

# **MINOR DISSERTATION**

Submitted for the Degree of MEng Transportation Studies

## **Investigating Pedestrian Safety Solutions on Rural High-order Roads.**

**Case-study: R71 Polokwane**

*Prepared for:*

*Centre for Transportation Studies  
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**Lesedi D Mokoma**

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## ABSTRACT

South Africa's pedestrian accident rate is one of the highest in the world. The percentage of pedestrian accidents to total road accidents is approximately 33% (RTMC, 2011) far greater than the world average of 22% (World Health Organisation, 2013). The problem is more acute in rural areas where 1 in 3 pedestrian accidents results in pedestrian fatalities. The ratio on urban roads is 1 in 10.

The sobering pedestrian safety statistics describing South Africa's rural roads have prompted the need to research functional and effective traffic engineering solutions that can improve pedestrian safety on rural high order roads located near human settlements. This investigation is conducted using the R71 Polokwane -a road with a history of pedestrian safety problems- as a case study.

Pedestrian safety risk factors and an assessment methodology for pedestrian risk on rural high order roads are derived from a review of local and international literature. The pedestrian risk assessment methodology is applied to the R71 study area. This process highlights the shortcomings of the current accident data collection process. Critical information such as accident cause and location; driver and pedestrian characteristics such as age and gender; important information such as vehicle type and age, injuries, fatalities, etc. are not recorded. The limited data minimises the depth of the analysis however a reasonable high level understanding of the pedestrian safety risk factors and the risk in the study area is attained.

The R71 study area is characterised by villages, farms and an urban settlement. The prevalence of pedestrian accidents is higher in villages and lowest in the urban settlements. This is attributed to the infrastructure provision in the urban settlement. The causes of pedestrian risk on the R71 are concluded as:

- Lack of integrated land use and transport planning;
- Lack of pedestrian infrastructure.
- Poor design of speed transition zones between rural areas and villages and urban areas.

A literature review of effective pedestrian safety measures that are being implemented locally and abroad is compiled. Some of the solutions are impractical for the rural South African context particularly because they are dependent on consistent energy sources and may require routine maintenance. A solution framework based on the pedestrian safety risk identified on the R71 is designed to guide countermeasure selection and design in rural contexts. In the end, solutions deemed suitable for the rural context are: effective high to low speed transition zones; the provision of fenced-off service roads and strategic crossing points; and the removal and enforcement of land use in the road reserve of high order roads. These solutions must be complemented with community training and consistent law enforcement.

# 1. INTRODUCTION

## 1.1 BACKGROUND

South Africa's pedestrian accident rate is one of the highest in the world. The percentage of pedestrian accidents to total road accidents is approximately 33% (RTMC, 2011) far greater than the world average of 22% (World Health Organisation, 2013). This is true for some of the other developing countries. The problem is more acute on rural high order roads which comprise a large proportion of the extensive road network in the country. Infamous roads include the R71 Polokwane, Moloto Road (R573) in the North of Pretoria, the R61 in the Eastern Cape, N1 section in Hammanskraal and many others.

South Africa is a signatory of the Decade of Action for Road Safety 2011-2020 campaign. As part of the campaign the government has committed to reducing road fatalities by 50% in 2020 (DoT, 2015). The campaign highlights the importance of understanding major risk factors and effective countermeasures. This thesis responds to this need as well as Pillar 2 of the campaign; which is safer roads and mobility, where member states are required to invest in improved road design for all users (UN, Unknown).

## 1.2 THE PROBLEM

On a higher level, the high pedestrian accident predicament in South Africa may be attributed to the lack of integrated land use and transport planning evident on many problematic rural high order roads. Inadequate planning is particularly visible along roads located in high pedestrian volume areas. Such conditions yield a mismatch between the road function, which is to facilitate mobility, and the movement needs of the surrounding pedestrian environment, resulting in a hazardous road environment. Jaywalking on rural highways is symptomatic of the aforementioned limited pedestrian access opportunities and it increases the probability of pedestrian and vehicular conflict. The reasons for this road function versus pedestrian environment disconnect are as follows:

- The path of least resistance (in terms of construction cost) is selected for the design of Greenfield's rural highway projects. Selecting the path of least resistance sometimes results in the expropriation of households and farming land and the provision of a high mobility road that segregates a community.
- Regional connectors such as Class 2 and 3 provincial roads are often located within rural settlements. One of SANRAL's strategies is to incorporate provincial roads of national significance into the primary network; the increase in mobility of roads that were historically used for access is problematic.
- Another reason is the encroachment of land use onto high order roads particularly in rural or remote areas that do not have an established road network.

