School for School of Transportation Sciences
Master of Transportation Sciences

Master’s thesis
Safe pedestrians’ facilities in Kigali City
Jean Damascene Uwizeyimana
Thesis presented in fulfillment of the requirements for the degree of Master of Transportation Sciences, specialization Traffic Safety

SUPERVISOR :
Prof. dr. Davy JANSSENS

CO-SUPERVISOR :
dr. Ariane CUENEN

MENTOR :
Dr. ir. Alphonse NKURUNZIZA
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Preface

This master thesis has the purpose of applying the knowledge learned during the master program of transportation sciences at Hasselt University. The topic of “safe pedestrians’ facilities in Kigali city,” has come in mind after understanding the importance of walking while much attention has been given to the car users in the design of the transport system. My main purpose was to emphasize the concept of designing for people as the majority of people in the cities are the pedestrians; they should have safe and comfortable facilities.

Completion of this master thesis was not an easy task that I could achieve by myself, that why I would like to thank all the people who involved and provided their help for this research to be fruitful. I want to express my special thanks of gratitude to my Co-supervisor Ariane Cuenen, my local supervisor Alphonse Nkurunziza as well as my supervisor Davy Janssens who have been a source of guidance and support in all problematic situations during the research. I would also like to thank the developers of Route2 school tool as they invested much efforts to make the R2S tool available to be used in Kigali city; the only one place in Africa where the tool has been used.

I would also like to give special thanks to VLIR-OUS scholarship that has been a source of funding for my master studies; finally, I would like to thank my family, friends, and classmates who had been a source of motivation throughout the ups and downs in this study.

Jean Damascene UWIZEYIMANA

0. Abstract

As pedestrians are the most vulnerable road users, special measures are needed to ensure their road safety. Pedestrians constitute a large proportion of total road fatality global, but this number becomes higher in the African region. Road users behaviours, road environment, and vehicles condition are the factors that influence pedestrians safety. The study recognizes the importance of combining 5 E’s (Engineering, Enforcement, Education, Engagement, and Evaluation) to improve road safety of pedestrians, but it focuses on Engineering as road environment can be an essential contributing factor itself or through interaction between road users and vehicles.

In Kigali city; the capital city of Rwanda, the modes of transport used are buses, mini-buses, Moto taxis, private cars and a significant proportion of walking. Kigali city recognizes the importance of walking as it has a target of becoming a city of green transport which will be achieved through promoting public transport and non-motorized transport. Walking has been identified to have many benefits on health, environmental, mobility, and economy; However, pedestrians are still the most vulnerable road users, with a large proportion of road fatality in Rwanda. Lack of safe pedestrians’ facilities is one of the factors that reduce pedestrians’ safety in Kigali city. Unsafe roads, danger locations, and the causes of pedestrians accidents need to be identified to improve the safety of pedestrians. The research has come up with pedestrians’ danger locations, their associated problems that reduce the safety and comfort of pedestrians in Kigali city; Then it has proposed the appropriate countermeasures on those problems.

The research follows the roadway safety management process to identify and to propose the countermeasures for improving the safety and comfort of pedestrians. The Route2 School(R2S) tool which has been successful in identifying bottlenecks on the routes to school in Belgium was used in data collection. From R2S, 201 notifications were obtained in which each was analysed individually to identify location, type, and description of the reported problem. The majority of identified problems were related to the pedestrian crossings (33.8% for unsafe and absence of pedestrian crossings), pedestrian paths (21.4% for unsafe and lack of pedestrian paths), traffic behaviour(12.4%), bad road surface(9%), dangerous intersections(6%) and others(14.9%which was dominated by different kind of obstacles and uncovered ditches). The countermeasures to those problems were also proposed based on manuals for designing pedestrians facilities, analysing similar case studies, and discussing with road safety sectors in Rwanda.

The study recognizes the benefits of improving existing infrastructure to promote the safety and comfort of pedestrians, but it recommends to construct new road infrastructure by considering all pedestrians features as it becomes more expensive to include those features after the roads have been constructed, and this can not be a proactive way of promoting road safety.

Keywords: Pedestrians, Crashes (accidents), Danger locations, Facilities, Route2 School, sidewalks, crossings.
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List of abbreviations

*AASHTO*: American Association of State Highway and Transportation Officials

*EU*: European Union

*HEAT*: Heath Economic Assessment Tool

*HSM*: High Safety Manual

*MINIFRA*: Ministry of infrastructure

*NUDOR*: National Union of Disability Organizations of Rwanda

*R2S*: Route2 School

*RTDA*: Rwanda Transport Development Agency

*WHO*: World Health Organisation
1. Introduction

Pedestrians are the most vulnerable road users and their road safety still a serious problem Worldwide. Globally, more than 270 000 pedestrians each year lose their lives on the world’s roads, this is a significant number as it constitutes 22% of all traffic fatalities and it becomes much higher in some countries (WHO, 2013). Almost half of all road deaths are among road users with the least protection (vulnerable road users) such as motorcyclists, cyclists, and pedestrians. Pedestrians deaths vary with regions; the African Region has the highest number of pedestrians’ deaths 39% of all road traffic deaths (WHO, 2016). The number of pedestrians deaths is not only high in African countries as in Europe also it varies country to country from 10% (Netherlands, Norway) to 38% (Lithuania) (Cavallo, et al., 2017), and there is a very low decrease in pedestrians deaths in EU countries (EU, 2016). The number of pedestrians’ deaths is not the only indication of how pedestrians are at risk, as millions of people are injured in traffic-related crashes while walking and suffer serious injuries with life-changing consequences.

The number of road accidents might be high in the low income and developing countries as the data collection system is still poor; there are many unreported accidents especially accidents involve non-motorized traffics, which result in underestimation of pedestrians’ crashes (WHO, 2015).

According to the Global Plan for the Decade Of Action For Road Safety 2011-2020, road transport systems should be able to accommodate human errors and take into consideration the vulnerability of the human body. Human errors cannot be fully avoided which implies that traffic crashes cannot also be completely avoided, but road infrastructure should be designed to ensure that accidents do not result in serious injuries. The target should be to shift a major share of the responsibility from the road users to the designers of road transport system to ensure traffic safety (Sminkey, 2011).

Making walking and cycling ways safer is crucial for reducing the number of road traffic deaths and important for achieving the Decade of Action for Road Safety’s aim of promoting non-motorized forms of transport (WHO, 2015).

This research aims to identify the road infrastructure related problems that (may) reduce the pedestrians’ safety and comfort in Kigali city. The study focused on sidewalks, pedestrians’ crossings, and intersections; then it proposed the appropriate countermeasures to make pedestrians’ facilities safe.
1.1. Description of the study area

1.1.1. Background of Kigali city

In 1907, Kigali was founded as the administrative centre of Rwanda, and it quickly developed into a major commercial centre primarily due to its central location. It became Rwanda’s capital when it gained independence in 1962, and since then, it has become Rwanda’s major economic, cultural, and transport hub (Ellison, Ang, & Nugroho, 2013). Kigali city is composed of 3 districts and has a total area of 730 kilometre square; its population in 2018 is 1,318,000 with a high population density of 1806 per kilometre square (Kigalicity, 2018). Kigali city has a tropical climate with the lowest temperature of 15.73 and the highest temperature of 26.89 Celsius degree. The annual average precipitation is 950.9 mm. It rains throughout the year; however, it peaks between March-April and October-November. It gets dry between June and August with less than 50mm of rain. The tops of the ridges of Kigali city have an average elevation of 1,600 metres above sea level (ASL), and the valleys are around 1,300 metres ASL. Slopes are generally steep, and most roads traverse along contours to ascend the slopes (Ellison, Ang, & Nugroho, 2013).

1.1.2. Transport modes in Kigali city

Passengers in Kigali depend on various road-based modes of public transport, which include buses, mini-buses, and motor-bike taxis (Moto taxis), private cars and a significant proportion of walking. The Moto-taxis is unique to Rwanda, and some other cities in Africa as they are very flexible, fast and cheap but also unsafe compare to other public transport means (Zyl, N.J.W, Swanepoel, & Bari, 2014).

Figure 1: Transport mode share in Kigali city. Source: (Zyl, N.J.W, Swanepoel, & Bari, 2014)
1.1.3. Walking as a mode of transport in Kigali city

In terms of all trips, the share of walking as the main mode of transport is 11% in Kigali city (Zyl, N.J.W, Swanepoel, & Bari, 2014). This number is quite low as it represents the trips that were made by walking only from origin to destination. The proportion of trips made by walking might be much high by including walking parts of public transport users coming to bus stops or walking part of people circulating within the city centres.

In Kigali city, people walk as it is the cheapest way to reach their destinations, and this might help to reduce transportation expenses, other people walk to stay healthy. Walking in Kigali is favourite due to its climate. It does not get much cold or much hot, although it rains much in few months. The walking rate can be increased by public transport services which are still poor although there are more improvements. The main problems in public transport include the absence of schedules, congestions, long queues at bus stops and stations, long travel time and, road infrastructure which does not allow buses to reach close to all citizens (Mininfra, 2012). Walking rate is also increased by the topography of the city (mountainous) which is not favourable for biking.

Kigali city recognises the importance of walking as it has the goal of becoming a city of green transport. This goal will be achieved by improving public transport services and promoting non-motorized transport. Kigali city transport master plan also recognizes public transport and non-motorised transport as a sustainable mode of transportation but which can not be achieved without investment in non-motorized transport infrastructures such as pedestrian walkways and cycleways (Ellison, Ang, & Nugroho, 2013). In May 2016, The City of Kigali initiated “a Car Free Day” a monthly event to encourage people to walk, jog and cycle as part of active transport and healthy lifestyle promotion (Nkurunziza, 2018). Kigali city also introduced car-free-zone as it recognises the importance of introducing public spaces in the city (Nkurunziza, 2018). All these activities expect to increase the number of pedestrians and promote mobility and health sector, but it might be a problem with the traffic safety if all those pedestrians will be directly exposed to the motorized traffics.

1.2. Problem statement

Road crashes take the lives of many people worldwide; many accidents involve non-motorized or active transport users (pedestrians or cyclists) with motorized traffics (cars or motorcycles). Pedestrians are the most vulnerable road users; their risks of being injured in a traffic accident are much higher compared to other road users. Motor vehicles have been only around a century, but during that comparatively short time, they have made walking hazardous (Campbell, Zegeer, Huang, & Cynecki, 2004).

Emphasis on highway transportation historically has focused on increasing the safety and mobility of motor vehicles and less attention has been given to pedestrians (Campbell, Zegeer, Huang, & Cynecki, 2004). In developing countries, the number of vehicles has grown fast compare to the development of roads infrastructure, the situation worsens as non-motorized vehicles have not disappeared. The presence of different modes of travel on poor roads infrastructure results in unsafe roads (Khanal & Sarkar, 2014) and make the pedestrians the most vulnerable group of road users in developing countries (Quimby, 2001).

Rwanda has made more efforts in improving road safety. According to WHO, Rwanda had one of the worst road-safety records in the world but once the government recognised that
making roads safer could help with the rehabilitation of a nation traumatized by the 1994 genocide, its efforts have won international acclaim (WHO, 2018). The trends of road accidents in Rwanda up to 2013, show an increase in the number of accidents but due to the new measures that were implemented, like campaigns and enforcement (introducing speed governors in all buses and heavy vehicles with maximum speed of 60 km/h), currently police reports a decrease in number of accidents.

![Figure 2: Trends in road traffic deaths, source (a): (WHO, Global Status Report for Road Safety, 2009), (b): (WHO, Road safety in the African Region , 2016)](image)

The pedestrians have occupied a large percentage of road fatality in Rwanda for a long time ago, according to WHO in 2007, 40% of lives lost in traffic accidents were pedestrians, this percentage has not decreased despite increasing of motorcycles usage in Rwanda. According to Rwanda traffic police, in 2016, 34% of lives perished in road accidents were pedestrians, 14% were bicycle users and 22% were motorcyclists. The comparison of pedestrians deaths’ percentages between 2007 and 2016, shows that pedestrians are still the most victims of road crashes.

![Figure 3: Deaths per road users category, source: (WHO, Global Status Report for Road Safety, 2009).](image)
Lack of protected sidewalks for pedestrians and cycle ways for cyclists was identified as one of transport infrastructure problem in Kigali city (Minifra, 2012). There are currently a few stretches of roads in Kigali that have formal pedestrian walkways. Some roads do not have any pedestrian walkway, where pedestrians are required to walk on the carriageway, and the other roads have walkway provision on one side of the road, but pedestrians still walk on the carriageway due to convenience and lack of safety awareness (Ellison, Ang, & Nugroho, 2013). This is the same for pedestrian’s crossings, which are still not safe for them. The drivers and motorcyclists also do not give priority to the pedestrians either in their crossing points. Poor road markings and non-signalized intersections also reduce pedestrians’ safety. There is no underpass or overpass for pedestrians or cyclists in the whole country. Considering the news and some reports about the causes of road accidents in Rwanda, road infrastructure is not identified sometimes in the leading causes of road accidents. The reason is that an accident usually occurs due to certain unsafe behaviour performed by road users. Safe infrastructure can help in minimizing the risks or controlling some behaviours of road users to avoid road crashes.

Lack of safe and well-connected pedestrians facilities is not only the problem on road safety, but it is also a particular problem for people who are disadvantaged in their transportation way like children, people with disabilities, elders, and people with low incomes. Inadequate walking facilities can contribute to social exclusion, physical, economic, and social isolation of vulnerable populations (Litman, 2018).

