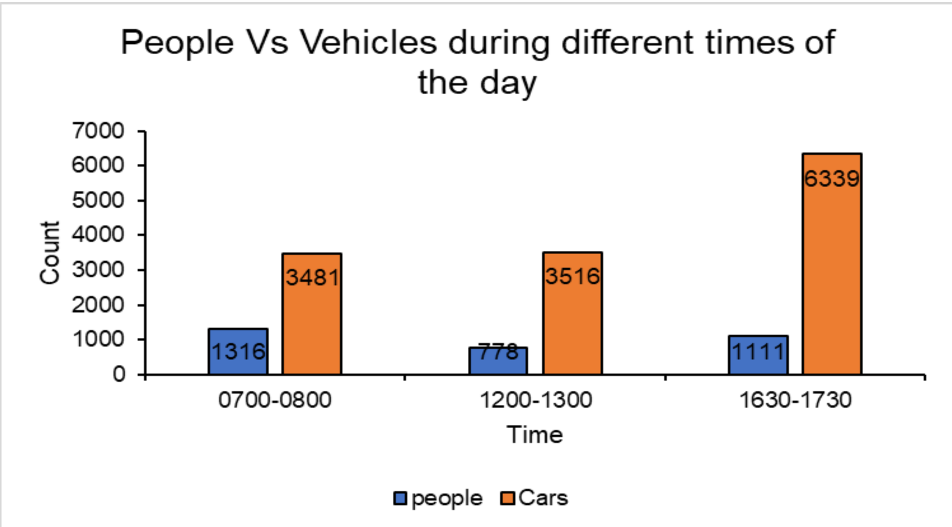


Figure 22: Vehicular and VRU Demand Volumes In Different Times of The Day *Source: Self, 2019*

Across the six day survey , the morning hour peak hour had the highest number of VRUs ratio to vehicles that passed through. The huge number of people crossing during this period could be attributed to journeys to work, to school and for various personal mandates. The afternoon hour receives the lowest number of VRUs crossing despite having a high volume of vehicles than the morning peak hour. The evening peak hour experiences a higher number of VRU to vehicle ratio signifying it is the time most return home from a day's work , school and other activities , hence the more interaction of VRUs and vehicles on the junction.

It was also in the interest of this study to observe from the video observation verbal and non-verbal communication between drivers and VRUs crossing. Due to issues of high speed moving vehicles in a highway set up, it was commonly observed that most drivers sounded a horn and slightly reduced speed as they passed through the junction. This acted as a warning to the VRUs that stood waiting on the kerb for a suitable gap upon which they could cross in between the vehicles. No other notable gestures could be observed on the part of the drivers but looking on behaviour in both directions by the VRUs before they could engage on their crossing.

4.5 VRU Characteristics.

Aspects like gender, age and other personal attributes of VRUs have proven to be key in the analysis of crossing behaviour in many studies . Again in this study , these could not be ignored as important for they explain some of the crossing dynamics that were observed in the data collection period. It is however unfortunate that only gender attributes could be gathered, without precise ages of all people that crossed on the junction. The ages could only be estimated but not precisely gathered, through playing the video footages since no interviews or questionnaires were utilised in the survey. The results show that most people that crossed are males (67%) compared to females (33%). Of the females that crossed most of them could be seen in the morning and afternoon period as they were accompanying children to school or coming from the other neighbourhood for various endeavours . Morning peak was characterised by many men who crossed to the other side to hike for informal private vehicles headed towards the CBD of Harare . In most instances the children that crossed the junction were accompanied by an adult male or female and in cases they did so alone , they did in a group of at least two or three peers going or coming back from school. A huge number of women that crossed also carried some baggage on them or would have buckets carried on top of their heads. These observations are in line with some of the studies that have been conducted before on the subject matter. They point out to some of the conclusions made in them regarding the contribution of gender dynamics to crossing behaviour on the junction.

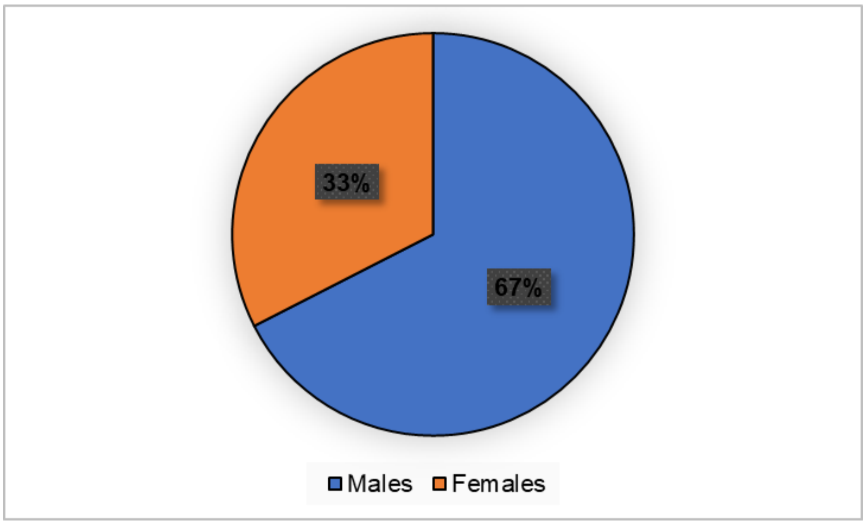
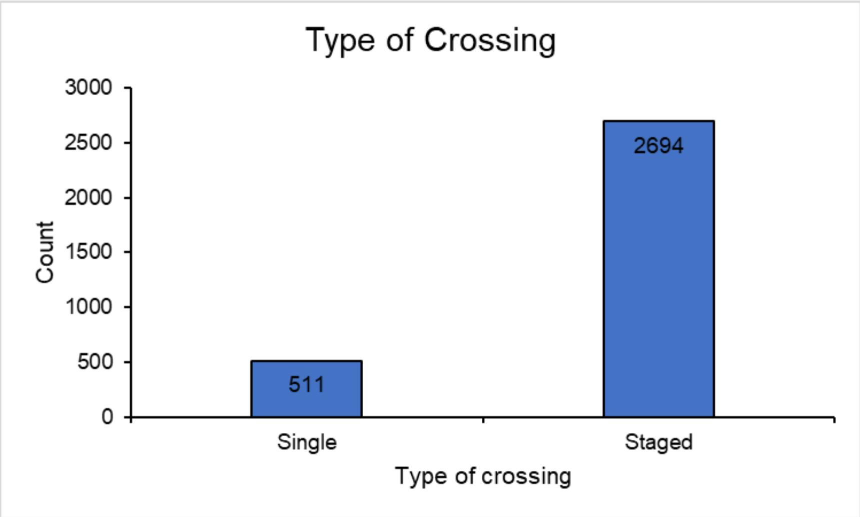