Pedestrian safety has been identified as a national goal for decades; however, the problem still remains. Periodic awareness campaigns, sporadic law enforcement and engineering

solutions such as the installation of warning signs, expensive pedestrian bridges and fences have been applied in problem areas but many have proven to be ineffective. The reactionary nature of pedestrian safety mitigation provision has often resulted in a disintegrated problem solving process: accident hot spots are identified and solutions (stated above) are typically provided in isolation of the many factors that culminate in an incident.

**The problem addressed in this dissertation is the high pedestrian accident rate on rural high-order roads in South Africa which is caused by the lack of recognition of this mode in planning and design of roads.**

### 1.3 SCIENTIFIC PROBLEM

The scientific problem addressed in this dissertation is that there is a lack of understanding of the causes of pedestrian accidents as well as the limited evidence of countermeasure effectiveness on pedestrian safety on rural high-order roads in South Africa. Rather, guidelines provide specifications about individual countermeasures with minimal scientific backing.

International literature and its practical applications on the subject are abundant. A literature review is a starting point for identifying innovative processes and countermeasures –with scientific backing- that may be effective in South Africa.

### 1.4 PURPOSE OF THE RESEARCH PROJECT

**The research has two aims, firstly to conduct a literature review that investigates the causes of pedestrian accidents, methods for assessing pedestrian safety risk and functional and effective traffic engineering solutions that can improve pedestrian safety on rural high order roads. The outcomes of the literature review are; a methodology for assessing pedestrian safety risk and a cross table of effective pedestrian safety countermeasures.**

**The second aim is to conduct an explanatory case study of the R71 pedestrian safety problem guided by the outcomes of the literature review to identify pedestrian safety problems and recommend measures for the problem in a rural South African context. The overarching outcome of the case study is a solution framework for pedestrian safety on rural high-order roads.**

The research objectives and questions are:

1. **To provide a methodological approach for identifying pedestrian safety risk areas in settlements located near rural high-order roads.** The questions asked to achieve these are:
  - a. What are the underlying causes of pedestrian accidents on rural high order roads?
  - b. Which methodology can be used to assess the underlying causes of pedestrian accidents?

- c. Which pedestrian safety risks are revealed by the application of the aforementioned assessment methodology in a South African context?
- 2. To identify traffic engineering countermeasures empirically proven to improve pedestrian/vehicular conflicts or accidents in high risk areas with similar conditions as the R71.**
    - a. Which technologies or countermeasures have the potential to remedy the underlying cause of the problem?
  - 3. To provide a solution framework that guides the design of pedestrian safety countermeasures for the R71 and other similar contexts.**
    - a. Which solution framework can be applied to guide the selection and design of countermeasures in a South African context?
    - b. Which solutions are feasible for the R71 case study?

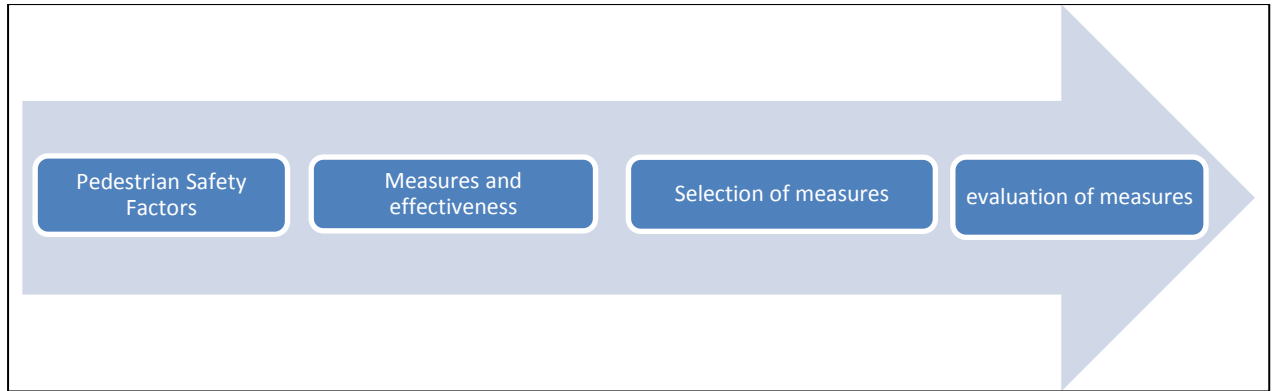
Understanding the underlying causes of pedestrian accidents is essential when identifying a methodological approach for identifying pedestrian risk areas and determining effective countermeasures. Assessment methodologies and countermeasures should be sourced from current and cutting-edge research to ensure that the very best solution for the problem is applied. Most importantly, they should have scientifically proven effectiveness in a rural setting.