1.3. Objectives

The Main objective of this research is to identify the road infrastructure factors that reduce or may reduce pedestrians’ safety as well as their comfort. The study had focused on sidewalks and zebra crossings condition at road segments and intersections, and then it proposed the appropriate countermeasures.

Specific objectives

1. To identify the danger locations for pedestrians in Kigali city
2. To classify and rank the types of problems affecting pedestrians safety in Kigali city.
3. Analysis of identified types of pedestrians’ problems to find out detailed road infrastructure related factors that cause or may cause pedestrians’ crashes and pedestrians’ unsafe feelings.
4. Proposing short, medium and long-term solutions to identified problems
1.4. Research questions
The key question of the research is to identify and recommend the solutions to unsafe pedestrians’ facilities in Kigali city.

Specific research questions
1. Where are danger locations for pedestrians in Kigali city?
2. What are the most problems for pedestrians safety in Kigali city?
3. What are the specific road infrastructure factors that (may) reduce pedestrians’ safety and comfort in Kigali city?
4. What are short, medium, and long-term countermeasures to the identified problems reduce pedestrians’ safety?

1.5. Research boundaries
The pedestrians safety depends on many factors, which means interventions should also be a combination of many countermeasures. Combination of 5 E’s (Engineering, Education, Enforcement, Engagement and, Evaluation) countermeasures of traffic engineering can play a significant role in improving pedestrian safety. This research acknowledges the importance of other 4 E’s to improve the safety of pedestrians, but it focuses on the engineering part, which is making pedestrians’ facilities safe. The research had focused on Kigali city, but it couldn’t cover all the roads in the whole city, it focused mainly on the most used roads in Kigali city which were selected from all three districts of Kigali city. In the section of providing countermeasures to the identified problems, the countermeasures were given briefly as the study has identified many locations with different problems. Also, the cost of countermeasures was not discussed in this research.

1.6. Assumptions
The study admits the issue of subjective safety in the data collection process; it has considered all identified locations by considering unsafe feelings of road users who reported them. As subjective safety is based on the feelings of road users, the identified locations might not be the same as locations which can be identified from crash data. However, the study considers subjective safety as important as objective safety. The study has assumed that there is a relationship between the occurrence of road accidents and unsafe road infrastructure. Danger locations might be considered as latent failures in the Swiss Cheese Model. Latent failures are contributory factors that may lie dormant in the system for a while until they contribute to an accident (Larouzée & Guarnieri, 2015). It may be possible that no accident has been yet recorded at specific danger location, but in case such locations are not well treated, they may result in road accidents in the future.
2. Literature review

2.1. Walking in history

Walking is the most traditional and basic mode of transportation (Campbell, Zegeer, Huang, & Cynecki, 2004), (Schmeidler, 2010). Walking characterize an important part of the traffic system, specifically in urban areas (Draskóczy & Hydén, 1995). Each trip has a walking component, every trip starts and ends with walking, motorized trips also involve non-motorized trips, to access public transit and between parked cars and destinations. Parking lots, transport terminals, airports, and commercial centres are all pedestrian environments (Litman, 2018) but despite fundamental importance of walking, walking is sometimes considered as a neglected mode of transport. For many years ago pedestrians did not receive much attention from transport planners and engineers while walking has been an important form of movement of people in historical cities for many centuries (Olszewski, 2007). The significance of walking has gradually declined with the emergence of public transport, with the increasing popularity of private cars and with less attention from transport planners (Olszewski, 2007). During transport networks design, it is important for transportation officials to provide facilities that enhance the safe movement of pedestrians along roads and streets (Rankavat & Tiwari, 2016).

During the middle of the 20th century, the focus of transportation policy and planning practice was focusing on solving the problems of rapid motorisation and urban development. The first response to the growth of car numbers was to build large and many roads and car parks to accommodate all possible cars. This response had negative consequences on pedestrians since the extension of roads consumed urban spaces that were previously used by pedestrians (Olszewski, 2007). When it became clear that the full accommodation of cars in cities was not possible, a variety of policies were devised aimed at improving public transport and managing traffic congestion (Olszewski, 2007). The research community came to acknowledge walking as a practice and a mode of transport in the middle of the 20th century (Lindelöw, 2016). Later on, active transport was considered as a sustainable mode of transport. Many measures were taken and are still being taken to promote active transport (walking and cycling). Some cities have already banned and limited motorized vehicles within the cities centres. In Europe, the European Commission actively supports sustainable urban mobility planning, which promotes a shift towards cleaner ways of city travelling, including walking, cycling and using public transport (Nieuwenhuijsen & Khreis, 2016).
2.2. Benefits of walking

2.2.1. Health benefits/ Physical activity

Lack of sufficiency physical activity has been identified by the World Health Organization as the fourth leading risk factor for global mortality and morbidity due to its impact on several non-communicable diseases (WHO, 2011). The problem is not likely to be solved by classical health promotion approaches alone (organized forms of sport or exercise done in leisure time) (Kahlmeier, et al., 2017). Many governments have adopted health plans to promote regular physical activity. Transport activity like walking and cycling can be an important source of regular, incidental physical activity, (Pérez, et al., 2017). Walking, cycling or actively getting to public transport can provide the opportunity for city dwellers, particularly for people who claim to do not have time for physical exercise, to incorporate more physical activity into their daily routines (Nieuwenhuijsen & Khreis, 2016). Public health agenda emphasises the positive effects of walking as a means to increase physical activity as well as reduce obesity (Bostock, 2001). To walk for 40-60 minutes daily is the easiest way to prevent major disease (cardiovascular diseases, dementia, type 2 diabetes, breast, and colon cancers and stress and anxiety) by 95 %. It is well recognized that regular aerobic exercise improves cardiovascular health and cerebrovascular health. More specifically, it reduces one’s risk of developing chronic conditions such as high blood pressure, diabetes(type II), and high cholesterol (Ahmed, 2017).

2.2.2. Environmental benefits

Air pollution has been a serious environmental problem in the cities especially in developing countries. Emissions from motor traffics are the most important source of air pollution throughout the world as they are high in quantity and are directly exposed to the citizens (Mayer, 1999). Promoting active travel and public transport have environmental benefits due to its reduction in air pollution which lead to decreases of greenhouse gas emissions in the atmosphere (Pérez, et al., 2017) , (Olszewski, 2007). Walking and cycling are recognized as sustainable transport modes which have the potential to contribute to energy efficiency (Zhao, Sick Nielsen, Olafsson, Trine, & Xiaoying, 2018). Traffic noise pollution has also become the most serious and pervasive type of noise pollution especially in cities (Tania, 2014). Noise is an important factor that needs to be considered during the design, construction of new transport systems; and improving existing systems (Nejadkoorki, Yousefi, & Naseri, 2009). Walking does not produce any noise pollution as no engine needed for this activity to move around and within the cities (Pérez, et al., 2017). Walking has more environmental benefits which include Reducing the land needed for roads and parking facilities, open space preservation, improved aesthetics and even reduced water pollution (Litman, 2018).

2.2.3. Mobility benefits

In many regions and cities where urban measures supportive walking and cycling implemented, they show improvement in reducing congestion but most of those measures were not implemented with the main purpose of reducing congestion. From the perspective of congestion reduction, these seem as “co-benefits” from walking and cycling. Yet, these measures are interdependent and can help to reduce congestion in the long run. Most of the
walking and cycling measures have the potential of promoting behaviour change and improving the modal shift to non-motorised modes over time (Koska & Rudolph, 2016).

### 2.2.4. Economic benefits

Walking and cycling are affordable basic modes of transport. Physically, economically and socially disadvantaged person often rely on walking and cycling. Improving nonmotorized transport can help achieve social equity and economic opportunity objectives (Litman, 2018).

Pedestrian facilities (sidewalks, paths, and hallways) are a crucial portion of the public realm. Most of the beneficial activities (socializing, waiting, shopping and eating) occur in pedestrian environments, all these activities are affected by pedestrians environments quality. Walkable environments are essential to attract customers in Shopping districts and resort communities. Improving pedestrians environments have a positive impact on commercial sectors, which is the main activity in cities.

Walking and cycling are ones of the most popular recreational activities. Improving walking and cycling conditions provides enjoyment and health benefits to users, and it can support related industries, including retail, recreation, and tourism.

Walkability can reduce consumer transport costs. Improved walkability helps consumers to save on vehicle expenses; Motor vehicle use imposes various public costs for road and parking facilities, traffic congestion, crash risk, and environmental damages. Shifting travel from motorized to non-motorized modes reduces these external costs (Litman, 2018).

### 2.3. Health economic assessment tool (HEAT) for cycling and walking

The importance of active transport usually is underestimated as it is difficult to measure. Walking or cycling shows low status in many countries to people who use them. Planners tend to ignore or undervalue benefits like fitness, public health benefits of active transportation, enjoyment of walking and cycling, and improved mobility options for non-drivers. Fishman, Garrard, Ker, and Litman, (2011) explained why transport planners ignore the benefits of active transport as the health benefits are not considered in the economic evaluation of transport policies and projects. Any evaluation that fails to appreciate the co-benefits of active transport leads to significant underestimating the value of active transport programs to the community. Away from all no private sector that can invest in walking as result no more investments in constructing and promoting walking. Society itself sometimes does not recognize important of walking and they do it as last option for their mode of transport.

To address this problem, it was important to develop practical tools for a more comprehensive evaluation of active transport benefits, including public fitness and health benefits. WHO developed HEAT tools to facilitate evidence-based decision-making with the aim of creating economic arguments to advocate investment in transport policies that promote active transport (Kahlmeier, et al., 2014). HEAT enables economic assessment of the health benefits of walking or cycling by estimating a value for the reduced mortality that results from specified amounts of walking or cycling at the population level. The tool can be used when planning new cycling or walking infrastructures to calculate the economic value of the
reduced mortality when compared to past and/or current levels of cycling and walking. Furthermore, it can aid in developing more comprehensive economic appraisals and provides input for assessing the health impact of these new infrastructures (Pérez, et al., 2017).

2.4. Promoting walking

Walking requires space; the movement of pedestrians differs from all other types of traffics (Schmeidler, 2010). The pedestrians have a tendance to access all available activities in the cities which make irregularity in their movement. Planning and designing proper pedestrian’s infrastructure with well-connected and amenable facilities give benefits to the whole community. Creating safe pedestrians’ facilities does not have benefits only on road safety of people who usually walk but also encourages people to choose walking as a mode of transport which is a way to foster more sustainable, healthier and safer communities. Safe pedestrians’ facilities create also independence in selecting transport mode as it becomes possible for more people including the elderly, children, families and people with disability to travel themselves (Haning, et al., 2016).

The governments should take it as their responsibility to promote and invest in active transport. The health benefits assessment of walking can help local decision-makers to move towards sustainable modes of transports in the city. Increasing potential awareness of the health benefits of regular walking can encourage more people to use active transport as part of daily activities (Arsensio & Ribeiro, 2011).

2.5. Pedestrians as vulnerable road users

Despite all the benefits of walking, when it comes to the issue of road safety, the pedestrians are in a vulnerable group of road users. A group of road users can be called to be vulnerable in different ways, which include the amount of protection in traffic (pedestrians and cyclists) or the amount of task capability (the young and the elderly or disabled people). Vulnerable road users do not usually possess a protective shell, and the difference of mass between the colliding opponents is often an essential factor (Zegeer & Hunter, 2010). This can be well explained by Newton’s 3rd law, which states “to each action there is equal and opposite reaction” when two cars or two road users of different masses crash in head-on collision they would have the same force of impact and the same impulse but with different accelerations, a road user with less mass will have high acceleration (McElroy, 2000). Pedestrians and cyclists have negligible mass compare to the mass of motorized vehicles. Vulnerable road users can be protected by limiting the speed of motorized vehicles and separating unequal road user types as much as possible (Zegeer & Hunter, 2010).

Pedestrians and cyclists are the most vulnerable road users as in case of road crash they suffer the most severe consequences. Their personal protection level compared to persons in a vehicle is low. They miss the protection of an enclosed vehicle, and they do not benefit from any vehicle safety features like seatbelts or airbags, which make them likely to get injured or killed in a collision. Due to their greatest vulnerability, pedestrians and cyclists are often described as vulnerable road users (Constant & Lagarde, 2010). When the age factor is also included, elder and younger pedestrians or cyclists become the most group of vulnerable road...
users. When a vulnerable road user is involved in a crash with a motor vehicle, the amount of overall damage suffered is extremely disproportionate.

2.6. Road safety analysis

It has been common to use crash data in many studies analysing road safety. This is obviously as crash frequency and severity are the direct measures of road safety and make them being used for the traditionary analysis of road safety. However, there are problems associated with crash data in its availability and its quality (Tarko, Saunier, & Sayed, 2009). The relative rarity and randomness of accidents make them difficult to study without a significant amount of historical data (Johnsson, Laureshyn, & De Ceunynck, 2018). Accident data are not always sufficient due to small sample sizes leading to inconclusive results, and not all accidents are reported. The level of reporting depends on the severity of the accidents and the type of road users involved. There is also a lack of details that improve understanding of crash failure mechanism and especially the driver crash avoidance behaviour (Tarko, Saunier, & Sayed, 2009). The other problem with using crash data in safety analysis comes as a reactive approach where a significant number of road accidents need to be recorded before an action can be taken.

To overcome all these challenges, road safety analysis needs to be conducted by also including reliable analysis methods that use observable non-crash traffic events and other surrogate data instead of waiting for the accumulation of crashes.