Figure 23: Male and Female Composition of VRUs in The Study *Source: Self, 2019*

4.6 VRU Crossing Behaviour

4.6.1 Type of Crossing

The commonly observed type of crossing on the junction is the staged crossing which constitutes 84% of the total number of VRUs that crossed on the six day period. This may be attributed to: the speed upon which the vehicle moved, the distance needed to complete all four lanes including a midblock section , as well as the presence of the midblock section which staged crossing more convenient . A wide median of 10m enables pedestrians to wait on the median while they assess the next gap to cross the other half of the highway. A wider median improves the safety of vulnerable users as it offers an island to stop and assess the next gap to cross the road. Single crossing which constitutes 16 % was mostly observed in the not so busy periods and this was mostly done by jogging action. By jogging action the VRUs were forced to complete the crossing faster than they would normally do when walking freely at desired crossing speed. The figures may be graphically shown in the below :



source : Self, 2019

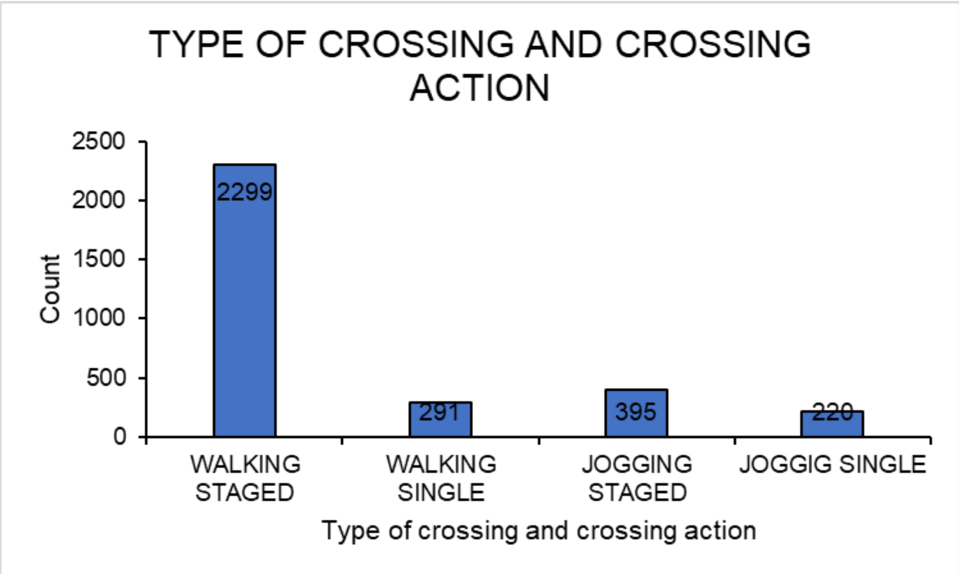


Figure 24: Type of Crossing & Resultant Crossing Gesture *Source : Self, 2019*

The study also observed that due to the nature of the vehicular speeds , most VRUs either walked swiftly or engaged in some jogging gesture as an evasive action to manage their gaps and successfully complete their crossing. The commonly observed type of crossing was through normal walking gesture and it was staged (71%). Single crossing at normal walking speed was mostly observed (9%) during periods of less traffic volumes in all periods of the day, and in this period VRUs had flexible gaps that enabled them to do so. Furthermore, 43% of those that engaged in single crossing ran all the way, while the other 57% crossed the highway while walking. The latter again was mostly observed in periods of less vehicular volumes which enabled gaps in both sides of the highway for a complete single crossing action. The evasive action to complete the crossing through some jogging gesture is indicative of the willingness of some VRUs to take some critical gaps to complete a crossing . Such a risk taking behaviour can be attributed to various factors which are personal attributes of the one crossing and the nature of the available gap in the stream of traffic . Like in many studies on pedestrian crossing behaviour, males were the ones that engaged in both single and staged crossing whilst jogging than females. Man constituted 14 % of those who did so, while only 5% were women which answers to what studies have shown that men are more risk taking and less patient than women when crossing the road

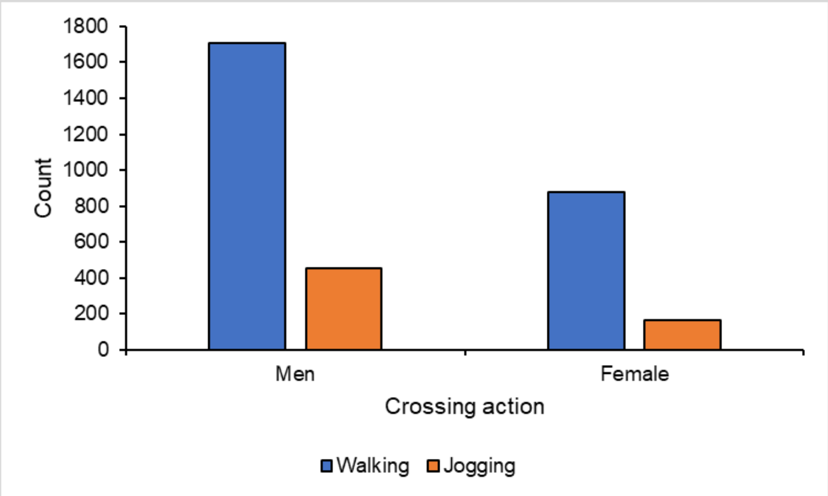


Figure 25 : Volumes by Gender and Resultant Crossing Gesture *Source : Self , 2019*

4.6.2 Crossing Patterns

The study also probed into the crossing gestures and path chosen to cross by VRUs given there is no specific crosswalk point provided for on the junction. In much busier periods like morning peak and evening peak, there are more people who crossed in a jogging or running gesture than the afternoon period where more people walked at normal free walking speed. The following graph illustrates the above which points out to VRUs taking more evasive action through jogging to complete their crossing in the peak periods.

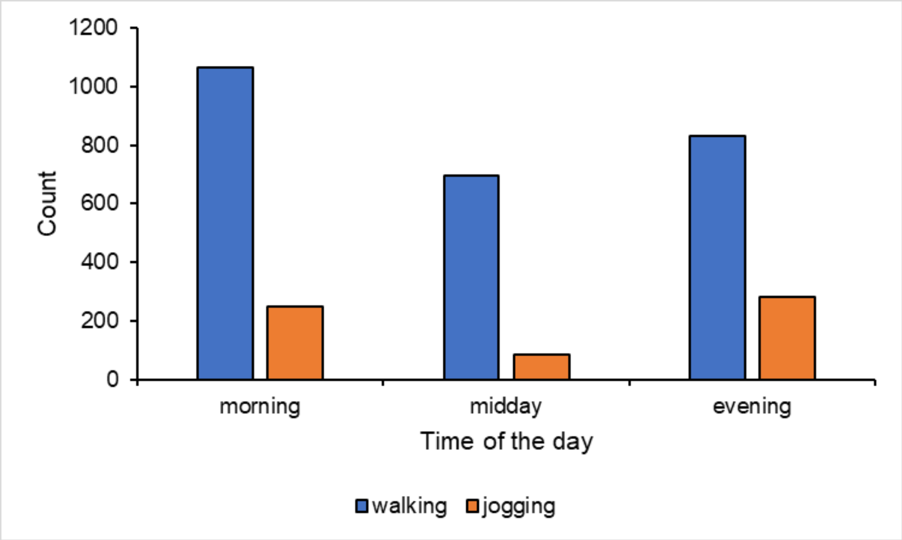


Figure 26 : Crossing Dynamics in Different Times of The Day*Source :Self , 2019*

There are some commonly used crossing paths that were noted in the study and categorised into four sections for the purposes of the study. These are crossing path 1, 2 , 3 and 4 which are areas that could be noted from the island section which is covered with some green vegetation. By consequence of people constantly walking in these they have thus been eroded into dust footpaths with Part 2 being the largest and most eroded showing it's the most commonly used path. As was observed in the analysis, path 1 is the second most used path with path 3 and 4 being the least used. It appears path 2 seems to offer certain advantages for most people to cross on than other points . These are a more direct route to get to the other end of the road which channels them straight on to the dust road heading to the other suburb Glaudina, and the available crossing gaps that were provided for by turning movements. The latter was observed in many instances of VRUs crossing as pedestrians waiting to get some crossing gap took advantage of the temporal blockage to the main traffic provided for by turning movements in to and out of Kuwadzana extension suburb. It was notably too risky for many to take their crossing directly on the junction, and as such those very few that did so were recorded in either path 1 or 2 depending on the closeness to the path in question. The paths are graphically presented in **Fig 27**, as well as **Fig 28** showing one of the reasons path two is a favoured crossing point for many pedestrians