Multitudes of research have been done in other countries particularly in Europe, America and Asia however this is not the case for Africa. Lessons can be learned from these studies however solutions that are based on the African context are pivotal for progress in our environment.

The research questions are addressed in the body of the report.

## **1.5 METHODOLOGY**

The project scope will include an extensive background study; a case study of the R71 comprising of data collection and analysis and the design of a solution framework which will inform a conceptual design of road safety interventions on the R71. The research approach followed for the Masters dissertation is shown in **Figure 1**; each block in the Figure will be discussed subsequently.



**Figure 1: Research project approach.**

### **1.5.1 Literature Review:**

A literature review of known pedestrian safety risk factors that are appropriate for the rural environment was conducted.

### **1.5.2 R71 Case-study - Status-quo analysis:**

Assessing the risk on the R71 based on the outcomes of the literature review and identifying the problem statement for the case-study. The following information will be analysed:

- Land use information using GIS maps.
- Accident statistics obtained from Polokwane Metro Police.
- Pedestrian and vehicular traffic counts from site surveys and SANRAL Comprehensive Traffic Observations (CTO) database.
- Desktop study and site surveys of pedestrian desire lines, GIS mapping of survey data and overlaying with Land use data.
- Vehicle speeds obtained from Tom-tom.
- Identification of problem areas.
- Investigation of problem areas.
- Deduction of the Problem statement.

### **1.5.3 Measures and effectiveness: Literature review**

- Literature Review:
  - A literature review of traffic engineering solutions and complimentary measures (i.e. law enforcement) applied locally and internationally was conducted to ascertain the following:
    - Functional and effective traffic engineering and complimentary interventions for pedestrian safety. Functional refers to measures that are practical and useful, rather than just attractive. These are solutions that can be provided, used and maintained in a rural environment with relative ease. Effective refers to

measures that are successful in producing a desired result. A balance is required to identify measures that are both functional and effective.

The information was sourced from journals, policy documents and any other form of applicable and available research.

#### **1.5.4 Selection of measures**

Solutions – based on the literature review - were selected for the problem areas identified on the R71. These were selected based on functionality and effectiveness. A conceptual design is provided.

Functionality is characterised in terms of ease of implementation and the extent of required operational and maintenance costs. The conceptual designs of the proposed traffic engineering interventions are presented.