2.7. Surrogate safety measures

The surrogate measures are a set of measures that can be extracted from simulations and observations which are specifically designed to be crash-free. They are indicators that can be used to study critical traffic events that occur more frequently which makes such incidents easier to analyse (Tarko, Saunier, & Sayed, 2009). The term surrogate implies that the indicators do not rely on accident data. Instead, they are meant to be alternatives or complements of analyses based on accident records. Surrogate measures should have reasonable connectivity to the safety assessment of particular facilities like the frequency and severity of resulting crashes. The surrogate measures can be used to support traffic engineering alternatives evaluation concerning safety for both signalized and non-signalized intersections (Gettman & Head, 2003).

2.8. Near-crash events

A near-crash event implies that a driver makes a rapid evasive action such as an emergency braking or a steering operation (Naji, Xue, Lyu, Wu, & Zheng, 2018). In case of absence of these actions, a real crash may occur. The indicators for the near-crash event include time headway, deceleration, braking pressure, and steering wheel. These actions might be caused by the conflicts between road users who share the same roadway. The area with many traffic conflicts is likely to be linked to traffic accidents. Intersections and pedestrians’ crossings are the areas that show a large number of conflicts, and when they are not well treated, these areas are reported to be one of the danger zones especially for the pedestrians who are the most vulnerable road users.
2.9. Measuring road safety

Road safety can be measured as objective and subjective safety. Objective safety is described as the actual number or risk of road accidents or injuries, it is obtained from an analysis of crash data. Subjective safety is the feeling or perception of safety, how people subjectively experience accident risk in traffic (Sørensen & Mosslemi, 2009). Analysis of information form Route to School is one of the examples of measuring subjective safety. In most of the case, the policymakers focus on objective safety as it is quantifiable, and it can not vary from one person to other. The problem with subjective safety is how people perceive the same situation in different ways, which make it varies from one observer to another. In some cases, subjective safety is not taken into consideration during safety studies. The main reason that can cause its ignorance is about how people tend to avoid using the locations that they feel unsafe for them and policymakers can keep to assume that the areas are safe since no accidents recorded while it is due to low traffic.

2.10. Factors affecting involvement of pedestrians in crashes

Like all other types of road crashes, pedestrians crashes result from one or a combination of many factors. This may include the factors related to the behaviours of all road users, including pedestrians themselves, road infrastructures or environmental factors and vehicles related factors. According to studies conducted on the factors cause pedestrians’ crashes, there is a clear difference between the cause in developing and developed countries. In developed countries, the majority of pedestrians crashes are due to either the behaviour of pedestrians or other road users. When it comes to the developing countries, the problem of behaviour for road users gets combined with poor infrastructure, which mainly does not separate the traffic of different volume.

Spainhour, Wootton, Sobanjo and Brady, (2000) identified the behaviour of road users to be 80% the causes of pedestrians crashes, and it was found to be same in more than 76% of conducted studies. Although, road users behaviour was the leading cause of crashes, 71% of crashes occurred on locations without lighting, more than 50% the pedestrians were trying to cross the roads while 57% of crashes occurred on the roads without sidewalks. Despite, road users behaviour was identified as the main cause of crashes, focusing on changing road users behaviour only may not be enough to avoid these accidents, environmental factors also have to be considered as the leading causes of pedestrians’ crashes.
2.10.1. Impact of motor vehicles speed on pedestrians safety

Speeding is a key risk factor in road traffic injuries; it influences both the risk of a road crash and the severity of the injuries that result from crashes. High speed reduces the possibility to respond on time when necessary. People need a moment to process information, to decide whether or not to react and, finally to execute a reaction. The correlation between speed and injury severity is particularly critical for vulnerable road users (pedestrians and cyclists) (WHO, 2014). Higher vehicle speeds can increase the risks to pedestrians in several ways. First, vehicle stopping distance increases substantially as vehicle speed increases. Second, the risk of a pedestrian death occurring from a collision with a motor vehicle is much greater for higher vehicle speeds (Zegeer & Hunter, 2010). It has been shown that a pedestrian has 90% chance of survival when struck by a car traveling at 30 km/h or below, but has less than 50% chance of surviving an impact at 45 km/h and a pedestrian has almost no chance of surviving an impact at 80 km/hr (WHO, 2014). The probability of a pedestrian being killed increased by
a factor of 8 when the impact speed of the vehicle increases from 30 km/h to 50 km/h (Rosëna, Stigson, & Ulrich, 2010). In the developed countries, speed contributes to about 30% of road fatality, whereas in some low-income and middle-income countries, it is estimated to be the major contributory factor in about half of all road crashes (WHO, 2014). Changing behaviour about speeding takes time, and not all drivers who understand it. Even for those who understand for some circumstances, they can keep speeding to save time. Changing people’s behaviour is, but engineering and enforcement measures should follow it.

![Figure 5: Pedestrian fatality risk as a function of the impact speed of a car. Source: (Campbell, Zegeer, Huang, & Cynecki, 2004)](image)

### 2.11. 5 E’s for promoting road safety

Generally, road safety is achieved by combining the countermeasures from different perspectives. This is the same for achieving road safety for pedestrians. Combining infrastructure and non-infrastructure projects and programs are needed and these are known collectively as the "5 E’s": Education, Encouragement, Engineering, Enforcement, and Evaluation. Vermont state, (2018) applied these 5 E’s to promote the safety of students (pedestrians and cyclists).

- **Education**: it consists of teaching students and community members about walking and biking safely. Education can be done through the school curriculum, cyclists/pedestrians safety assemblies (small competition in cycling or running can be used to assembly community), newsletter blurbs, tips sheets, and send-home flyers.

- **Encouragement**: Students and parents should get excited about walking and biking by organizing special events like walking school buses and bike trains, holding schoolwide competitions, celebrating walking and biking with student art, or other projects.
• **Enforcement:** This is about reducing negative behaviours of road users such as speeding, double parking, and disobeying traffic signals, and this can be achieved by collaborating with local law enforcement. The officers can attend walking events to monitor speeding activity or to build relationships with school children and neighbours.

• **Evaluation:** The taken countermeasures should be evaluated to check if they are working. The schools and local governments can record walking and biking rates, parent concerns, and traffic data to evaluate the success of implemented measures. Evaluation activities help in setting goals and establishing baseline data for planning projects.

• **Engineering:** It consists of improving the physical walking and biking environment. Schools and local government agencies can work together to determine whether infrastructure improvements are necessary to encourage students walking or biking to school safely (Vermont state, 2018).

2.12. **Pedestrians facilities**

The pedestrian is entitled to live in a healthy environment and to freely enjoy the amenities offered by public open areas in conditions that safeguard his physical and psychological well-being (ITF, 2012). Pedestrians are least protected road users; it is crucial to provide facilities that are well designed and appropriate to the particular situation and user group to enhance their safety throughout the road network system (Haning, et al., 2016). Pedestrian facilities must also be designed to accommodate persons with disabilities. Pedestrian facilities should also support other activities such as street vending and waiting at bus stops without compromising pedestrian mobility (Jani & Kost, 2013).

2.12.1. **Principles for Pedestrian Network Planning**

Haning, et al., (2016) and Khisty, (1994) identified the criteria that should be considered while designing pedestrian facilities,

• **Comfort:** Ovstedal & Ryeng, (2002) defined comfort for pedestrians as a positive emotional reaction to external surroundings or the walking environment. Weather protection, climate control, properly designed shelters, the condition of the walking surface, cleanliness of terminals, and provision of adequate seating arrangements are the factors indicating pedestrians’ comfort (Khisty, 1994).

• **Convenience:** the convenience mainly is about how walking distances are connected to other features such as pathway directness, grades, sidewalk ramp locations, directional signing, activity maps, and directories. Convenient connections between frequently used locations, and other features making walking easy and uncomplicated (Haning, et al., 2016). Sidewalk obstructions and circuitous trip linkages should be avoided in pedestrians’ paths to increase their convenience.

• **Safety:** The important factor for promoting the safety of pedestrians is to restrict pedestrian-vehicle conflicts. These conflicts can be avoided by separating pedestrians with motorized traffics. In case this separation is not possible, the provision of properly
designed control devices, providing adequate time and space separation from vehicular movement can be applied (Khisty, 1994).

- **Security**: the pedestrians pathways need a clear observation by the public and the police through unobstructed lines of sight, sufficiency lighting, and absence of concealed areas. The pedestrian should feel reasonably safe and secure, commensurate with the neighbourhood and level of street activity prevailing (Khisty, 1994).

- **System Continuity**: Pedestrian system should meet the above criteria but it is essential to consider continuity and connectivity. Continuity is an important factor for multimodal facilities connected to pedestrian paths that unify the system efficiently.

### 2.12.2. Pedestrian sidewalk

A sidewalk is a space within the right-of-way dedicated to pedestrian travel or sidewalk can be defined as a portion of a road between the curb lines, or the lateral lines of a roadway, and the adjacent property lines, to be used of pedestrians (O'Donnell, Knab, & Athey, 2007). Sidewalks should be provided on both sides of urban collector streets that are used for pedestrian access to schools, parks, shopping areas, and transit stops and along all collectors in commercial areas. In residential areas, sidewalks are desirable on both sides of collector streets but it should be provided on at least one side. The sidewalk should be situated as far as practical from the travelled way, usually close to the right-of-way line (AASHTO, 2001).

#### 2.12.2.1. Zoning system for a sidewalk

In designing the sidewalk, three zones have to be differentiated; the figure below differentiate those zones and their minimum size.

![Zoning system for a sidewalk](image)

**The frontage zone**

The frontage zone varies from a minimum width of 0.5 m along a compound wall to 1.0 m in commercial.

**Pedestrian zone**

The pedestrian zone provides continuous clear space for walking. The clear width must be at least 1.8 m in order to accommodate two wheelchair users at the same time.

**Furniture zone**

Manholes, trees, benches, utility boxes and other potential obstructions should be placed outside the path of travel along a continuous line.

Figure 6: Zoning system for a sidewalk. source: (Jani & Kost, 2013)
2.12.2. Width of sidewalk

The width of the sidewalk varies with respect to land use and average daily trips: the table below summarises the minimum size of the sidewalk; as the values in the table are the minimum it is always better not to consider minimum values in the design process, the partitioner should consider values greater than minimum where it is possible.

<table>
<thead>
<tr>
<th>ADT (Average Daily Traffic)</th>
<th>&lt;400</th>
<th>400-1500</th>
<th>1500-2000</th>
<th>&gt;2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Roads and Streets</td>
<td>1.2m</td>
<td>1.5m</td>
<td>1.8m</td>
<td>2.4m</td>
</tr>
<tr>
<td>Collector Roads and Streets</td>
<td>1.2m</td>
<td>1.5m</td>
<td>1.8m</td>
<td>2.4m</td>
</tr>
<tr>
<td>Rural and Urban Arterials</td>
<td>1.2m</td>
<td>1.8m</td>
<td>1.8m</td>
<td>2.4m</td>
</tr>
</tbody>
</table>

Table 1: Minimum Roadside Shoulder Widths. Source (AASHTO, 2001)

The size of a sidewalk is not the only factor matter to have better movement of pedestrians, the colour and materials of pavement are also important factors. The surface of the sidewalk should be slip resistance, flat, and it should have a different colour to the carriageway (Haning, et al., 2016).

2.12.3. Pedestrian Crossing facilities

The Pedestrians should be able to cross roads safely, the crossings should be enough and well distributed in all necessary locations. Crossing facilities are designed to keep pedestrians is specified locations where they can be seen by drivers and where they can cross most safely across the flow of motorized traffic (Williams, 2005). Crossings for pedestrians affect the connectivity of their facilities. Pedestrians need to cross the roads in the short distance intervals especially in the cities. It is not an easy task to provide both safe and enough crossings due to the irregularity of pedestrians movements. Usually, many pedestrians’ crashes occur while they are trying to cross the road either in the appropriate crossing points or in inappropriate crossing zones. According to (Draskóczy & Hydén, 1995), the crossings which are not well treated tends to increase the number of crashes for pedestrians as they feel to be safe in those crossings while crossings expose them rather than providing protection. The crossing facilities for pedestrians should be designed by considering their locations and the speed of pedestrians. The average speed of fit adult is estimated to be 1.5m/sec while for an elder person is estimated to be in a range of 1m/sec to 1.2m/sec. In many cases, crossings are designed by considering the speed of 1.2m/sec (Haning, et al., 2016). There are many types of crossing facilities, some facilities indicate crossing point but without having an impact on the speed of vehicles in case drivers do not take action while others act as enforcement on speeding.
2.12.3.1. Types of pedestrians Crossings

Uncontrolled crossings

Uncontrolled crossings are crossings where pedestrians cross a single carriageway road. Usually, this is the informal crossing point, it may include dropped kerbs, tactile paving, and a traffic island if road width permits. They are usually used in areas where a formal (controlled) pedestrian crossing cannot be justified. The drivers are not required to stop at an uncontrolled crossing point (Clackmannanshire Council, 2018). A pedestrian is obliged to wait for a gap in both directions of traffic movement. Frequently a gap may become available in one direction but not the other (Williams, 2005). On busy roads, this can lead pedestrians to feel unsafe while crossing or can make them performing risky crossing movements like standing unprotected in the middle of the road. Children, the elderly and disabled people find it difficult to cross uncontrolled crossings on wide and busy roads and feel in danger (NRA, 2011). It is recommended to use this type crossing only on roads with no more than 1 lane of traffic in each direction, with adequate sight distance and with speed of vehicles less than 60km/hour (Haning, et al., 2016).

Controlled crossings

Controlled crossings are controlled zebra crossing and controlled signalised crossings (NRA, 2011). The controlled zebra crossing usually consists of black & white road markings, Pedestrians who wish to cross at a Zebra crossing must stop at the kerb and wait for the traffics to stop in both directions. When the traffics have stopped the pedestrian can cross whilst still watching for traffic. Drivers approaching a zebra crossing should do it with caution, as a pedestrian who steps onto the crossing has priority. Drivers must stop and give way to a pedestrian who has moved onto the zebra crossing and should only start again once all pedestrians have left the crossing (Clackmannanshire Council, 2018).