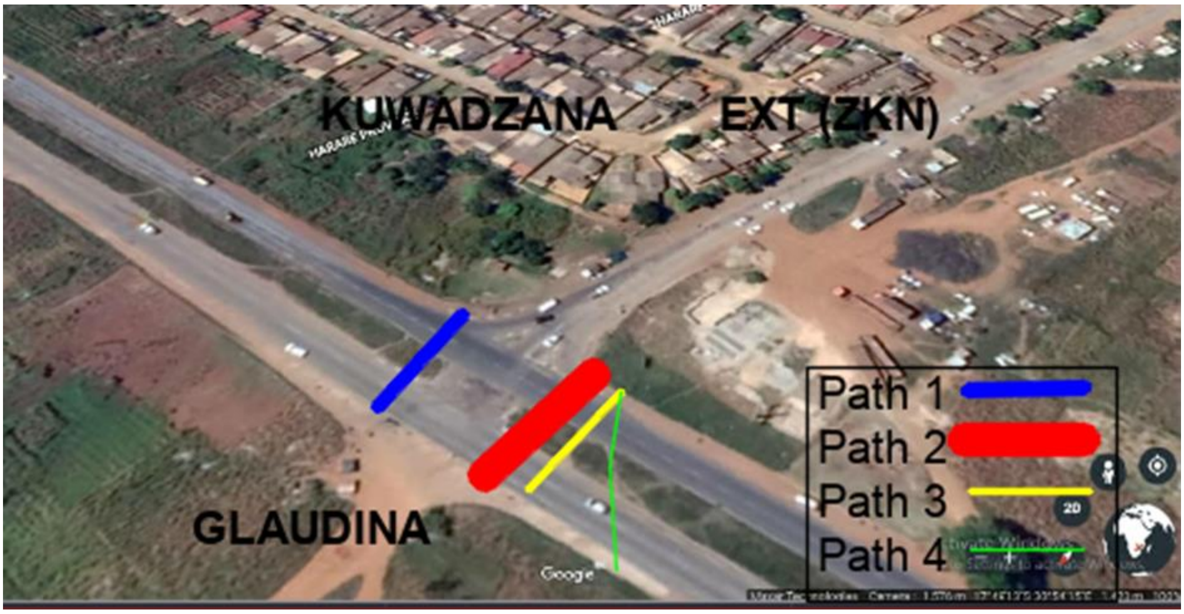


Figure 27:Diagrammatic Illustration of The Most Used Crossing Paths *Source : Self, 2019*

Figure 28: Image of Pedestrians Crossing on Gaps Created by Turning Movements *Source : Field Research, 2019*

The red arrow shows a stream of pedestrians utilizing the gap provided by the traffic in the junction making its way into the highway from Kuwadzana Extension end. The green arrow shows path 2 with an wider bare ground as explained in the section above. As can be shown in fig 3 , path 4 which is not commonly used is the only path that exhibits oblique crossing while the other paths show straight crossing . Straight crossing motion was commonly observed due to the fact that it seems to provide a more direct and shortest route from origin to destination. Those that used the path spent more time on the island as they looked for a suitable gap in traffic to proceed with their crossing. This also is indicative of the lack of patience in some VRUs to remain waiting for longer periods half way on the midblock section , hence took the longer indirect route as they waited for gaps in traffic.

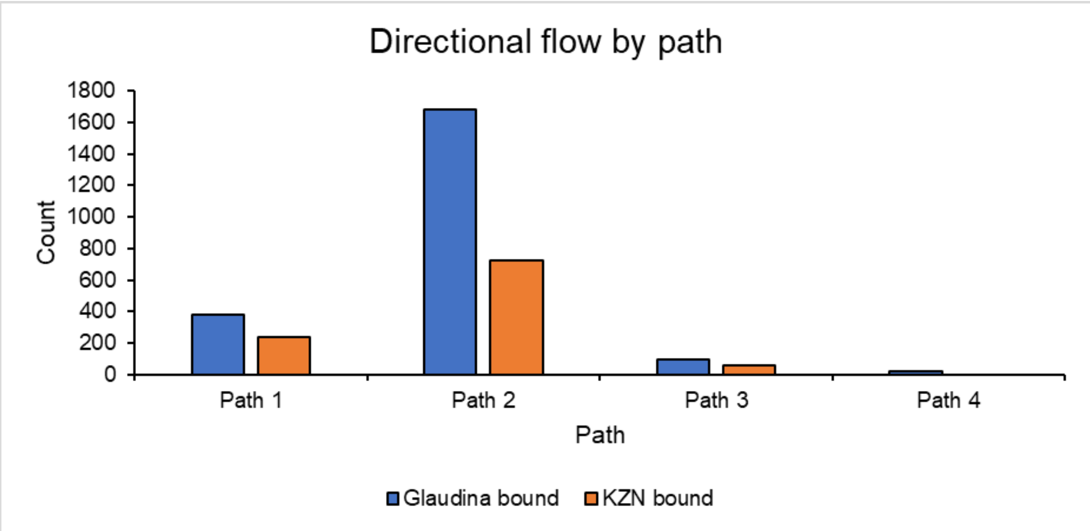


Figure 29: Directional Flow of VRUs Crossing By Path *Source : Self, 2019*

Most people who use the different path are coming from Kuwadzana (KZN) Ext and going towards Glaudina. This is because the people from Kuwadzana Ext who cross the highway do not usually proceed to Glaudina residential area but rather hitch hike on the highway. Hitch hiking is only possible from the other side of the highway thus people cross the highway from KZN bound to Glaudina. Important to note is that the practice of crossing is more common in the morning peak period than any other time of the day. When people who hitch hiked in the morning return form work they are dropped on the right side of the KZN side of the highway and they do not need to cross the highway again.

4.6.3 Crossing Speeds and Waiting Times

Crossing times and waiting times were generated through cutting the videos into smaller frames and playing the videos over and over again. These could however not be done for each and every individual that crossed but samples of both males and females were randomly picked across the six day period in different hours of the day. The average waiting time at the kerb was about 8 seconds while crossing the two lanes was about 7 seconds. For those who crossed the highway in stages most of the time was spent on the median waiting to cross the other lanes of the highway. This VRUs were crossing the traffic lanes on average speed of 1.29m/sec. Males had an average crossing speed of 1.32m/sec while women had an average of 1.27m/sec across the sic day period. These averages are above the average crossing speed of 1.25m/sec given in the Highway capacity Manual (HCM 2000), which shows the urgency with which men and women cross the highway junction. It was observed that those that managed to do a single crossing took on average of 22 seconds as compared to 40 seconds for those who crossed in stages. The waiting times, and time taken to cross the lanes was the same.