#### **1.5.5 Evaluation of measures**

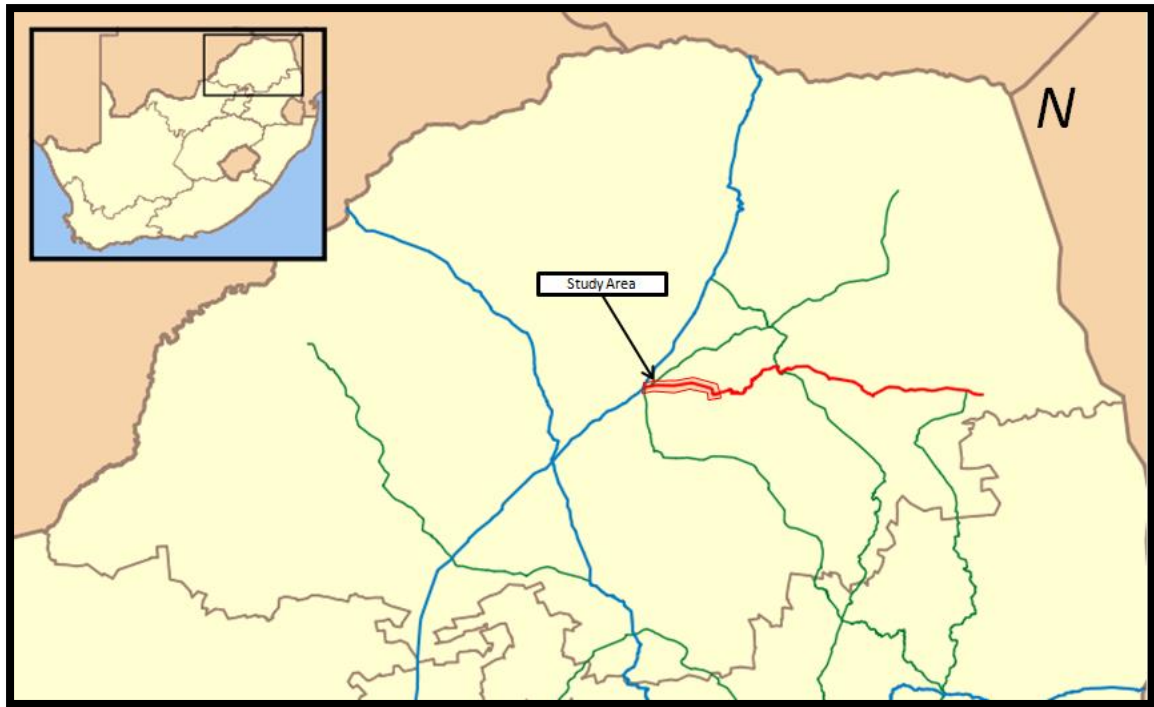
The methodology for evaluating the effectiveness of measures is outlined.

### **1.6 LIMITS TO THE RESEARCH PROJECT**

The pedestrian safety dilemma emanates from many important elements. Human behaviour, limited law enforcement, lack of education and a disintegrated built environment are some of them. The elements are interdependent and should be equally assessed to provide holistic solutions. For the contribution to engineering research, this project has focused primarily on the traffic engineering solutions that can be applied to the built environment while briefly considering the other elements of pedestrian safety.

### **1.7 CASE STUDY**

The R71 Polokwane provides a case study of a rural higher order road that has restricted pedestrian access for the adjacent human settlements resulting in safety issues. The R71 is a National Road that provides regional connectivity in the Limpopo Province; it is a mobility route that connects Polokwane in the Centre of Limpopo to Phalaborwa in the East of the Province and it is instrumental for local, regional and national movement and trade. A regional map of Limpopo illustrates the locality of the R71 and the extent of its connectivity (**Figure 2**).



**Figure 2: The regional locality of the R71.**

Most of the road is a high speed dual carriageway with a wide median and limited access. It can thus be classified as a Class R2 Major Arterial (RCAM, 2012). Formal access to vehicles on lower order roads and pedestrians is provided at one-way stop controlled intersections that give right-of-way to R71 users. Traffic calming measures upstream and downstream of pedestrian crossings are typically “yield for pedestrian” signs and road markings. More equitable priority is provided at two signalised intersections in Mankweng. The R71 bisects and segregates the communities and limits access to public land use and other facilities. The road serves as a barrier to North-South pedestrian movements and very few measures are in place to accommodate safe pedestrian movements across the road.

The study area comprises of two road sections of the R71 Polokwane:

- **Section 1** is a 3.67km stretch of road in the township areas of Myngenoegen (km 7.4) and Dalmada (km 8.5); and
- **Section 2** is a 18km section between the township areas of Nobody (km 24) and Moria (Boyne) (km 39).

The sections are illustrated in **Figures 3 to 5**. **Figure 3** provides an aerial view of the study area. Section 1 and 2 are located to the west and the east of the R71 study area.



**Figure 3:** An aerial photograph of the study area (blue) provides a view of sections 1 and 2 on the east and west (Google Image).

**Figure 4** and **5** are maps of Section 1 and 2 respectively. Section 1 is characterised by small agricultural holdings, schools, hospitality services and various industrial land uses. The overriding land use in Section 2 is rural residential areas such as Nobody, Viking and Moria (Boyne). Mankweng is an exception; it can be classified as an urban residential area. Typical to urbanised environments Mankweng has the most diverse range of land use on the R71 Polokwane. Major land use in Mankweng include the University of Limpopo and Mankweng Hospital. Other land uses comprise of general public facilities, retail, filling stations, shops and liquor stores.