Controlled Signalised crossing (Pelican, Puffin, Toucan, Pegasus) are crossings with a pushbutton facility for the pedestrian: A signal controlled pedestrian crossing is suitable for a wider variety of pedestrians and traffic flows but is more expensive to install and maintain than a zebra crossing. It offers pedestrians the advantage of a more positive form of control with a signalled green man crossing period where traffic is held on red (NRA, 2011).

2.12.3.2. Location of pedestrians crossings

Pedestrians should be able to notice and be noticed by approaching motorized vehicle. Visibility of pedestrians should not be obscured or restricted by an object around the road such as parked vehicles, trees or any street furniture (Williams, 2005). The location of crossings increases or reduces visibility. Clear visibility gives the drivers the time to take action in case a pedestrian has started crossing, and it also gives a pedestrian time to judge the speed of coming vehicles before starting to cross.

It is crucial to set pedestrians crossings at all signalized intersections, unsignalized intersections in urban transects, unsignalized intersections with no signalized crossing within 600 feet (183 meters), crossings near transit locations, shared use path crossings, high-pedestrian land use generators, and school zones (Haning, et al., 2016).
Crossings should be located far from conflict points at uncontrolled junctions to give drivers enough opportunity to appreciate the presence of a crossing and brake safely. Although the safe distance depends on the geometry of the junction and type of side road, a minimum distance of 20 metres is recommended for a signalled-controlled crossing and an absolute minimum of 5 metres for a Zebra crossing. Crossings on a minor street should not be located very close to a ‘GIVE WAY’ or ‘STOP’ line. Drivers turning into the minor road need time to judge the situation and space in which to stop. It is also important to provide sufficient distance between the crossing and the priority marking for at least one waiting vehicle (Williams, 2005).

2.12.4. Lighting for pedestrians’ facilities
The pedestrians’ facilities need to be used during day and night. It is necessary to ensure enough lighting, especially in crossings. Pedestrians are negatively affected by low-light conditions. Two-thirds of pedestrian crashes occur between dusk and dawn. In pedestrian-oriented development projects, it is crucial to provide a higher quality of pedestrian lighting, especially along sidewalks and paths with higher volumes of night-time pedestrian activity, specifically in commercial pedestrian districts, in high-density residential areas, and near colleges and universities (MSHA, 2015). The lighting in crossings should make pedestrians to be seen by coming traffic. Good road lighting reduces the majority of the problems related to extraneous light sources. An experienced lighting engineer should ensure that the level recommended in the appropriate part of BS 5489 is used at all pedestrian crossing sites and BS 5489 also gives details of lighting column positions and spacings, in relation to crossings (Williams, 2005). It is difficult for the drivers to see pedestrians waiting to cross unless the road lighting is designed to the standard.

2.12.5. Bus stops
Bus stops are one of the pedestrians’ facilities, they should be designed to be safe and convenient for them. Care should be taken to locate bus stops in areas that maximize pedestrian safety and convenience. Bus stops should be located on the right-hand side of the road and far from intersections or conflicting points (MSHA, 2015). Once there are parallel bus stops, a safe crossing with traffic calming measures should be provided as in such crossings, there are many pedestrians who may even be in a hurry trying to catch buses. The bus stops need to have shelters to increase convenience and safety. The size and design of bus shelters depend on available space and the number of passenger boarding, utility placement, and driver visibility needs.

2.12.6. Pedestrians Underpasses and Overpasses
One of the best methods to improve the road safety of vulnerable road users is to separate them from motorized vehicles. Pedestrian overpasses and underpasses are the best solutions of separating pedestrians from motorized traffic at crossing points. They allow an uninterrupted flow of pedestrians and motorized traffic. Pedestrian overpasses and underpasses should be designed to accommodate all types of users (wheelchairs and bicyclists). However, underpass and overpass should be the last option because it is more appropriate to use traffic calming measures or establish a pedestrian-activated signal which
is accessible by all pedestrians. The overpasses and underpasses are costly, visually intrusive, and poorly utilized when a more direct at-grade crossing is possible (Zegeer, Nabors, & Lagerwey, 2013). Many pedestrians tend not to utilise an overpass or underpass when they can cross at street level in about the same time. Overpasses work well when the topography enables for a structure without ramps. They also work well when designed to feel open and accessible. Underpasses are significantly less expensive when built as part of a construction or reconstruction project and generally offer gentler grade changes than overpasses.

2.13. **Traffic calming measures**

Traffic calming measures are defined as a combination of mainly physical measures whose purpose of reducing vehicle speeds and/or traffic volumes on existing public roads to achieve various goals and objectives such as reducing the negative effects of motor vehicle use, altering driver behaviour and improving conditions for the non-motorized street user (Bellefleur & Gagnon, 2012). The speed has an essential impact on the safety of all road users; it is crucial to enforce speeding in the areas accessed by pedestrians. There are available many measures that can be used to enforce the speeding; it is essential to select the appropriate ones during their implementation, depending on desired speed reduction and existing condition. It is also essential to keep in mind that people have different perceptions about traffic calming; one side likes it while another side hates it. Advocates argue that traffic calming protects residents, pedestrians, and bicyclists from externalities imposed by motor vehicle traffic, and allows residential and commercial streets to balance their multiple uses better. Critics argue that it wastes resources, that it imposes an unfair burden on drivers, that it simply shifts traffic impacts from one street to another, and that it does more harm than good (Litman, 1999).

Before implementing traffic calming measures, these arguments should be balanced, and four health determinants, which are the number and severity of collisions, air quality, environmental noise, and active transportation should be considered. These determinants are directly or indirectly linked to two main mechanisms of action associated with traffic calming measures; namely, the reduction of driving speeds and traffic volumes at intervention sites. The two main mechanisms of action can be used to classify traffic-calming measures into two broad categories (Bellefleur & Gagnon, 2012).
Figure 7: Classification of principal traffic-calming measures. Source: (Bellefleur & Gagnon, 2012).

In this section traffic calming measures for reducing the speed of motorized traffic are discussed (vertical and horizontal traffic calming measures).

2.13.1. Vertical traffic calming

Vertical traffic calming measures are elevated segments of roadway that require vehicles to slow down. Typical measures include speed humps/bumps, speed tables, raised crosswalks, and raised intersections (DOWL Engineers, 2001).

2.13.1.1. Speed humps

The speed humps are the raised areas in the roadway pavement surface extending transversely across the roadway. The speed humps usually have a minimum height of 3 to 4 inches (76 to 90 mm) and a travel length of approximately 12 feet (3.7 to 4.3 m), although these dimensions may vary (Parkhill, Sooklall, & Bahar, 2007). Speed humps are the best way to reduce the speed of motorized traffic. They can reduce speed to a critical point. They are
used for traffic calming and strategy used for the minimization of traffic injuries (Ullah, Wasim, Jahanzaib, & Hussain, 2016). Speed Humps should be located where very low speeds are desired and reasonable, and where noise and fumes pollution is not a major concern (Vanderschuren & Jobanputra, 2009).

2.13.1.2. Speed bumps

The speed bumps are the raised areas in the roadway pavement surface, extending transversely across the travel way. Generally, it has a height of 3 to 6 inches (76 to 152 mm) and a travel length of one to three feet (0.3 to 1 m). It is typically used on private property for speed control parking lots, apartment complexes, private streets, and driveways (Parkhill, Sooklall, & Bahar, 2007).

2.13.1.3. Speed table

A Speed table is a flat-topped speed hump often constructed with brick or other textured materials on the flat section. It is typically long enough for the whole wheelbase of a passenger car to rest on the flat section. Its large flat fields give speed table higher design speeds than a speed hump (Vanderschuren & Jobanputra, 2009). When marked as a pedestrian crossing, speed tables may also be referred to as "raised crosswalks" or "raised crossings" (Parkhill, Sooklall, & Bahar, 2007).
2.13.1.4. Raised crosswalk

Raised crosswalk is a speed table outfitted with crosswalk markings and signage to direct pedestrian crossings and providing pedestrians with a level street crossing. Raising the level of the crossing make pedestrians to be more visible to approaching motorists (Vanderschuren & Jobanputra, 2009).

2.13.1.5. Raised intersection

The raised intersection is a flat raised area covering the whole intersection, with ramps on all approaches and often made with brick or other textured materials on the flat section. They are usually built to the level of the sidewalk, or slightly below to provide a lip. That is detectable by the visually impaired (Vanderschuren & Jobanputra, 2009).

![Raised intersection](image)

Figure 11: Raised intersection. Source: (DOWL Engineers, 2001).

2.13.1.6. Textured pavements

Textured and coloured pavements include the use of stamped pavement or alternate paving materials to create an uneven surface for vehicles to traverse. They may be used to emphasise either an entire intersection or a pedestrian crossing, and are sometimes used along entire street blocks Textured pavements are suitable for "main street" areas where there is a substantial pedestrian activity, and noise pollution is not a major concern (William, 2008).

2.13.1.7. Speed cushion

Speed cushions can be described mainly as being speed humps with gaps to ease access for emergency vehicles while still being close enough to reduce the speed of normal vehicular traffic (William, 2008).

2.13.1.8. Rumble Strips

Rumble strips are essentially low bumps on the road surface that produce a noise when ridden over. They are usually formed by the use of a typical road marking paint. The spacing of the bumps is conventionally used to reduce speeds, particularly when approaching a hazardous area (Vanderschuren & Jobanputra, 2009).

2.13.2. Horizontal traffic calming

Horizontal traffic calming measures alter the typical straight line travelled way of a specific roadway to reduce speed. Typical measures include mini traffic circles, roundabouts, lateral shifts, and chicanes (DOWL Engineers, 2001).
2.13.2.1. **Traffic circle**

Traffic circle (minicircle or mini roundabout) is a raised island, placed in intersections, around which traffic circulates. They are suitable for reducing speeds at intersections, particularly in the neighbourhoods, where large vehicles are not the major concern, but speeds, volumes, and safety are problems (William, 2008).

![Traffic circle diagram](image)

Figure 12: Traffic cycle. Source: (DOWL Engineers, 2001)

2.13.2.2. **Roundabout**

Roundabouts require traffic to circulate around a centre island. Traffic Roundabouts are used on higher volume streets to allocate right-of-way between competing movements. They promote traffic calming at high accident locations, intersections where queues need to be minimised, intersections with irregular approach geometry, providing inexpensive-to-operate traffic control as an alternative to a traffic signal, handle a high proportion of U-turns and locations with the abundant right-of-way. The roundabouts should not be a better solution on the roads used by long vehicles in many cases they cannot accommodate large trucks.

2.13.2.3. **Chicanes**

Chicanes are a series of 2 or 3 curb bulbs, placed on alternating sides of the road and staggered to create a curved one-lane segment of roadway (forming S-shaped curves). Chicanes insert curvature in an otherwise straight stretch of roadway. They help to reduce vehicular speeds by requiring motorists to manoeuvre through the curb bulbs (Marek & Walgren, 1998). Chicanes can also be installed by alternating on-street parking, either parallel or diagonal, between one side of the road and the other. Every parking bay can be created either by installing raised, landscaping islands at the ends of each parking bay or by re-striping the roadway.

Chicanes are suitable for locations where speeds are a problem, but noise associated with speed humps and related measures would be unacceptable (Vanderschuren & Jobanputra, 2009). There two different types of chicane which are single-lane and two-way working. Single-Lane working consists of staggered build-outs, narrowing the road so that traffic from one direction has to give way to opposing traffic while two-way working uses build-outs to provide deviation, but with lanes separated by a central island or road markings (Sayer, Parry, & Barker, 1998).
2.13.2.4. Refuge Island

A refuge island is defined as an area between traffic lanes, for control of vehicle movements or for pedestrian refuge. An island may be designated by paint, raised bars, mushroom buttons, curbs, guideposts, pavement edge, or other devices. A median or an outer separation can be considered as an island within an intersection area (AASHTO, 2001). Several accidents and conflict studies have proven that refuges reduce the risk of being hit considerably for pedestrians (Draskóczy & Hydén, 1995), (Cao, Ni, & Li, 2017). Unfortunately, not all roads are wide enough to accommodate refuge islands. A minimum road width of 9.1m is required to install a refuge island of a comfortable size, but a narrow refuge island can be installed within an absolute minimum road width of 8.5m if necessary (NRA, 2011).

2.13.2.5. Centre island narrowing

A centre island narrowing is a raised island located along the centreline of a street that narrows the travel lanes at that location. Centre island narrowing is often landscaped to provide a visual amenity. Centre island narrowing is suitable for entrances to residential areas, and wide streets where pedestrians need to cross (Vanderschuren & Jobanputra, 2009).

2.13.2.6. Neckdowns

Neckdowns are curb extensions at an intersection. They reduce the roadway width from curb to curb and provide shorter pedestrian crossing distances and times. The short curb return radius also reduces the speeds of turning vehicles.
2.13.2.7. Chokers

Chokers are kerb extensions at midblock locations that reduce a street lane by widening the sidewalk or planting strip. When marked as crosswalks, they are also known as safe crossings. Two-lane chokers leave the street cross-section with two lanes that are narrower than the normal cross-section. One-lane chokers narrow the width of the road to allow travel in only one direction at a time, operating similarly to one-lane bridges. They are suitable for areas with substantial speed problems and no on-street parking shortage (Vanderschuren & Jobanputra, 2009).