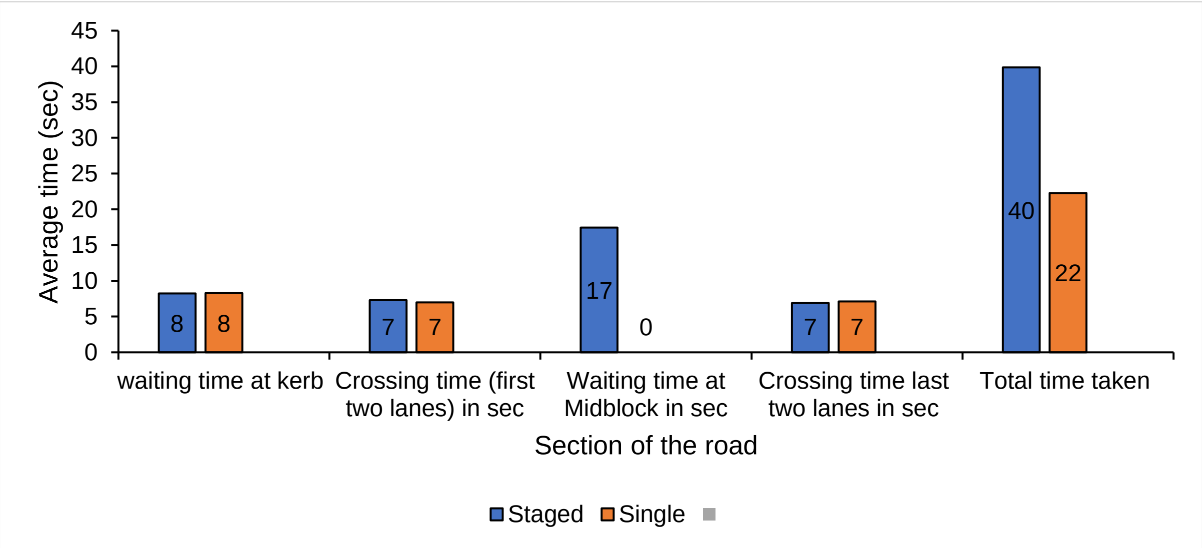


Figure 30: Crossing and Waiting Times *Source: Self, 2019*

According to the findings women , spent more time waiting at the midblock section than men did as they waited for a suitable gap in traffic. This supports the notion raised in previous studies which argues that men are more risk taking than women when crossing the road. This shall be further clarified in the next section on gap acceptance results.

4.7 Gap Acceptance Behavior On The Intersection.

Gap can be defined as the time difference between leader vehicle and lag vehicle and it is an important term in pedestrian road crossing behaviour (Kadali & Vedagiri, 2013). The study discovered that like in other studies there are a number of factors that determined if one accepted or rejected a gap in the traffic. One of these aspects is the gender of the VRU, and in this study average gap sizes were computed for men and women respectively. Men had an average accepted gap size of 6.73sec whilst women had an average of 8.43sec. The average accepted gap size for all VRUs was 7.25sec .

Binary logit model was incorporated to assess what factors contributed in determining if a VRU accepted or rejected a certain gap in traffic. The effects of the selected variable on VRUs road crossing behaviour is modelled using regression. To study the choice behaviour of the pedestrian (that is whether to accept or reject a gap) a binary logit model was developed using SPSS 26. The binary logistic is regression for a categorical outcome that is if VRUs accept or reject the gap. The probability of accepting an alternative (accept or reject) is based on a utility function (Kadali and Vedagiri 2013). The linear function is expressed as following.

$U_i = \alpha_i + \beta_{i1} X_1 + \beta_{i2} X_2 + \beta_{i3} X_3 + \beta_{i4} X_4 + \ldots\ldots\ldots\ldots\ldots + \beta_{in} X_n$ Equation 1

Where

Ui=the utility of choosing alternative i;

i= the alternative (accept/reject)

n= number of independent variables;

α= constant;

β = coefficients.

A number of variables were considered in the binary logit model to understand the pedestrian crossing behaviour. Chi square tests were run on the variable to see if they were some significant in modelling pedestrian crossing behaviour. Only variables shown on **Table 9** were significant in as far as explaining to the outcome variable between two independent variables . These are the decision to either accept or reject a gap in traffic. These variables are vehicle speed, gender and waiting time on the kerb.

Table 8: Variables Factored In the Model

Variable	*Type of Variable*	*Unit/Code*	*Description*
Gender	Discrete	1= Male 2= Female	Male or female
Evasive action	Discrete	1= Yes 2 =no action	Action taken to avoid collision with vehicles while crossing
Type of crossing	Discrete	1= single 2 =staged	Whether VRUs crossed the road once or they crossed in stages and waited on the median
crossing direction	Discrete	1= KZN bound 2=Glaudina bound	Direction which the VRUs were going
crossing path	Discrete	1= Path 1 2= Path 2 3= Path 3 4= Path 4	Path the VRU used to cross the highway
Crossing action	Discrete	1 =Normal Walking 2= Jogging	The way the pedestrians crossed the highway
Looking behaviour	Discrete	1=Left Traffic Look (LTL) only 2=Right traffic Look (RTL)only 3=Both LTL & RTL all lanes	Whether VRU looked on different side of the road before crossing
crossing time	Continuous	Time in seconds	Total time taken to cross the highway
Vehicle Speed	Continuous	Km/hr	Speed of the vehicle at the crosswalk
Accepted gaps	Continuous	Time in seconds	Size of gaps accepted
Waiting time at kerb	Continuous	Time in second	Time while waiting for an acceptable gap
Crossing time interval	Discrete	1=Morning peak 2=Afternoon (off-peak) 3 =Evening peak	Time of the day the VRUs crossed the highway
Accept or reject gap	Discrete	0=Reject 1 =Accept	Whether the pedestrian accepted or rejected the gap

Source : self, 2019

Table 9: Variables That are Significant In The Model

Variables	**β Coefficient**	**Standard Error**	**T-value**	**P-value**
Vehicle speed	-0,154	0,027	-5,7037037	.000
Gender	-1,499	0,497	-3,01609658	.003
Waiting time at kerb	-0,055	0,02	-2,75	.005
Constant	12,803	2,048	6,251464844	.000

(P values and T values are represented at 95% Confidence interval) Source : Self, 2019

UI= 12.803-0.154*vehicle speed – 1.499* gender – 0.055* waiting time at Kerb. Equation 2

The Model significance is based on the T value and P values. The R-squared is 60% which shows that 60% of the variance in the dependent variable can be explained by the predictor variable. The variables shown in the above table have a significant effect on whether they accepted or rejected a certain gap. The model confirms the notion that males are likely to take smaller gaps in traffic for their crossing than women as other studies in literature discovered. This further explains why they have a shorter average gap size than that of women in the study. Furthermore, VRUs are likely to accept gaps in traffic it the vehicles are travelling at lower speeds than higher speeds as shown in the vehicle speed variable in the table above. Smaller waiting times at the kerb also increases the probability of accepting the gap. This however does not seem to concur with studies that have shown that larger waiting times at the kerb increases the probability of VRUs taking smaller and risky critical gaps to complete their crossing . The HCM 2000 stipulates that a pedestrian will start considering risky gaps in traffic if they wait for a period of 30sec or longer beyond which they gamble with small critical gaps in traffic. The longer the waiting time , the more pedestrians start losing their patience and hence engage in risk crossing behaviour usually rolling gaps. In this study however, rolling gaps were very minimal with most VRUs taking sure gaps that landed them on the midblock section safely .