The R71 environment consists of numerous factors which lead to pedestrian safety risks. It also encompasses the general problems (settlement segregation, poor land use and transport planning etc.) that plague risky rural roads in South Africa. The section is therefore an appropriate case study for this research topic.

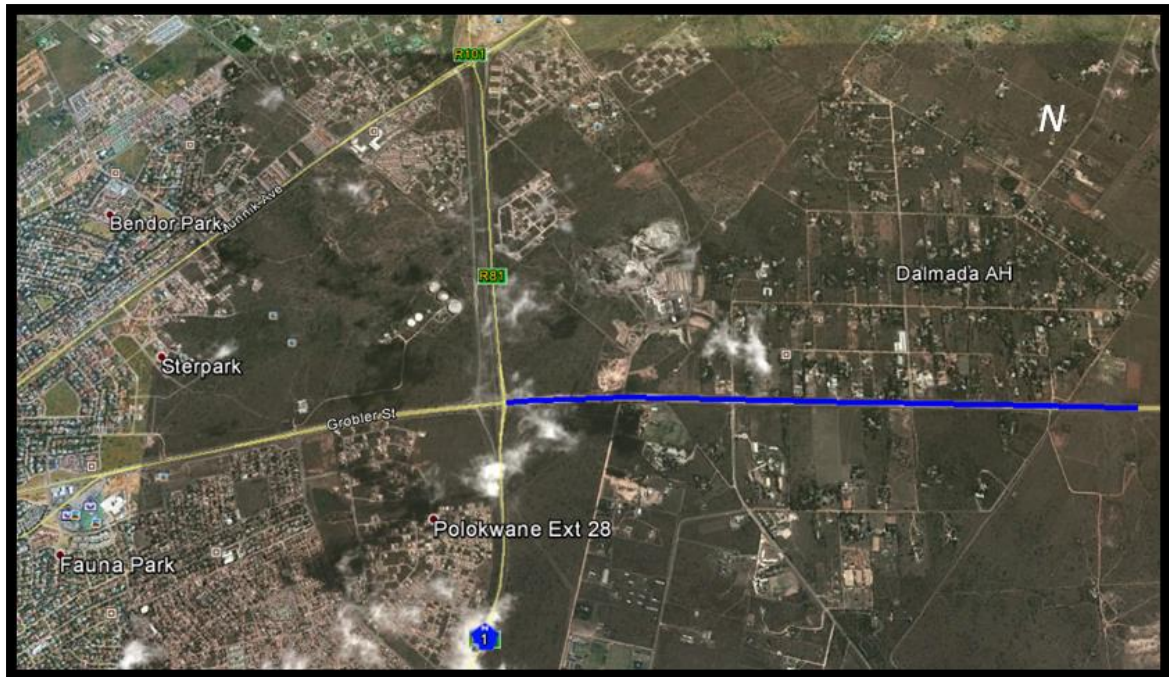


Figure 4: An aerial photo of section 1 between Myngenoegen and Dalmada (Google Image).