![Image of Chokers](image1)

Figure 15: Chokers. Source: (Seidel, Etchart, & Ericson, 2007)

2.13.2.8. Combined traffic calming measures

Combined Measures are a combination of the previously mentioned traffic calming measures that are installed to accomplish the desired goals (Seidel, Etchart, & Ericson, 2007). Each traffic calming measure has its own advantages and disadvantages. In some cases, one traffic calming measure might be not sufficient to address the speeding problem.

The figure below shows an example of intersection treatment by combining a raised intersection, traffic cycle, and neck down.

![Image of Combined Traffic Calming Measures](image2)

Figure 16: Combined traffic calming measures. Source: (DOWL Engineers, 2001)

2.14. Other measures for reducing speed

There are other measures that can be used to enforce or to reduce the speed of motorised traffics which includes speed cameras, speed activated signals, Speed limit painted on the asphalt, road markings, and sign.
3. Methodology

Having safe roads requires to analyse all components of the roads, and to identify all factors that can contribute to any type of road crashes. Identifying pedestrian-vehicle crash locations is essential for understanding the causes of pedestrian-vehicle crashes, and for determining effective countermeasures based on the analysis of the causal factors (Truong & Somenahalli, 2011). This research follows the roadway safety management process as a methodology to identify pedestrians danger locations and to propose the appropriate countermeasures in the city of Kigali. The roadway safety management process is a quantitative and systematic process for studying roadway safety on existing transportation systems and identifying potential safety improvement (HSM, 2009). This process consists of six steps, but the first three steps were selected as the main focus of this research. The road networks of Kigali city were screened by using route2 school, and the diagnosis was conducted by the analysis of identified problems, and lastly, recommendations/countermeasures were selected. The figure below shows the roadway safety management process and its components.

Figure 17: Roadway safety management process. Source: (Highway safety manual 1st Edition, 2009).

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3.1. Data collection process

The data used in this research was collected by using Route2 School tool and site visit.

3.2. A Short introduction on Route2school tool

Route2school is a tool that was created from a collaboration between the Transportation Research Institute at Hasselt University and ABEONA Consult with the aim of helping municipalities and schools to make a thorough analysis of safety on the school routes and the travel behaviour of children. Route2 school is currently being used in more than 65 municipalities with 760 schools. It was selected to be used in this research as it has been successful in identifying the bottlenecks (bad road, wrong parking, fast traffic, unsafe crossing, ...) along the route the pupils use walking to school in Belgium. The tool is used by pupils, parents, and teachers to identify the mobility bottlenecks in their municipality. As the tool showed good results in identifying bottlenecks and improving the safety of pupils in their ways to school, this research used it to identify the pedestrians’ danger locations (bottlenecks) and also to check its applicability in Kigali city. The tool has the advantages of identifying the danger locations proactively without relying on crashes data only, and the information collected from Route2 School is reliable as it comes from people who feel intimidated by the difficulties they face while walking daily.

During data collection by using Route2 school, the participants are asked to specify their home, their destination (schools), the routes, and to identify the areas or locations which they find to be unsafe (danger zones), to describe the problem, and to suggest a solution(s). The participants need to take a picture(s) of danger location and upload it (them) in Route2 School tool by using either a smartphone (downloaded application) or a computer (web application).

3.3. Participants

The participation was opened to teachers, students, parents, and other citizens to report any bottleneck or danger location for all road users. As the main objective of the research is safe pedestrians facilities in Kigali city, the data was collected from the areas that are mostly accessed by pedestrians. The schools (universities, secondary and primary schools) were selected as one of the areas accessed by many pedestrians. Also, schools were chosen to facilitate the way of communication with the participants during the data collection process. Universities and secondary schools were selected as the majority of students go to school by walking or by using public transport. Moreover this age group is also supposed to have access to smartphones or computers, which can lessen their difficulties for participating in data collection. For primary and nursery schools, the parents and the teachers were the targets to provide information on the problems they face while they travel or take their children to school.

As Kigali city has many schools that would not be included all in this research, some the schools or universities that are close to the busy roads were selected randomly. Twenty schools were selected randomly from each of 3 districts of Kigali city. Annex 2 and 3 represents the list and the map of participant schools.
3.4. The data collection procedure

Before the data collection process, the research was granted a permission by the city of Kigali as it is not allowed to conduct any research in Rwanda without having a permit. After getting the consent, the schools were contacted and informed about the purpose of the study and how the tool works. Then, the letters containing information and instructions on how the tool works were given to be distributed to the students, teachers, and parents.

The procedure of handling the letters to the participant schools, and let them follow instructions did not work well as it was planned. There were no more notifications received. To increase the number of responses, any person who lives or passes near one of the targeted schools was also invited to participate in the research. This was done by meeting people traveling and explain to them the purpose of the study and the data collection procedure. The volunteers who accepted to participate were asked to provide their email and the school, to help them with registration. There was also an exchange of contacts with the participants (phone number), which helped to make follow up and to solve the raised difficulties.

After registration, the participants received an email from the route2 school, inviting them to participate in the research. Then, they registered their address in route2 school, and started to report the bottlenecks. The participants had two options to report the bottlenecks; they should choose to use either mobile phone application, website platform (computer) or both. The mobile phone app was seemed to be user-friendly than using a computer as it finishes reporting at once without further works though it also requires a participant to stop for a while until the report is successfully sent. For computer users, it requires to take pictures and upload them late at working place or at home. This does not take much time on the field, but many participants did not like it because it late takes time to connect the phones on a computer and looking for the right picture(s) and it(their) corresponding right locations.

As there was an exchange of contacts (phone number), the participants were called to find out if they have been able to participate or if they faced some difficulties. This was the same for them; they also called to ask for more information or how they can solve the challenges they were facing. Some problems were solved via phone calls while the others were solved by setting appointments. An appointment was set on a condition that a participant has already taken the pictures of some bottlenecks. Those pictures were used to show how the tool works but at the same time as they were reporting the problems. Depending on a participant, after meeting them, some continued to report while others did not. The data used in this research was officially collected in three weeks.

The data obtained from routes to school were reported in two forms. The first one was to report a route and indicating an unsafe section on that route plus the reason why it is not safe. The second form was to report a bottleneck located at an exact point on the road and describe it.
3.5. **Field visit**

The site visit of most identified areas was conducted to observe in details the existing condition. The purpose of this field visit was to have a clear image of identified problems from Route2 School. Available sidewalks, their condition, obstacles in walkways, road signs at pedestrians crossings, available traffic calming at pedestrians crossings, a distance between two pedestrians crossings, escaping islands, and all other pedestrian features were observed.

The graph below summarizes the methodologies that were used to answer each research objective.

![Diagram](image)

Figure 18: Summary of methodology for each research objectives and its corresponding step for roadway safety management process.
4. Results

4.1. Descriptive of survey respondents

According to information from route2 school, 79 participants were registered to participate in this research; 52 participants (66%) were able to provide the reports while 27 participants (44%) have registered to participate but the time interval for data collection (three weeks) was ended without participating. Among 52 participants, 63% were male, while 37% were female. There were 201 reports in which 25.4% were reported by students, 18.9% by parents, 12.9% by teachers and 42.8% were reported by others (people who live or passes near the targeted schools). Considering the means of transport for participants, 88.1% were using foot, 9.5% were using cars, and 2.5% were using the bus.

4.2. Descriptive and analysis of reported bottlenecks and routes

From the analysis of the reports, 53 trips/routes, and 201 bottlenecks were reported. Each report was individually analysed; the reports for the routes were not detailed as the reports for bottlenecks. The reports for bottlenecks contained a type of the problem, the description of the problem, proposed solution, and the pictures of the problem. The reports for routes only described the reason why a specific section of the road is considered to be unsafe. In the data analysis, the reports of bottlenecks were the main focus as they contain many details. The analysis was grouped into two categories, the first is locations analysis, and the second is the type of problem analysis.

4.2.1. Analysis of locations for bottlenecks

The research identified different locations in the city of Kigali where different types of bottlenecks were reported. The identified locations with bottlenecks are shown on the map below (figure 19). The number of reported locations depended on the willingness of participants to report available problems. Some participants reported many bottlenecks as they can while others chose to report the problems by using the routes and give few reports about bottlenecks. This has affected the distribution of danger locations/bottlenecks as some roads have shown to have many notifications than others. However, more clarification was obtained from the site visit.

Among 201 reported problems, 63 problems were located at the intersection while 138 locations were located on the road segment. In the problems located on the road segment, 42 reports were related to the absence or unsafe pedestrian crossings while 96 remaining reports were dominated by uncovered ditches and obstacles along the pedestrian paths. From automatic analysis of reports by route2 school tool, 27% of reported problems were located within 200 meters from targeted schools, and 73% were located in more than 200 meters.
4.2.2. Types of bottlenecks analysis

The bottlenecks that were reported are divided into different types of problems, as shown in the graph below.

Figure 19: Map of reported bottlenecks and routes.

Distribution of types of pedestrian's reported problems

- Absence of pedestrian path/sidewalk
- Absence of a crosswalk
- Unsafe crosswalk
- Unsafe pedestrian path/sidewalks
- Dangerous intersections
- Poor visibility
- Bad road surface
- Traffic behaviour
- Other

Figure 20: Type of reported problems
The names of problems on the above graph (figure 20) are too general to know precisely how the problems are; the detailed analysis of each type of problem was conducted. The table below shows the type of problems with their detailed related problems, and some locations where these problems were found. It was not possible to find exact coordinates of the locations from route2 school; it was only possible to know the routes where these problems are located. It might be a challenge to find the exact location of a problem, but combining the name of the route and the map on figure 19, the approximate location of a bottleneck can be identified.

The table below shows a description of each type of problem. Each type of problem has its associated problems that can also be treated differently.

<table>
<thead>
<tr>
<th>Type of problem</th>
<th>The details on the problem</th>
<th>Some roads with the problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsafe pedestrian path</td>
<td>- Lack of continuity/ end of the path without a crossing</td>
<td>- KN 3 Avenue Kigali</td>
</tr>
<tr>
<td></td>
<td>- Pedestrian sidewalk which is not elevated</td>
<td>- KK 15 Rd Kicukiro</td>
</tr>
<tr>
<td></td>
<td>- Lack of fences</td>
<td>- KG 649 St Gisoi</td>
</tr>
<tr>
<td></td>
<td>- Bus shelters in sidewalks</td>
<td>- KN 5 Road Kigali</td>
</tr>
<tr>
<td></td>
<td>- Small sidewalks</td>
<td>- KN 14 Ave Kigali</td>
</tr>
<tr>
<td></td>
<td>- Construction works block sidewalks</td>
<td>- KG 11 Ave Kinyinya</td>
</tr>
<tr>
<td></td>
<td>- Improper arrangement of pedestrian path and greening</td>
<td>- KN 78 Street Kigali</td>
</tr>
<tr>
<td>Absence of pedestrian path</td>
<td>- No sidewalks provided</td>
<td>- KG 3 Ave</td>
</tr>
<tr>
<td></td>
<td>- Sidewalk provided on one side in commercial areas</td>
<td>- KG 541 St</td>
</tr>
<tr>
<td></td>
<td>- Big width of a crossing at intersections without an escaping island</td>
<td>- KN 3 Ave Kigali</td>
</tr>
<tr>
<td></td>
<td>- Markings for zebra crossings which are not visible</td>
<td>- KN 39 St Kigali</td>
</tr>
<tr>
<td></td>
<td>- Absence of traffic calming at the entrance of schools</td>
<td>- KG 548 St Gisozi</td>
</tr>
<tr>
<td></td>
<td>- Crossings without vertical signs</td>
<td>- KN 75 St Kigali</td>
</tr>
<tr>
<td></td>
<td>- Crossings without waiting area/ space</td>
<td>- KN 2 Avenue Kigali</td>
</tr>
<tr>
<td></td>
<td>- Absence of a crossing at the end of the pedestrian path</td>
<td>- KG 3 Ave Gisozi</td>
</tr>
<tr>
<td></td>
<td>- Absence of crossing after long distance</td>
<td>- KG 11 Ave</td>
</tr>
<tr>
<td></td>
<td>- Absence of crossing in front of public facilities(schools, hospitals, markets, commercial areas...)</td>
<td>- KN 5 Road Gisoi</td>
</tr>
<tr>
<td></td>
<td>- Absence of crossing between 2 parallel bus stops</td>
<td>- KN 4 Avenue Kigali</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- KN 5 Rd Kicukiro</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- KK 15 Rd Kicukiro</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- KK 18 Av Kagarama</td>
</tr>
</tbody>
</table>
| Dangerous intersection | **- Absence of crossing at busy intersections, roundabouts** | **- KK 27 Av Kicukiro**  
**- KN 5 Rd** |
|------------------------|----------------------------------------------------------|----------------------------------------|
| **- Intersections without marking, signs or traffic light** | **- KN 59 Street Kigali**  
**- Sonatubes Kicukiro** |
| **- A Small area at the intersection** | **- KN 2 Avenue Kigali** |
| Bad road surface | **- Small culverts which are not covered** | **- KG 548 St Gisozi**  
**- KG 544 St** |
| **- The Inappropriate slope of the sidewalk** | **- KG 563 St / Solace Way Gisozi** |
| **- Signpost in sidewalk** | **- KN 4 Avenue Kigali** |
| **- The Damaged pavement in sidewalks** | **- KN 74 Street Kigali**  
**- KN 7 Av Kigali** |
| **- Unpaved sidewalk** | **- KG 501 St Gisozi**  
**- KG 501 St Gisozi** |
| Poor visibility | **- Houses reduce visibility** | **- KG 548 St Gisozi** |
| **- Tall trees reduce visibility** | **- KG 5 Avenue Kigali** |
| **- Corners that reduces visibility** | **- KN 3 Road Kigali** |
| Traffic behaviour | **- Drivers do not give priority to pedestrians at a zebra crossing** | **- KN 2 Avenue Kigali** |
| **- Motorcyclists use sidewalks** | **- KK 15 Rd Kicukiro** |
| **- Pedestrians who cross without checking coming vehicles** | **- KN 2 Avenue Kigali**  
**- KK 15 Rd Kicukiro**  
**- KK 18 Av Kagarama**  
**- KN 75 St Kigali** |
| **- Motor vehicles and bicycles park on the sidewalk** | **- KN 70 St Kigali**  
**- KN 18 Av Kagarama** |
| Other | **- Misuse of sidewalk/ sell airtime on it** | **- KG 563 St / Solace Way Gisozi** |
| **- Traffic lights do not work** | **- KN 63 St Kigali** |
| **- Obstacles in sidewalk/ trees/signpost on the sidewalk** | **- KN 4 Avenue Kigali**  
**- KN 123 St Kigali** |
| **- Crossings on fenced road/unnecessary crossing** | **- KN 5 Road Kigali** |
| **- Uncovered ditches** | **- KN 2 Avenue Kigali** |
| **- High slope for the road** | **- KG 5 Avenue Kigali**  
**- KG 3 Ave Gisozi** |
| **- Steeps or step ramps** | **- KG 4 Ave**  
**- KG 7 Ave** |

Table 2: Summary of reported pedestrians problems and some of their locations
4.3. Detailed analysis of each type of reported problem

4.3.1. Unsafe pedestrian path

From the collected data, unsafe pedestrian paths/sidewalks were identified among the major problems for the safety pedestrians. About 16.4% of reported problems were concerned with unsafe pedestrians path. From the analysis of the reports, the graph below represents specific problems related to the unsafe pedestrian path.