4.8 Analysis and Discussion

The results from the analysis clearly shows that the functionality of the highway has shifted to serving both accessibility and mobility needs. Hence the authorities in charge of managing and maintaining the road need to work in partnership with local authorities towards addressing concerns of other road users in this case VRUs. There is also need for some reflection on the speed limits which by international standards (120km/hr) is still quite high . Therefore there is need to review the later in light of the other localised traffic with lower speed vehicles and the growing number of VRUs using the junction for their crossing on a daily basis. This however will not be easy to balance given there is a trade-off between lowering the speed limits which is safer for VRU crossing as well as ensuring vehicles have enough speed allowance to move within the freeway to serve the mobility function.

It was also of paramount importance to map the movement patterns of the VRUs crossing the junction in different periods of the day. The much higher volumes of people recorded during the morning hour were people who just crossed to the other side of the highway to hike for informal public transport headed towards the CBD. These are mostly people coming from Kuwadzana extension end, and given there is adequate and affordable formal public transport means, a greater number of these VRUs would not be subjected to the dangerous highway crossing. The afternoon and evening hour characterises people coming from school and work and reflect more interaction between the two neighbourhoods. At all times of the day there was a considerable stream of VRUS on the shoulders of the highway waiting for some private cars and commuter omnibuses to take them to the city centre. Although looking-on behaviour is like a default aspect on the junction , due to vehicle speeds there is limited to no interaction between motorist and VRUs with the latter needing to practise extreme caution before engaging in their crossing.

Furthermore, people usually accepted gaps when they had someone else waiting to make a crossing or rather a platoon of pedestrian utilising the same gap. This behavioural trait shows a lot of compliant behaviour to cross when one assumed a suitable gap to engage in the crossing. Young school going children utilised these kind of gaps mostly . Both men and women also utilised gaps created by left turning movements which slowed traffic in the highway and allowed for a passage for them to cross. This has already been shown in **Fig 28** and such gaps were utilised mostly in the morning and evening peak periods . The study also raised and buttressed the gender dynamics in crossing behaviour given that women had more average crossing times and speeds, much longer waiting times and accepted much longer gaps in traffic than men(Khan et al, 1999, Tiwari et al ,2007 & Kadali & Vedagiri,2013). This is not withstanding the fact that most women had either some luggage on them or a kid they held in their hands before engaging in a crossing which could have significantly influenced their crossing decisions.

Vehicle speeds also influenced the crossing decisions of both men and women and the resultant crossing action taken . This implies that it was much safer to take gaps of cars moving slower than those moving very fast especially in the inner lanes . This is in line to the conclusions reached in previous studies on crossing behaviour in developing countries (Cherry et al ,2012, Oxley et al, 1997, Lobjois & Cavallo, 2007). According to table.. on estimated vehicle speeds on the junction , the lowest vehicle speed was 45km/hr. Research has shown that the probability of a pedestrian being killed rises by a factor of 8 as the impact speed of the car rises from 30km/hr to 50km/hr (Ashton & Mackay, 1983). There is further evidence to suggest that even at lower speeds the probability of fatality is still possible. A study by Holskudur,(2015), discovered that 93% of the severity injury accidents occurred at locations with a mean speed below 50km/hr , 63.2% at locations with a mean speed between 40km/hr and 50km/hr. This further implicates the vulnerability of those that have to cross the junction given the highway setting and the estimated speeds . Thus a lot in terms of counter measures could hinge also on a review on the speed limits or countermeasures towards speed enforcement on the junction.

In comparison to other studies , the values in seconds for accepted(critical gaps that were sufficient to complete a crossing) and rejected gap sizes (gaps turned down in seconds), in the current study are much higher than in some studies(Kadali & Vedagiri , 2013) . In the study by Kadali and Vedagiri, (2013), the mean accepted gap without rolling gap was 5.38s and 4.05s when drivers yielded which is less than the values in the current study mentioned above. This indicate of the risky and diverse nature of highway crossing compared to suburban or city centre crossing conditions under mixed traffic. The critical gap is also much larger and this may be attributed to vehicle speeds in a highway set up where by drivers do not yield for VRUs to cross. Despite the growing number in VRUs and vehicular volumes due to settlement growth, there is still no measures that have been put in place to lessen their risk when crossing which enhances their vulnerability. The crossing action of jogging or some running action is a forced evasive action which reflects of the difficulty some VRUs face in order to get to the other end. Thus any measures that would lessen their need for crossing or ease their crossing would be a welcome development.

The risky nature can be further explained by a situation witnessed in the data collection where one male pedestrian crossing with a bicycle was knocked down by a fast moving vehicle headed towards the CBD end . Although due to field restrictions , not much in terms of detail could be gathered of the pedestrian who was immediately rushed to Hospital for medical assistance. The area is known for such kind of crashes which are most often underreported and not so documented of , probing to the need for some counter measures on the junction. There was also another related case of a man that was attacked by some armed robbers after crossing the highway to the other side of Kuwadzana extension to hike for public transport headed towards the city centre of Harare. It also came on record that the corpse of the VRU was discovered lying on the bush on the sides of the highway. Thus , the above two cases that were captured in the data collection indicate the risk aspects associated to VRUs crossing the junction. Nonetheless, the latter doesn’t reflect much on the actual crossing but effects of the need to cross in order to access public transport. Despite not having access to data from police records on previous accidents involving VRUs on the junction, the vendors and brick layers close to the junction gave an account of number of accidents they witnessed over the course of the days and years on the junction. In those informal discussions they remarked of how some these occurred and how VRUs lost their lives or were seriously injured from the collision impact. Thus, with improved accident data reporting and database management , it may reflect the true nature of the risk elements on the junction which can henceforth, drive the relevant authorities to device some countermeasures to improve the safety of VRUs.

There are other points or paths further from the junction that could be observed on the midblock section that are paved showing use by VRUs crossing . These however could not be captured in the study due to video frame coverage and distance limitations .

4.9 Recommendations

Based on the findings from the study , the following are recommendations that can be taken into consideration to better the crossing conditions for VRUs on the junction. Firstly, there is need for coordinated land use planning and transport planning by the relevant stakeholders to ensure that the continued developments of linear settlements along the highway are curbed. This also includes ensuring that road classification and functionality is regularly updated and monitored to ensure that mobility and accessibility are not compromised. In this instance it is clear that the road has assumed more than the initial mobility function but also the accessibility function resulting in many safety concerns on the junction. One way to ensure that the functionality and classification of the road are updated is by reviewing the current speed limits pegged at 120km/hr to be lowered and at least match up with international standards especially on the junction and its immediate surroundings.

Secondly , on the engineering side , to ensure that motorist at least lower their speeds when approaching the junction speed humps can be put in place towards the junction in both direction of movement. The same kind of measure has already been put in place in the Harare-Mutare highway around Masasa area in an attempt to curb the high number of crashes around the area . This however , also entails that the regional function of the road in channelling fast moving traffic will be altered, and this will mean lower LOS for vehicles travelling on long distance journeys. Thus , such a measure will only be meaningful if all road user concerns are taken into account. There is also need to factor having some speed warning signs and signs for speed limits which will be complemented by speed limit enforcement to ensure motorist reduce speed when approaching the junction.

Overpass infrastructure for VRU use can also be considered on the junction as a mid-term to long term solution to the junction. This however needs quite some huge financial investment and as such the volumes that cross on a daily basis should be sufficient to warrant such a development. The volumes recorded on the junction in the survey are indicative of the growing demand for crossing by VRUs which is likely to keep growing as the two settlements grow and develop in terms of population figures. However , before this can be put in place, it was observed that the greater bulk of VRUs that cross from Kuwadzana extension end do so to get access to the hiking spot for private cars going towards Harare CBD. These private cars offer cheaper rates as compared to the commuter omnibuses which makes them the go to option. This implies that if reliable and efficient formal public transport is put in place to serve the neighbourhood , a greater chunk of the people would have no need to cross the busy highway. Thus , public transport reforms are another measure that can be put in place to reduce the demand for crossing on the junction and ensure the safety of VRUs . In the short run , there is need for some provision of designated crosswalk points and markings around the junction for VRUs. Findings from the study shows that VRUs are utilising many points for their crossing with most utilising Path 2. As such, area around Path two can be considered a point on the junction for putting up some crosswalk markings across all four lanes on the highway.

Traffic safety education still remains a key intervention measure that can be used through awareness to inform the VRUs of the necessary caution they need to practise when crossing the road. This also extends to encouraging drivers to lower their speeds and respect crossing VRUs on the junction to enhance their safety. There is also need to invest more in studies of this nature to understand more of VRU crossing behaviour and challenges on highways , especially those that address some of the shortcomings of this study which will be highlighted in the below.

4.10 Limitations Of The Study

The study was not without limitations of its own and these were physical, technical, institutional and time related constraints. On the physical constraints, the site did not offer availability of a pole or elevated stand upon which the camera could be mounted on close to the junction to give a much closer and more accurate picture of the data. As such , improvisation to rectify this was only possible some metres away from the junction and this was at a side angle and not on bird's eye view. This in a huge way compromised the quality of the data collection process as it also complicated the data analysis process due to the video quality and angle. On the technical side, a drone could not be utilised due to issues of battery capacity and instead the conventional digital camera was utilised. Again , the vehicular speeds could not be gathered through a speed gun, but through measuring a distance of 400m using tape measure and a stop watch as the cars passed through. This might have compromised coming up with exact and accurate speeds for the vehicles and hence the study relies on estimated speeds. It was also a huge challenge to decode the data from the video footages in the data analysis stage. To address such the videos were cut into frames through creating a software that made sure the variables could be generated. This however, could not guarantee complete accuracy to the process and after this most of the variables like crossing time and speeds were manually gathered which prolonged the data analysis stage. Again the video angles made some aspects very complicated to generate in one video play thus the videos had to be played numerous times fast forwarding, rewinding and pausing in some instances which was a time consuming process.

At an institutional level, digital maps of the study area could not be found from the relevant authorities who can only provide hard copy maps of the area. One of the objectives of the study is to analyse the nature and intensity of developments in the respective neighbourhoods over time. This however, could not be done without the digital maps to create the overlays of the area in the past 3-4 decades. Bureaucratic challenges also characterised the data collection process , where it took a two weeks delay to have the letter of approval to collect the data signed by the City of Harare. It was also complex to get some secondary sources of information from the ministry of Transport and one challenge that was easily detectable is the lack of available and up to date traffic data at institutional level. The challenge also translated to cumbersome time delays which above all prolonged the data collection as well as analysis and reporting of the findings. Due to the technical, physical and institutional limitations, the study took much longer time than anticipated since the period of data collection. Furthermore there are some ethical and unforeseen events that also affected the data collection process. In one of the days during the evening hour , a pedestrian crossing with a bike was knocked by a car on the shoulder of the last two lanes as he was about to complete his crossing. This generated a lot of traffic volumes of pedestrians who came running from Kuwadzana Extension , to witness the crash and it distorted the normal flow of traffic even for vehicular traffic. It was also captured in the recording although from such a distance , not much detail could be deduced from the scene itself. The same distortion was encountered when a corpse of one man was found lying in the grass besides the main highway, a lot of people crossed to witness the such. Despite all these limitations, the study made observations which gave insights on the condition of the junction and the crossing dynamics for VRUs and it paves way for future studies to address some of these shortcomings

4.11 Areas of Future Research

There are a number of areas and pointers from the current study that can be addressed by future studies on VRU crossing behaviour. One of these would be studies that will utilise the current technologies in data collection like drones so that a much closer , and accurate reflection of the junction can be collected. There are aspects like vehicle speeds also that can be more precisely gathered by speed guns and for a greater composition of the volumes. Studies that will also look at microscopic characteristics of vehicular and VRUs will also provide more insights on the study as opposed to averaged values, which were mostly relied on in the case in the current . These include microscopic behavioural attributes of the VRUs in terms of age group, use of gestures when crossing , individual crossing speeds , communication with drivers of vehicles and other road users . After all is done , there is need for studies that will create a behavioural model for VRUs crossing in highway and mixed traffic conditions. Such can be used as a reference for intervention measures on junctions of this nature which are typical of many areas in Zimbabwe and other developing countries.

4.12 Conclusion

In a nutshell, the above findings have reflected of the current state of interaction between VRUs and motorist on the particular junction. A close look at aspects like vehicular speeds, crossing gestures, crossing speeds, waiting times, gap sizes in terms of accepted and rejected gaps, shows averages which are slightly higher than standard provisions in the HCM 2000 and 2010. Average vehicular speeds , crossing speeds and gap sizes are suggestive of the risk element posed on VRUs on the junction and some countermeasures could be worth considering. This is also given the fact that a crash was even witnessed in the data collection period, which suggests there could be more of these witnessed on a regular basis . Some of these countermeasures , will need to be informed by further and detailed studies of this nature and these can be in the short run, mid-term and long run. Further studies could also explore the subject more and address some of the ills and shortcomings of the current study towards improving the crossing conditions for VRUs on such junctions in the developing world context.

References

(CUTR), C. f. (2015). *Understanding Interactions Between Drivers and Pedestrians : Features at Signalized Intersections.* florida: Centre for Urban Transportation Research (CUTR) University of South Florida.

(OECD), O. F.-o. (1998). Safety of Vulnerable Road Users: Scientific Expert Group on The Safety of Vulnerable Road Users . Paris , France .

(SATC), S. A. (2009). *Safe Route To Schools : Briefing Sheets* . Texas: SATC.