![Distribution of 33 reports for Unsafe pedestrian paths](image)

**Figure 21:** Reported problems related to unsafe pedestrians paths

1. **Lack of continuity/ end of the path without a crossing**

Continuity is an important criterion for designing pedestrians facilities (Khisty, 1994), as Kigali city has many roads with pedestrians path provided on a single side, there are also problems related to their continuity. The pedestrians’ path ends on one side, and pedestrians are required to use a path provided on the other side, but there was no crossing provided in many of such cases. The lack of continuity also come with some roads where the drainage systems are well covered or constructed. Alternatively, this problem occurs on the roads without any pedestrian’ path provided.

2. **Roads without raised Pedestrian’ path/sidewalk**

The roads without raised pedestrian’ path are considered to be unsafe as they make the pedestrians to share the same pavement with motorized vehicles (Movahed, Azad, & Zakeri, 2012). These kinds of roads also make the drivers use the sidewalk space that is reserved for the pedestrians. In Kigali city, these sidewalks are mostly violated by motorcyclists, especially in a congested period when they want to overtake the vehicles.

3. **Construction works block sidewalks**

Though there were no many reports about construction works that block pedestrians’ path, some sites were reported where the sidewalk was occupied by construction activities which
push pedestrians to walk in the carriageway. On these sites, there were no signs to warn the drivers that construction works are going on so that they can reduce speed or generally pay more attention.

4. Improper arrangement of pedestrian path and greening
Due to lack of enough space, many roads in Kigali city have pedestrian’s path constructed along carriageway immediately without a greening in between. Some roads were also reported to have enough space but constructed in the way that greening was not left in the middle to separate pedestrians’ path with carriageway.

5. Small sidewalks
When the sidewalk is small, the pedestrians immediately choose to use the carriageway (Corazza, Di Mascio, & Moretti, 2016); some commercial areas in Kigali city were reported to have small sidewalks while there are many pedestrians in these areas.

6. Lack of fences
Lack of fences was identified in commercial areas where the shops are distributed on both sides of the road. Pedestrians cross at any point of the road while moving from the shops on one side of the road to another. As there is no separate pedestrians’ path in many parts of the city when there is a large number of pedestrians on sidewalks, they choose to walk also on the carriageway. On such roads, fences should be used for preventing to cross at any point and to walk on the carriageway.

7. Bus shelters constructed in sidewalks
Bus shelters are also important features for pedestrians (MSHA, 2015); in Kigali city the bus shelters are covered on both or on one side to prevent rain or wind. This should not be a problem if they are constructed out of sidewalks, some of these bus shelters are constructed in the middle of sidewalks and become obstacles for pedestrians walking. When a pedestrian is passing, he/she has no other options except to use carriageway or to pass behind the bus shelter.
4.3.2. Absence of pedestrian path

Absence of pedestrian path was not reported many times; only 5% were reported. The roads without pedestrian path force the pedestrian to walk on carriageway which exposes them to motorized traffic.

Figure 23: Reported problems related to absence of pedestrian paths/sidewalks

Absence of pedestrian paths was reported on the roads without any pedestrian path at all or on the roads with a sidewalk provided on a single side. As Kigali city has a hilly topography (Ellison, Ang, & Nugroho, 2013), pedestrians should not be allowed to walk on the same pavement as motorized traffics due to reduced visibility and high slope for some roads.

A sidewalk provided on a single side of the road cannot be seen as a big problem in the areas without more activities attracting the pedestrians, but it becomes a problem in commercial areas or other busy areas where pedestrians need to walk on both sides of the road. There are
some commercial areas with shops on both sides, but the pedestrian path was provided only on one side. In some locations, this one-sided walkway is provided on the side which does not generate more pedestrians, or on the side without many shops. The pedestrians either choose to cross the road (without a zebra crossing) and walk on provided single sidewalk or choose to walk in the road.

4.3.3. Unsafe pedestrian crossing

The unsafe crossing was also reported among the major problem for pedestrians safety in Kigali city. 15.4% of reported problems were concerned with unsafe pedestrians crosswalk. The problems related to unsafe pedestrian crossing were reported as follow:

- Big width of crossing at intersections without escaping island
- Markings for zebra crossings which are not still visible
- Absence of traffic calming at the entrance of schools
- Crossings without vertical signs
- Crossings without waiting area/ space

Figure 25: Reported problems related to unsafe crossing
1. **A big width of a crossing at intersections without an escaping island**

At some intersections/junctions in Kigali city, when the roads are about to connect, their size becomes wide, and when a crossing is painted without an escaping island, it also becomes wide. There are also some intersections with physical escaping islands, but the crossings were painted close to the island but without passing through the island. This makes the crossings to become wide too and make a pedestrian to use a long time cross it. At such intersections, the motorized traffics also do not need to reduce the speed when they are about to pass through, which can increase the probability of the pedestrians to be in collusion with motorized traffic.

2. **Markings for zebra crossings which are not still visible**

Many zebra crossings were painted on different roads in Kigali city (Frederic, 2018), but not all of them are still visible to both car users and pedestrians. Some crossings can only be visible to a pedestrian crossing as he/she can see some small remaining lines painted on the road, but the drivers in the coming vehicles can not see these lines. This can increase the probability of the accident as the pedestrians might think that they are crossing in proper locations while car drivers do not see the same.

3. **Absence of traffic calming at crossings (even at the entrance of schools)**

Traffic calming measures play a role of reducing the speeds of motorized traffics, and they should be implemented at crossings on all roads which may promote speeding (Bellefleur & Gagnon, 2012). In Kigali city, there are many schools which are located close to the major roads; this makes their gates to be also located on the roads. On such schools in many areas, speed humps were installed, but there are other schools where no humps or other traffic measure were implemented.

4. **Crossings without vertical signs**

Vertical signs have a decisive contribution to improve road safety. They offer optimum visibility even in the most unfavourable conditions, and they can last longer than on pavement markings (TSO, 2015). In Kigali city, only a few crossings have a vertical sign. In some cases, it can not be easy to visualize a crossing from long distance as only a zebra crossing was painted on the road surface without any other signal and sometimes the painting for the crossing might not be still visible too.

5. **Crossings without a waiting area/space**

Waiting area or waiting space was not given much attention in many crossings implemented in Kigali city. This space has advantages for both pedestrians and car users (Williams, 2005). The pedestrians can wait at this place before crossing, and they can be seen by the coming vehicles and being differentiated from pedestrians who might be standing or walking at the sidewalk. Some of these waiting areas were left planted with gardens which prevent the pedestrians from waiting at the right point.
4.3.4. Absence of pedestrian crosswalk

In Kigali city, the crossings are distributed at many intersections and at many road segments (Frederic, 2018). Despite this, the absence of crosswalk was the most reported type of problem, with 18.4% of the reports. To describe the problem in details, it was grouped into categories as following depending on the locations where a crossing is missing:

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**Figure 26:** The pictures of some reported problems related unsafe pedestrians crossings

**Figure 27:** Reported problems related to absence of pedestrian crossing
1. **Absence of crossing at the end of the pedestrian path**

As it has been described in the problems related to the absence of pedestrian path, some roads have pedestrian path provided on one side. This increases the needs for crossing points; on many roads with sidewalk provided on one side, the crossings were forgotten while the pedestrians are required to cross at these locations.

2. **Absence of crossing after long distance**

In Kigali city, the people need to perform different activities that are distributed all around the city; In Kigali city, the buildings are distributed on both sides of the road which make the people need to cross the road frequently. Some roads have no crossings after traveling a long distance while there are activities that generate the needs for crossing, in these situations pedestrians choose to cross at any point which make them disturbing the flow of motorized traffics and put their life in danger.

3. **Absence of crossing at public facilities**

In Kigali city, some public facilities such as schools, hospitals, markets, commercial areas... have no zebra crossing while they are located on major roads, and people who need services from these institutions come from both sides of the road.

4. **Absence of crossing between 2 parallel bus stops**

Bus stops also generate the movement of many pedestrians in Kigali city. There are parallel bus stops which generate much needs of crossing the road, at some bus stops no crossing was provided, or the provided one is no longer visible.

5. **Absence of crossing at busy intersections and roundabouts**

Intersections should have crossings for pedestrians; but this is not the same for all roads in Kigali city. There are busy intersections without any crossing or marking. On such intersections, pedestrians are responsible for looking at a gap as they have no priority. During rush hours it becomes difficult to find a gap which makes some pedestrians to penetrate in traffics and this can lead them to be hit by motorized traffics.
4.3.5. Dangerous intersections

Intersections or junctions have a big impact on the road network in various aspects such as safety, capacity, mobility, and operation cost (Xi, et al., 2013). The dangerous intersections were reported with 6% according to the reports; these intersections have two main common problems which are lack of markings, signs and traffic lights and a small area at intersection. Absence of markings and signals increase conflicts between the traffics and the problem with priority raises among road users. The pedestrians suffer more as they are required to wait until a gap is available, and in some case, they may misjudge the length of the gap which can cause a road crash. When marking and signage are not well implemented at intersections, it gives more responsibility to the pedestrians to check the traffics coming from many directions. The small intersections were reported as an intersection with many connecting roads, and the size of the road remains constant without any addition lane or space at intersection. Some of these intersections are located on the roads where the cars (including long buses) coming and going in any direction without marking, signal, and escaping island. The figure below represents the distribution of reports related to dangerous intersections.

Figure 28: The pictures of some reported problems related absence of pedestrian crossing

Distribution of 12 reports for dangerous intersections

Figure 29: Reported problems related to dangerous intersections
4.3.6. **Bad road surface**

9% of the reports were about the bad road surface. Bad road surface makes pedestrians to choose walking on carriageway once they arrive on such surfaces. This can make them be hit by motorized traffics coming behind them as a driver could not expect a pedestrian to deviate and use a carriageway. The identified problems related to bad road surface are:

1. **The damaged pavement of sidewalk:** Sidewalks need to be maintained the same as a carriageway (Corazza, Di Mascio, & Moretti, 2016). There are some locations which were identified to have damaged sidewalk while the carriageway was still in good condition.

2. **Unpaved sidewalk:** It is not common to find a paved road in Kigali city without a paved sidewalk, but there are some locations where a small part of the sidewalk was left unpaved.

3. **Inappropriate slopes of sidewalks:** This problem can be found in many locations within Kigali city where the slope of sidewalks was affected by leaving a way to access different properties. This make it difficult for a person in a wheelchair to travel a long distance independently.

4. **Small culverts about 20 to 30 cm (crossing sidewalks) were left uncovered,** these culverts cannot be seen as a problem for a person without any physical disability, but it is a problem for old and disabled persons.

---

**Distribution of 18 reports bad for road surface**

- 22% **Culvert which is not well covered**
- 56% **Damaged pavement of sidewalks**
- 17% **Inappropriate slope of sidewalk**
- 5% **Unpaved sidewalk**

Figure 30: Reported problems related to bad road surface
4.3.7. Poor visibility

Few reports were concerned with poor visibility; only 2.5% were reported to be poor visibility. Trees on the road, some houses at junctions/intersections and bad corners were identified to cause reduced visibility. Poor visibility reduces the sight distance for the driver and may put a pedestrian who crosses in that area to be in danger.

![Distribution of 5 reports for poor visibility](image)

Figure 31: The pictures of some reported problems related bad road surface

4.3.8. Traffic behaviour

The reports of traffic behaviours are the ones that were related to the behaviour of all road users. 12.4% of reports were concerned with the behaviour of road users. The traffic behaviour was reported for both pedestrians and motorized users. The graph below shows the type of behaviour identified.
Figure 33: Reported problems related to traffic behaviour

1. Drivers who do not give priority the pedestrians at zebra crossings

The drivers were reported to ignore the pedestrians at zebra crossings which make the pedestrians to wait until the motorized traffics give a gap. When it takes a long time for the pedestrians to find a gap, sometimes they choose to penetrate in traffics, which can cause a crash.