.E.M, D. (2002). Theory Of Planned Behavior and Pedestrians' Intentions to Violate Traffic Regulations. *Transportation Research Part F*, 169-175.

.P.C, R. (2017, May). Safety of Pedestrians and Cyclists when Interracting with Auttomated Vehicles . Deft , Netherlands.

A, T. (1996). Functional Classification of Roads: Paper Presented at the annual meeting of the Transportation Research Board. *The Transportation Research Board* . Washington DC.

Akbar, A. (2017). Road Crossing Behavior of Pedestians At Unsignalised Intersections of Dhaka City. Department of Civil ENgineering , Bangladesh University of Engineering and Technology, (BUET), Bangladesh.

Amo, T. M. (2014). The Epidemology of Road Traffic Accident (RTA) in Ghana from 2001-2011. *Life Science J 11(9).*

Asaithambi.G., K. &. (2016). Pedestrian Road Crossing Behavior Under Mixed Traffic: A Comparative Study of an Intersection Before and After Implementation. *Transp.in Dev. Econ.* .

Ashton. S.J, &. M. (1983). Some Characteristic of The Population Who suffer Trauma As Pedestrians when Hit By Cars and some resulting Implications . *Proceedings of the IRCOBI Conference* .

Barton.B.K, &. S. (2007). The Role Of Age , Gender and Parental Supervision on Children's Selection of Risky Pedestrian Routes . *Journal of Pediatric Psychology* , 517-526.

Billingsley .S. (2018). *Streets for Life: Safe and Health Journeys for The Children of Latin America and The Carribean* . FIA Foundation, Save The Children Foundation And Unicef .

Bourquin, E. A. (2016). Conditions That Influence Drivers Yielding behaviour : Effects of Pedestrian Gaze and Head Mivement . *Volume 8, Number 1*.

Brijs.T., P. .. (2018). *How To Analyse Accident Causation? A Handbook with Focus on Vulnerable Road Users Deliverable 6.3.* Hasselt , Belgium: Horizon , 2020 EC Project.

Cavallo.V., L. .. (2007). Age Related Differences in Street-Crossing Decisions : The Effect of Vehicle Speed and Time Constraints on Gap selection in an estimate Task . *Accident Analysis & Prevention*.

Chandra. S, R. R. (2014). Descriptive and Parametric Analysis of Pedestrian Gap Acceptance In Mixed Traffic Conditions. *KSCE Journal of Civil Engineering 18(1)*, 284-293.

Cherry.C. Donlon.B., Y. M. (2010). Illegal Mid-block pedestrian Crossing In China : Gap acceptance , conflict and crossing path analysis . *Journal of Injury Control and Safety* .

City of Bristols, U. (2018). *Traffic Choices BS1*. Retrieved from https://www.trafficchoices.co.uk/traffic-schemes/puffin-crossing.shtml

D, M. (undated). *Road Deaths in Developing Countries : The Challenge of Dysfuctional Roads.* International Road Assessment Program (IRAP).

Eby, D. W. (2011). *Naturalistic Observational Field Techniques for Traffic Pyschology Research* . CRC Press, Taylor & Francis .

Evans. D., &. N. (1998). Understanding Pedestrian Road Crossing Intentions: An Application and Extension of the Theory of Planned Behavior. *Health Education Research 18(3),* 267-277.

Ferenchak, N. N. (2014). Pedestrian Age and Gender In Relation to Crossing Behavior at Midblock Crossing in India. *Jorunal of Traffic and Transportation Engineering 3(4),* 345-351.

FitzPatrick.K, T. B. (2006). Improving Pedestrian Safety at Unsignalised Crossings : Transit Cooperative research Program and National Cooperativee Highway. Washington DC, USA.

Francis.J, E. M. (2004). Constructing Questionares Based on The Theory of Planned Behaviour : A Manual for Health Service Researchers. Newcastle , UK.

Grayson.G.B. (1984). *The Malmo Study: A Calibration of Traffic Conflict Techniques (No . R -84-12)* . Leidschendom : SWOV Institute For Road Safety.

Group, T. R. (2014). New Jersey School Zone Design Guide : The Ne Jersey Department of Transportation . New Jersey, USA.

H.J.S, L. .. (2001). Course on Traffic Conflict Measuring Technique. Pretoria, Western Cape Provincial Office , South Africa.

Hamed, M. (2001). Analysis of Pedestrian Behavior at Pedestrian Crossings . *Safety Science 38 (1)* , , 63-82.

Hill.R., H. .. (2007). The Effect of Age and Driver Status on Pedestrians Intentions to Cross The Road In Risky Situations . *Accident Analysis and Prevention 20(3),* 187-197.

Hollan, C. &. (2010). Gender and Differences In Factors Predicting Unsafe Crossing Decisions in Adult pedestrians across the life Spsn. *Accident Analysis and Prevention 42* , 1097-1108.

Hoque. M.M.D, M. S. (undated). Dealing with Vulnerable Road Users(VRU) Safety and Mobility In Urban Areas of Bangladesh. *Critical Sustainable Transport Development Challenge(CODATU).*

Hoque.S.Md, D. &. (2007). Impact of Garnent Industries on Road Safety In Metropolitan Dhaka. *Proceedings of The Eastern Asia Society for Transportation Volume 6*.

Hunsanon .T., K. .. (2017). Control Strategy for Vehicular and Pedestrian Midblock Crossing Movements. *Transport Research Procedia* .

I, Z. (2015). *2000 pedestrians killed on Zimbabwe roads in Three years.* Bulawayo: Bulawayo News 24.

Ibrahim, N. K. (2005). Motorist and Pedestrian Interaction at Unsignlaized Pedestrian Crsossing In : . *Proceedings of the Eastern Asia Society for Transportation Studies* , 120-125.

J, V. H. (2013). Linear Settlements Along Highways, Vulnerable Road Users and the Implications for Urban Land use and development in Different Countries . *Building Road Safety Capacity , Congress in Warsaw.* Warsaw: World Road Association ,Mondiale DE La Route.

Jansen, R. L. (2017). Interactions with Vulnerable Road Users . *UDrive Deliverable 44.1 EU FP7 Project*.

Jovanov D., V. H. (2017). Most Common Road Safety Engineering Defficiencies in South Eastern Europr as part of a safe systems Approach. *IOP conference series,* (p. Engineering Volume 252).

Khan. M.A, E. B. (2017). Unmanned Aerial Vehicle -Based Traffic Analysis: A Case Study for Shockwave Identification and Flow Parameters Estimation at Signalised Intersections . *MDPI, Remorte Sensing* .

Khan.F.M, J. C. (1999). Pedestrian Environment and Behavior In Karachi, Pakistan . *Accident Analysis and Prevention*, 335-339.

Kroyer, H. (2015). Is 30km/hr a 'Safe' speed? Injury Severity of Pedestrians struck by a vehicle and the relation to travel speed and age. *IATSS Research.*

Lenon .A., W. ,. (2016). *Distractions And Attitudes Towards Safe Pedestrian Behaviour.* Syde: AustroRoads Ltd.