2. Motorcyclists who use sidewalks

It has found that on some roads motorcyclists use the sidewalk to overtake the vehicles, but this happens during the congested period and on the road without raised pedestrian sidewalks.

3. Pedestrians who cross the road without checking coming traffics

Though the pedestrians are the most vulnerable on roads, some of them choose to cross the carelessly. When they reach zebra crossings, they assume that they have the full right to cross and they tend to cross immediately. The traffic police have started to educate the pedestrians by standing at zebra crossings to observe and stop the pedestrians who make the inappropriate crossing and get the advice on how they should have crossed.

4. Wrong parking

The majority of wrong parking were caused by motorcyclists who park on the sidewalk waiting for passengers or dropping off the passengers. Cars were also reported to park on the sidewalk, but this happens in the areas with on-street parking. As the cars park perpendicular to the road, some cars have an extended length which make them occupy a part of the sidewalk and block the visibility for pedestrians and coming vehicles, and force the pedestrians to use carriageway.
4.3.9. Others

The others are the problems that are not classified in the above categories but which also have a negative impact on the comfort and safety of pedestrians. 14.9% of reports were classified as others. Among them, there is the misuse of sidewalks where people sell airtime on sidewalks, uncovered ditches while they are used as sidewalks, obstacles of a different kind in sidewalks like trees and signposts and steeps and step ramps which were mostly left at the entrance of some facilities and zebra crossings; The end of the footpath with abrupt curbs makes sidewalks inaccessible for many pedestrians, especially the old and disabled persons (Kost, et al., 2018).
Figure 35: Reported problems related to other

- Misuse of sidewalk/ sell airtime on it
- Obstacle in sidewalk/ trees/sign post on sidewalk
- Crossings on fenced road
- Uncovered ditches
- Steps or steep ramps

Figure 36: The pictures of some reported problems related other
4.4. General discussion

There are some inadequacies in the provision of road infrastructure for pedestrians in Kigali city. The identified problems have two main effects on pedestrians, which are safety and comfort.

For the safety issues; most of the problems make pedestrian to use carriageway and get exposed to motorized traffics. This can be seen by exposure of pedestrians walking along roads where there are no sidewalks, sidewalks which are not raised, sidewalks which are not separated from the carriageway, and pedestrians who cross where there are no facilities provided, or provided ones are not safe. By considering the type of the problems, absence of crossing (18.4%) and unsafe crossings (15.4%) was identified in the major problems, by making their total, both make 33.8% of total reported problems. This implies that there is a need for improving the design and increasing the number of pedestrians’ crossings in Kigali city. Unsafe pedestrian paths/ sidewalks were also reported many times (16.4%), this can be understood as Kigali city still have many roads whose single sidewalk or sidewalks on both sides but which are not separated from the carriageway. Obstacles, uncovered ditches, Traffic behaviour, and bad surface were also identified among major problems.

For comfort issues, the identified problems make walking difficult and unfavourable for many pedestrians, especially disabled and older people.

4.4.1. Effects of identified problems on young, old and disabled people

Even if all these identified problems can affect all pedestrians in general, it comes worst for the disabled people. In Rwanda the major of disabled have sight, mobility and mental problems (M’kumbuzi, et al., 2014). Despite being hit by a traveling vehicle, there are many obstacles that can cause other types of injuries for disabled people, or which can cause them to stay home rather than traveling alone. For people with a physical(mobility) disability; the signposts in sidewalk, steps or steep in the sidewalk, lack of continuity and the bad surface can prevent them from traveling. For people with sight disability, it becomes worst as they are not able to identify any of these problems. Njelesani, et al., 2018; in their reseach on realization of the rights of persons with disabilities in Rwanda considered Rwandan roads to be Impassable roads for this group of people.

When disabled people want to travel, they need external support from other people to reach their destination (for example: The persons on wheelchair need someone to push them, sight disabled persons need someone to direct them at crossings and prevent them from hitting different kind obstacles or falling in uncovered ditches,...). Also, many children are being accompanied to schools.

4.5. Implemented countermeasures

Despite all these above-reported problems, many countermeasures have been implemented in Kigali city to improve the comfort and safety of pedestrians. As there is a section of providing countermeasures in this research, it is important to appreciate what have achieved and make it as a reference point for providing countermeasures.
4.5.1. Infrastructure

<table>
<thead>
<tr>
<th>Features</th>
<th>Implemented countermeasures</th>
</tr>
</thead>
</table>
| Crossings  | - Painted in red to increase their visibility  
|            | - Two vertical bars painted in white and red which increase visibility and serve as an  |
|            |   indication for people whose sight disability                                               |
|            | - Enforcement by traffic police for all road users; car users, and pedestrians                |
| Sidewalks  | - The separate sidewalk on some new roads                                                   |
|            | - Elevated sidewalks                                                                         |
|            | - Planting trees to make paths comfortable                                                   |
|            | - Constructing bus shelters                                                                   |
|            | - Painting road edge line and using studs to separate shoulder/sidewalks and to help the    |
|            |   drivers keep driving in the carriageway                                                    |
| Intersections | - Using traffic police to control the vehicles in the congested period                        |
|            | - Traffic lights on some intersections with count down numbers to indicate the remaining    |
|            |   time to pass or to keep waiting                                                             |
| Public lighting | - Most of the roads in Kigali city have public lights, and there is a plan to                |
|             |   put light on the few remaining ones                                                         |

Table 3: Summary of implemented countermeasures for promoting safety of pedestrians

4.5.2. Campaigns

In Rwanda there is a road safety week for every year; but currently (May 2019), there is an special campaign called “GERAYO AMAHORO” means “ARRIVE SAFELY” which will last 52 weeks (one year). It has the purpose of reducing road accidents caused by human behaviour (RNP, 2019). The campaign has many components in which a specific group of road users has its relevant message. Focusing on the part of a campaign dedicated to the pedestrians, there is an interesting component of the campaign which focuses on students; traffic police officers, school teachers, and students paint the zebra crossings together and teach the students the proper way of crossing the road being on field. There are also some messages addressing the drivers to drive carefully. An example message says: “drive carefully as every child on the road is yours.”

4.5.3. Enforcement

From the reported problems, speeding was not among them; thanks to national traffic police that has implemented different measures to enforce the speeding which was among the factors that increased number and severity of accidents in Rwanda. The most efficient solution for speed enforcement was to install the speed governors in the minibuses, buses, and all commercial vehicles so that they can not exceed 60km/hour (Janvier, 2017). Traffic police officers also work 24/7 to make patrol on roads in Kigali city (especially at intersections) to enforce all traffic rules.
Proposed countermeasures on identified problems

Though the above countermeasures were implemented, according to the obtained findings in this research, there is still room for improvement on both infrastructure and behaviour of road users. The countermeasures that are presented in this research are mainly focused on infrastructure; for the behaviour further studies need to be conducted to understand clearly the factors that influence the road users’ intention to perform certain behaviours. Focusing on infrastructure has many benefits as infrastructure can act as enforcement to avoid the performance of certain behaviours. For example, the motorcyclists who were reported to use pedestrians’ path to overtake cannot do so when pedestrian’s path is elevated or separated from carriageway; this can be the same when the carriageway is large enough to accommodate all the motorized traffics.

4.6.1. Generalized countermeasures

The countermeasures were grouped in short-term (in 2 years), middle-term (2 years ≤ t ≤ 4 years) and in long-term (≥ 4 years).

No depth analysis of the cost for each countermeasure was done, but the countermeasures which expected to cost high were not immediately classified in the short-term period; as it might need to be included in the budget for coming years. Also, some countermeasures were grouped in the short term as they may be considered to have a significant impact on safety. As the countermeasures are suggested based on currently available problems, they are mainly reflecting to existing roads. New roads should be constructed by avoiding all these identified problems plus other problems which were not identified in this research.

<table>
<thead>
<tr>
<th>Problem</th>
<th>In short term</th>
<th>In middle term</th>
<th>In long term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsafe paths &amp; absence of sidewalk</td>
<td>-Identify all roads with unsafe sidewalks or without sidewalks</td>
<td>-Construct sidewalks on both sides in all commercial areas</td>
<td>-Separated paths for pedestrians</td>
</tr>
<tr>
<td></td>
<td>-Construct elevated sidewalks</td>
<td>-Solve the problem of discontinuity</td>
<td>-Overpasses on some busy intersections</td>
</tr>
<tr>
<td></td>
<td>-Remove Bus shelters in sidewalks</td>
<td>-Widening small sidewalks</td>
<td>-Use fences</td>
</tr>
<tr>
<td></td>
<td>-Provide painted sidewalks on local roads where sidewalks cannot be constructed</td>
<td>-Using studs on the road edge</td>
<td>-Remove all steeps or step ramps (curb ramps to be usable by disabled individuals)</td>
</tr>
<tr>
<td>Unsafe &amp; absence of crossings</td>
<td>-Identify all areas to install the zebra crossings</td>
<td>-Install all crossings and traffic calming measures</td>
<td>-Regular maintenance and studies of the new areas to implement crossings and traffic calming measures</td>
</tr>
<tr>
<td></td>
<td>-Paint zebra crossings which are not still visible by using the paint with high visibility (red+ white)</td>
<td>-Install escaping islands (physical and painted ones)</td>
<td>-Try to use other traffic calming measures (currently, only humps are used in Kigali)</td>
</tr>
<tr>
<td></td>
<td>-Use vertical signs on crossings</td>
<td>-Including waiting areas at crossings</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Install controlled crossings</td>
<td></td>
</tr>
<tr>
<td>Bad road surface</td>
<td>-Identify areas with the bad road surface</td>
<td>-Regular maintenance</td>
<td>-Regular maintenance</td>
</tr>
<tr>
<td></td>
<td>-Repair damaged pavement</td>
<td>-Pave all unpaved sidewalks</td>
<td>-use nice pavement materials for sidewalks</td>
</tr>
<tr>
<td></td>
<td>-cover uncovered small culverts</td>
<td></td>
<td>-Painting all sidewalks</td>
</tr>
</tbody>
</table>
### Poor visibility
- Identify all part of roads with poor visibility
- Cut tall trees block visibility
- Where possible remove the houses that reduce visibility (expropriation)
- Plant the trees that do not affect visibility
- Remove bad turns on the roads

### Dangerous intersections
- Making new designs with traffic lights, clear markings, and signs
- Using traffic policeman
- Priority signs
- Implementing designs starting from intersections on busy roads
- Further studies to identify intersection which can be changed into the roundabout
- Regular maintenance

### Traffic behaviour
- Campaigns
- Enforcements
- Education from primary schools
- Training for drivers
- Campaigns
- Enforcements
- Education from primary schools
- Training for drivers
- Campaigns
- Enforcements

### Uncovered ditches
- Study to identify all ditches need to be covered
- Cover damaged ditches
- Cover all ditches used as sidewalks
- Cover all ditches close to sidewalks
- Cover all ditches available in Kigali city on both sides of the road
- Regular maintenance

### Obstacles
- Remove all obstacles on major roads
- Remove obstacles on all roads including the local roads
- Regular check up

<table>
<thead>
<tr>
<th>Table 4: Brief of suggested countermeasures grouped in time interval</th>
</tr>
</thead>
</table>

#### 4.6.2. Countermeasures for sidewalks and crossings

Considering the results obtained in Route2 school tool, the figure below (figure 36) was drawn to represent the current possible arrangement of sidewalks on the roads in Kigali city (number of lanes was not the main concern).

**Figure 37: Possible arrangement of sidewalks on roads in Kigali city**
Seven different arrangements for sidewalks were identified; an entire road can have one or a combination of many sections. Considering characteristics of a safe sidewalk, section 6 and section 7 are the best practice. Section 2 can also be considered as a safe section when it has a clear edge line combined with studs, but the drivers also have to pay attention and follow traffic rules. Section 1 and 3 can also be used in the areas that generate pedestrians on a single side of the road. Section 4 and 5 should be avoided on new roads and removed from existing roads as they expose the pedestrians to motorized traffics.

Having different arrangements of sidewalks has a significant effect on the number and locations of crossings. For example, there are many roads whose combination of section 1, 2, and 3. This has been identified in the reports in the absence of crossing or discontinuity of sidewalks. There are some locations where there is no zebra crossing while the arrangement has changed from section 2 to 1, 3, or vice versa. The zebra crossings should be painted on all the locations where there is a change in these three sections plus all other locations where pedestrians need to cross. Though changing cross sections may save some money during the construction phase, on the safety perspective, a section should be kept constant at least for the whole segment to reduce the needed number of crossings. There are other roads whose combination of section 6 and section 7, on these roads, the safety of pedestrians is not affected but such combination makes discontinuity for bicycle path which makes cyclists always to use carriageway rather than using provided discontinuous paths. Even if there are many roads in Kigali city with section 6, there is no continuous road with this section which can be used by cyclists from origin to a specific destination. As a recommendation, Kigali city should at least select some specific roads and implements section 6 on the whole road so that the people will use their bikes from home to some specific destinations.

Although there may be a burden for budget, Kigali city should put more efforts in implementing section 6 and 7 for increasing the safety and mobility of pedestrians. Implementing these sections might need more money for construction and expropriation of the land, but this can cost much high when the city needs to do so later after the roads have been already constructed.