Lho, I. (2018, July 26). *Karkatha Dekitnews*. Retrieved from https://news.detik.com/foto-news/d-4134957/ini-lho-pelican-crossing-yang-nantinya-gantikan-jpo-hi

Li. D., R. =. (2016). Analyzing Pedestrian Crash Injury Severity Under Different Weather Conditions. *Traffic Injury Prevention* .

Lobjois, R. &. (2009). The Effect of Aging on Street Crossing Bwehavior from Estimation to Actual Crossing . *Accident Analysis & Prevention 41(2)*, 259-267.

Lobjois, R. ,. (2013). The Effects of Age and Traffic Density on Street Crossing Behavior. *Accident Analysis and Prevention 53* , 166-175.

Nemeth.B, T. R. (2014). *Uncontrolled Pedestrian Crossing Evaluation Incorporating Highway Capacity Manual Unsignalized Pedestrian.* Minnesota: Bolton & Menk, Inc. .

Noora. L.C, A. A. (2016). Pedestrians Adherence to Road Traffic Regulations on the N1 Highways in Accra , Ghana . *Pan African Medical Journal , School of Public Health , University of Ghana* .

Nordfjaern.T, J. &. (2011). A Cross-Cultural Comparison of Road Traffic Risk Perceptions , attitudes towards traffic Safety and Driver Behaviour. *Journal of Risk Research 14(6)*, 657-684.

Ontario, M. o. (2011). *Ontario.ca*. Retrieved from www.mto,gov.on.ca.

Oxley.J., F. I. (2005). Crossing Roads Safely: An Experimental Study of Age Differences In Gap Selection by Pedestrians . *Accident Analysis and Prevention 37(5)*, 962-971.

P, K. &. (2013). *Marked versus Unmarked Pedestrian Road Crossing Behavior at Uncontrolled Midblock Crosswalk in Mixed Traffic Conditions.* Washington DC: Transportation Research Board , National Research Council .

P, K. .. (2013). Modelling Pedestrian Road Crossing Behaviour Under Mixed Traffic Conditions . *European Transport , Transporti Europei Issue 55 Paper no 3 , ISSN* , 1825-3997.

Palamarthy. S, M. H. (1994). *Models of Pedestrian Crossing Behavior at Signalized Intersections* . Research Report 1296-1.

Pele.M, B. D. (2017). Cultural Influence of Social Information use in Pedestrian Road crossing behavior. *Royal Society Open Science* .

R., H. .. (1988). Analysing The Behaviour Of Pedetsrians and Car Drivers on Pedestrian Crossing . *PubMed.gov*.

R.K, M. (2012). Pedestrian Compliance with Concurrent and The Exclusive Phasing at Traffic Signals . *BSE University of Connecticut*.

Rasouli.A, K. &. (2017). Agreeing To Cross: How Drivers and Pedestrians Communicate: Department of Electrical Engineering and Computer Science . Toronto, Canada .

Samuel. S, R. M. (2013). Effects of Advanced Yield Markings and Symbolic Signs on Vehicle-Pedestrian Conflicts in Field Evaluation. *Journal of Transportation Research Board (2393)*, 139-146.

Sarkar. S., H. A. (2016). Identification Of High Risk Road Locations on National Highway N2 of Bangladesh Using GIS. *BUET- ANWAR, SPAT 1st Bangladesh Civil Engineering Summit* . Dhaka .

Schroeder. B. J, R. N. (2009). Woeking Concerpt of Accessibility Perfomance Measures for the Usability of Crosswalks by Pedestrians with Vision Impairments . *Journal of The Transportation Research Board* , 103-110.

Sudhira.S.H, R. &. (2003). Urban Sprawl Pattern Recognition and Modelling Using GIS Map India . Bangalore , India .

Sun, D. U. (2003). Modelleing of Motorist -Pedestrian Interaction at Uncontrolled Mid- Block Crosswalk In TRB. *Annual General Meeting* .

Sutheerakul.C., K. K. (2017). Application of Unmanned Aerial Vehicles to Pedestrian Traffic Monitoring and Management for Shopping Streets. *Transportation Research Procedia 25* , 1717-1734.

Tarawneh, M. (2001). Evaluation of Pedestrian Speed In Jordan with Investigation of some Contributing Factors . *Journal of Safety Research 32 (2)*, 229-236.

Tiwari, G. B. (2007). Survival ANalysis : Pedestrian Risk Exposure At Signalized Intersections . *Transportation Research Part F 10(2)*, 77-89.

Tiwari. G., B. S. (2007). Survival Analysis: Pedestrian Risk Exposure at Signalized Intersections. *Transportation Research Part F 10(2)*, 77-89.

Tulu. G.S, W. S. (2013). Why Pedestrian Crashes are so different in Developing Countries? A review of relevant factors in relation to their Impact in Ethopia. *Australasian Transport Research Forum (TA TRF) Transport and the New World City* . Brisbane : Centre for Research and Road Safety .

Tulu.G., S. (2015). Pedestrian Crashes in Ethopia : Identification of Contributing Factors Through Modelling of Exposure and Road Environment Variables. Queensland , Australia, Australia: Centre for Accident Research and Road safety Queesnland (CARRs-Q).

Uk, T. H. (2018). *The Highway code Uk*. Retrieved from https://www.highwaycodeuk.co.uk/rules-for-pedestrians-crossings.html

Van Haperen .W., R. D. (2018). Observing the Observation of (Vulnerable) Road User Behaviour and Safety : A Scoping Review Into Current Practices . *Accident Analysis and Prevention*.

Van Houten .R, M. &. (2001). Advance Yield Markings : Reducing Motor Vehicle -Pedestrian Conflicts at Multilane Crosswalks With Uncontrolled Approach . *Transportation Research Record 1773,*.

W, V. H. (2016). *Review of Current Study Methods for Vulnerable Road User Safety - Systematic Literature Review Behavioural Observations.* Lund, Sweden: Horizon 2020- The Framework Programme for Research and Innovation (InDev).

Williams.M.J. (1981). Validity of the Traffic Conflict Technique . *Accident Analysis & Prevention 13(2)*, 133-145.

Zeeger. C.V, &. B. (2012). Pedetsrian Crash Trends and Potential Countermeasures From Around The World . *Accident Analysis and Prevention*.

Zeeger.C, &. H. (2010). Safer Vulnerable Road Users : Pedestrians, Bicyclists, Motorists, and Older Users: White Paper for 'toward Zero Deaths'. USA.

Zhuang, X. &. (2011). Pedestrian Crossing Behaviors and Safety at Unmarked Roadway In China . *Accident Analysis and Prevention*, 1927-1936.

Annex

Human Observer Data Collection Form

Date: Time: Weather Conditions:	Junction Name : Observer Name :

VRU Characteristics Behaviour									VRU Crossing position			
ID	Gender		Age				Looking on (all directions left & right)		On the junction		Not on the Junction	
	M	F	C	Y	M	O	Yes	No	Single	staged	single	staged
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												

ID:

ID of observed Interaction

Gender:

M= Male

F= Female

Age: (Assumed)

C= Child (age 0-17years)

Y= Young Adult (age 19-30years)

M= Middle aged (age 31-65

O = Old (65+ years)

Type of Crossing:

Single: This entails crossing all lanes at once without stopping in between **Staged:** This entails Crossing lane by lane or crossing up to the pedestrian island then stop and continue after yielding / looking out for traffic