4.6.3. Countermeasures for on-street parking

Wrong parking was identified in some reports; normally, some of those reports should not be classified as wrong parking since the people were parked in the right place. The problem was the arrangement of parking. There are some on-street parking which are perpendicular to the road, and the drivers are required to cross sidewalks to be able to park. Crossing the sidewalk disturb the movement of pedestrians; despite this, some long vehicles occupy a pedestrian path when they park (as shown on the figure 37). Such kind of parking should be replaced by parallel parking, which does not have any conflict with the pedestrians. Despite considering the safety of pedestrians, Parallel parking is preferred over angular or perpendicular parking because it saves space and is safer when exiting the parking bay (Kost, et al., 2018).
Figure 38: Perpendicular parking vs parallel parking

4.7. Limitations

In the research; mainly during data collection, there were some difficulties that could either reduce number of responses or the quality of obtained data. The difficulties were grouped two categories; Some were related to the participants while the others were related to Route2 school tool. Exchanging contacts (phone number ) was key to overcome many of these difficulties as it has increased communication with participants.

4.7.1. Limitation on Route2 school

The Route2 school played an important role in the data collection for this research, but it also had some of the following difficulties:

- During the data collection period, the tool itself had some technical issues; the first step of registering email for a participant in Route2 School was taking quite a long time to open the page; in most of the case it opened only a blank page. Also, sometimes, when trying to log in, the tool showed different types of errors.
- In Rwanda, the address is known as a village, cell, sector, district and province or city of Kigali. Before starting data collection, the participants were asked to provide their home address in the form of street number, house number, and zip code. Some of the participants were not aware of such kind of address. In Kigali city, the streets have their names, and many houses have house number too; but there are also other houses without house numbers. Some persons who did not know these address chose not to participate.
- The mobile phone users had the main difficulty of turning on the location on their phones; some people do not know if this function exists in their phones, which make them keep it either on or off. It was not very easy to show people how to turn the location on as it is different from one phone to another.
• The computer users had the main problem of taking a picture with less than 4 Megabytes. Currently, mobile phone manufacturers are improving their features. The camera is one of the features that is being developed at a high level. Unfortunately, the more camera is improved, the more the size of the picture increases. Many phones take pictures of more than 4 megabytes by default. The size of the image can be reduced from camera settings or by adjusting/editing an image after it has been taken, but only a few people knew this; and not all the people who knew it had much willingness to do so.

• Another challenge with this tool was that the participants were required to have good internet either on phone or computer. Internet is available in Kigali city but not all the citizens can afford it.

4.7.2. Limitation on participation

• Convincing the participants was not an easy task: In Rwanda road safety is mainly in the responsibility of traffic police, during the data collection, it was not easy to convince people how a civilian can deal with road safety; they thought traffic police should be the one to do such researches.

• Participating in the study was easier for pedestrians that car users; it is prohibited to use a mobile phone in Rwanda while driving. It has become a challenge for car users as it was difficult for them to stop or slow down to take the pictures of bottlenecks, and away from this, they claimed to use the road most of the time in rush hours where they are required to pay much attention on the road.

• The knowledge of participants was also a bit challenge; some of them were asking the kind of the problems they should report. This has an impact on obtained results as it could be easier to remark a particular type of problem than others.

• The research was also intended to use the accidents data for pedestrians in Kigali city, to relate the kinds of problems identified with the actual causes and locations of pedestrian crashes, but this was not possible because pedestrian’s accidents data was not found.
5. Recommendations

The recommendations for this research were grouped into two parts; the first part is concerned with an important tool (Route2 school) that played a big contribution in the data collection process, and which helped to achieve on the purpose of the research. The second part of the recommendations is based on the findings of the research.

5.1. Recommendation on route2school

A route2 school is a useful tool for identifying the bottlenecks in the routes; it can be user-friendly when the participants commit to reporting. The best thing about it is how it classifies the types of problems and makes the users to have an insight on the kind of the problems that they can report. Generation of an excel and PowerPoint documents summarizing the reported problems make the analysis of collected data more easier. This makes the tool to be user-friendly for both people who report and the people who analyse the recorded information. Despite all these benefits, on Kigali project, there were some challenges which have reduced the number of respondents. Some of these problems include taking a long time to open some pages, showing errors sometimes when trying to log in, and the limited size of the picture that can be uploaded in the tool. These problems could be adjusted for future use. As this tool was being used in research purpose for Kigali project, the responses were not many; people can put more efforts in reporting when they expect their reported problems to be solved soon. In the next project, when the tool will also be used in research purpose in Kigali city or other similar locations, a researcher is recommended to work/collaborate with the sectors that deal with traffic safety (traffic police for Rwanda) in the area to convince the participants. For sure the rate of response can be increased when the tool is being used for the project whose purpose is to identify the problems and provide the countermeasures afterward and, also when the message is conveyed to the participants by the person whom people know.

In data analysis, the developer of the tool should include the way of detecting the geographical coordinates of the location where the problems are reported, not only to indicate the route name since one single route might have many kilometres which can reduce the precision on location. Geographical coordinates can also serve as inputs for other tools for further analysis or making mapping of the reported problems, and it also can make this tool to serve many purposes and be needed by many agents.

The tool also has another part which is Route2school (R2S) Education; an online learning platform where students can improve their traffic insights in a pleasant way by ensuring that they learn to cope better with difficult traffic situations. Further research on the applicability of this feature in Kigali city can also be done as this platform can also be useful to educate the students in the schools of Kigali city.

5.2. Recommendations on the research

Providing full provision of pedestrian infrastructure is quite expensive for existing roads, but it can be less expensive to incorporate nice sidewalks and crossing points into new roads without a more additional cost (Kost, et al., 2018). As the budget might not be available at the same time, the problems which likely to cause more accidents should be the priority and the
countermeasures should be implemented starting from the locations where pedestrian numbers and risk are high. Researches in western countries have provided evidence that three engineering countermeasures such as separation of pedestrians from motorised traffic, increase in visibility through pavement markings and pedestrian lighting; and speed controls for motor vehicles in pedestrian zones have brought substantial reductions in pedestrian crashes (Alemgena, Quezon, & Kumela, 2018). This should also be applied in Kigali city as well as in the other cities from developing countries.

In the last years, engineering treatments for pedestrians was not common practice in Kigali city, but currently, there is awareness of improving road safety (Ellison, Ang, & Nugroho, 2013). This can be seen on some new roads that are being constructed in the city which have safety features for pedestrians; the city should keep this initiative and consider to improve the existing roads that were constructed before the raising of awareness.

The city of Kigali, as well as the whole country, have initiatives of expanding road networks (Mininfra, 2018); road safety studies for the planned roads should be given a priority before starting construction, during the construction period and as well as after construction works. The safety for all road users should be considered, but pedestrians should be given a priority on the roads that are planned to be constructed in the city areas. The designs should be made to avoid pedestrian-vehicle conflicts on major roads by reducing interaction between pedestrians and vehicles.

On existing roads, all components of road safety improvement system such as road safety impact assessment, road safety audits, road accident investigation and road safety inspection should be conducted periodically by considering all road users but with priority for pedestrians in city areas.

As other road users like motorcyclists, public transport users, have some bodies/institutions which follow their activities daily, it should be essential to include in governmental institutions like Ministry of infrastructure(MINIFRA), Rwanda Transport Development Agency (RTDA) or in city of Kigali at least a person who will only be concerned with mobility and safety of pedestrians daily. This person can be involved in the studies about road construction but focusing on the benefits of pedestrians. This person can also lead or conduct pedestrians safety audits on existing and new roads.

The government of Rwanda has the politic treating all its people equally, including disabled persons, in this case, all public buildings are required to be accessible by all persons, including disabled people (Njelesani, Siegel, & Ullrich, 2018). It should also be the same when designing pedestrians facilities so that disabled people can be able to move independently and help in the development of their families rather than being a burden to their families who always help them with mobility. The body that represents the disabled people in Rwanda(National Union of Disability Organizations of Rwanda, NUDOR) should put more efforts in increasing awareness and ask for funding to make the mobility of disabled people safe and comfortable since transport plays a significant role in the development.

Some of the countermeasures proposed in this research might not be new, some of them were implemented on some parts of the road in Kigali city, they should also be implemented on all roads to help the drivers be familiar with the same road environment.
All the above recommendations will need fund to be realized, as it has found that no many (or none of) private sectors which are much interested in funding the projects related to the pedestrians mobility and safety, this should make the government thinks about pedestrians mobility and safety when planning the budget.

There are also other factors that influence the safety of the pedestrians which need to be investigated. More researches should be conducted on road users behaviours for both pedestrians and drivers. This research was only conducted in the city of Kigali while the pedestrians accidents also occur in the other areas of the country, more the researches should be conducted in the other areas of the country especially on national roads and in secondary cities.
6. Conclusion

Cities produce significant pedestrian activities and movement; therefore, it is crucial to think about the safety of this vulnerable group of road users in the design of urban and road development. The safety of pedestrians depends on many factors; safe facilities is one of them. The pedestrians need the facilities which are well connected, safe, attractive, convenient, and easy to use. The research found different detailed factors that reduce the safety and comfort of pedestrians in Kigali city; these factors were found to be distributed in different parts of the city but not on all roads. Some new routes were identified to be safe for both pedestrians and car users, while other roads, especially old ones, were reported to be dangerous or uncomfortable for pedestrians. Absence of sidewalks, unsafe sidewalks, lack of zebra crossings, unsafe crossings, and different obstacles were identified as the main infrastructure problems for pedestrians. The improvements for the road safety of pedestrians in Kigali city should focus on these identified features.

As Kigali city has a high willingness to achieve its target of becoming a city of green transport; this research can bring a significant contribution to achieve this target. Providing safe and comfortable infrastructure for pedestrians will encourage many people in Kigali city to walk and to use public transport rather than using private cars, which will result in a reduction of transport problems such as congestion, air pollution, and road accidents.

It may not require much knowledge resources to correct some of the identified problems as the city has some parts where the best practices were implemented. It is just recommended to distribute the best practices in the whole city, as the pedestrian facilities and all the concerned factors should be provided in all parts of the cities and maintained to efficiently promote and encourage people to walk and to improve pedestrian safety and comfort.
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Annex

Annex 1: Cities where a Route2 School is being used in Belgium
Annex 2: The list below shows the selected schools to be a part of the data collection process.

<table>
<thead>
<tr>
<th>Schools</th>
<th>Type of school</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. University of Kigali</td>
<td>University</td>
<td>KG 541 St, Kigali, Rwanda</td>
</tr>
<tr>
<td>2. University of Rwanda college</td>
<td>University</td>
<td>KN 7 Ave, Kigali, Rwanda</td>
</tr>
<tr>
<td>of science and technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. University of Rwanda college</td>
<td>University</td>
<td>KG 11 Ave, Kigali, Rwanda</td>
</tr>
<tr>
<td>of education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. University of Tourism</td>
<td>University</td>
<td>KN 3 Rd, Kigali, Rwanda</td>
</tr>
<tr>
<td>Technology and Business Studies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(UTB)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Saint Joseph Integrated</td>
<td>University</td>
<td>KN 2 Ave, Kigali, Rwanda</td>
</tr>
<tr>
<td>Technical College</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. IPRS Kigali (Kicukiro)</td>
<td>University</td>
<td>KK 15 Rd, Kigali, Rwanda</td>
</tr>
<tr>
<td>7. Goupe scholaire Camp Kigali</td>
<td>Primary + Secondary</td>
<td>KN 75 St, Kigali, Rwanda</td>
</tr>
<tr>
<td>8. Ecole technique Saint Joseph</td>
<td>Secondary</td>
<td>KN 182 St, Kigali, Rwanda</td>
</tr>
<tr>
<td>de Nyamirambo</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Cyivugiza primary school</td>
<td>Primary</td>
<td>229X+63 Kigali, Rwanda</td>
</tr>
<tr>
<td>10. Intwari primary school</td>
<td>Primary</td>
<td>23H4+XP Kigali, Rwanda</td>
</tr>
<tr>
<td>11. Belgian school of Kigali</td>
<td>Nursery + Primary + Secondary</td>
<td>KN 78 St, Kigali, Rwanda</td>
</tr>
<tr>
<td>12. Lycee de Kigali</td>
<td>Secondary</td>
<td>KK 2 Ave, Kigali, Rwanda</td>
</tr>
<tr>
<td>13. Birla nursery school</td>
<td>Nursery</td>
<td>23X6+W5 Kigali, Rwanda</td>
</tr>
<tr>
<td>14. Pacific nursery and primary</td>
<td>Nursery + Primary</td>
<td>KN 18 Ave, Kigali, Rwanda</td>
</tr>
<tr>
<td>school</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. The earth school</td>
<td>Nursery + Primary</td>
<td>KN 46 St, Kigali, Rwanda</td>
</tr>
<tr>
<td>16. Path to success</td>
<td>Nursery + Primary</td>
<td>KN 14 Ave, Kigali, Rwanda</td>
</tr>
<tr>
<td>17. Kagarama primary school</td>
<td>Primary</td>
<td>2462+W6 Kigali, Rwanda</td>
</tr>
<tr>
<td>18. Friends church primary school</td>
<td>Primary</td>
<td>KK 15 Rd, Kigali, Rwanda</td>
</tr>
<tr>
<td>19. Little bears Montessori school</td>
<td>Nursery</td>
<td>KG 674 St, Kigali, Rwanda</td>
</tr>
<tr>
<td>20. Saint Paul International School</td>
<td>Nursery + Primary + Secondary</td>
<td>24WC+J6 Kigali, Rwanda</td>
</tr>
</tbody>
</table>

Participant schools.
Annex 3: map of targeted school for data collection

Kigali city map with participant schools and universities. Source (edited from google earth)
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Ik/wij verlenen het wereldwijde auteursrecht voor de ingediende eindverhandeling:

Safe pedestrians' facilities in Kigali City

Richting: Master of Transportation Sciences-Traffic Safety
Jaar: 2019

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Uwizeyimana, Jean Damascene

Datum: 3/06/2019