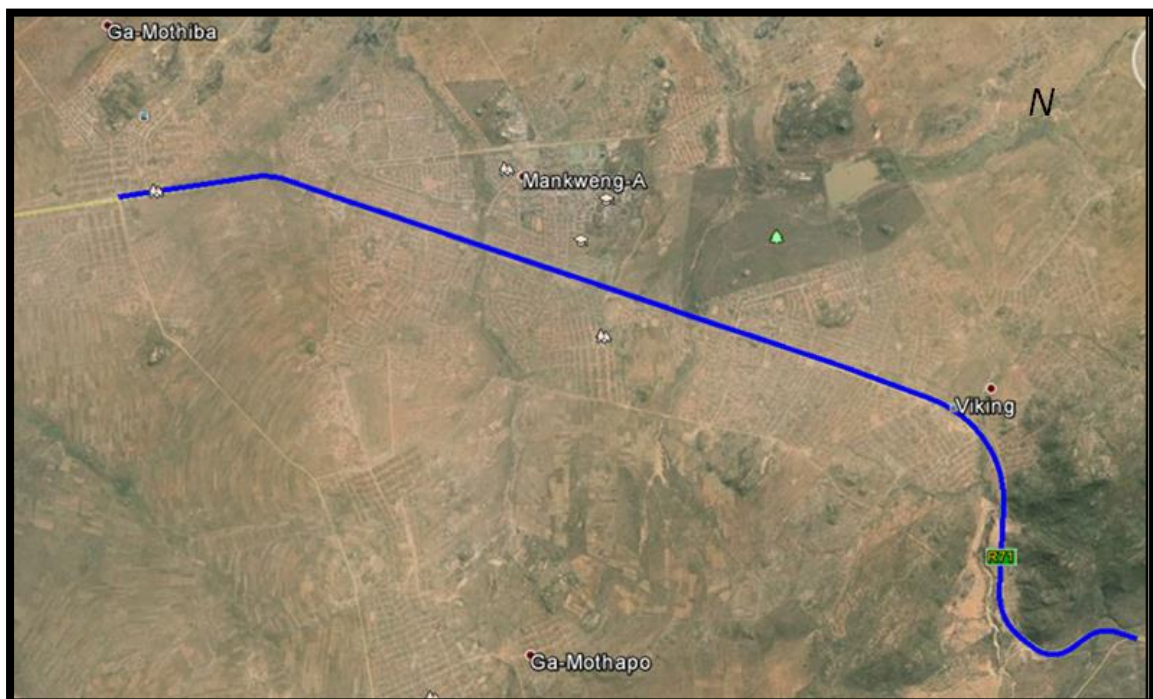


Figure 5: An aerial photograph of Section 2 illustrates that it stretches from Nobody in the west to Moria (Boyne) in the east (Google image).

The communities are highly dependent on public transport modes, most of which are obtained on the R71. The R71 therefore serves the purpose of a high mobility road, a public transport route, it functions as an activity street in higher density areas and it is also a pedestrian corridor. There is currently no boundary to prohibit pedestrian and vehicular access along the road reserve, access for pedestrians and motorists is therefore obtained from any location.

The conflict between pedestrians and vehicles has resulted in fatal accidents over the past couple of years. The South African National Roads Agency (SANRAL) has received a letter from the Members of the Mayoral Committee (MMC) for Community Safety in Polokwane requesting that SANRAL address the safety concerns of the community along the R71 National Road.

The safety concerns that were raised by the community on the route were:

- A number of schools are located within close proximity of the R71 and everyday learners are faced with the daunting task of crossing the road, particularly primary school learners who are more vulnerable.
- A variety of attractions are located in proximity to the road. Of greater concern are the liquor restaurants and bottle store establishments that result in intoxicated patrons with impaired judgement crossing the road.
- Motorists drive in excess of the speed limit due to the wide roadways and right of way.
- The lack of a median barrier enables illegal u-turn movements which create conflict with oncoming motorists.
- Intersection visibility is hampered by mini-bus taxis that pick-up and drop-off passengers at intersections. This also creates conflict on the road.
- The Zion Christian Church (ZCC) has a pilgrimage for religious occasions. During this time, members flock to the church creating serious congestion problems. It is estimated that approximately 7 million people gather at the church during the Easter Holidays.

## **1.8 CONTENT OF THE REPORT**

The report begins with a literature review of pedestrian safety risk factors as well as the methodologies used to assess them in the rural context. The literature is summarised in a risk factor table to guide the R71 case study assessment. The case study status-quo analysis follows in the third chapter; it culminates with the identification of pedestrian safety risks on the R71. Chapter 4 is a review of pedestrian safety countermeasures used worldwide; measures that are functional and effective for the rural South African context are summarised in a cross-table at the end of the Chapter. A framework for selecting engineering countermeasures is derived in Chapter 5 by using pedestrian safety risk factors and matching them with appropriate countermeasures. This framework is applied to the R71 case study to recommend functional and effective solutions on the road. Chapter 6 is a short description of various evaluation tools for engineering countermeasures. Final chapters provide a summary of the thesis, highlight the limits to the research and how these can be improved in future.

## 2. PEDESTRIAN SAFETY RISK FACTORS: LITERATURE REVIEW

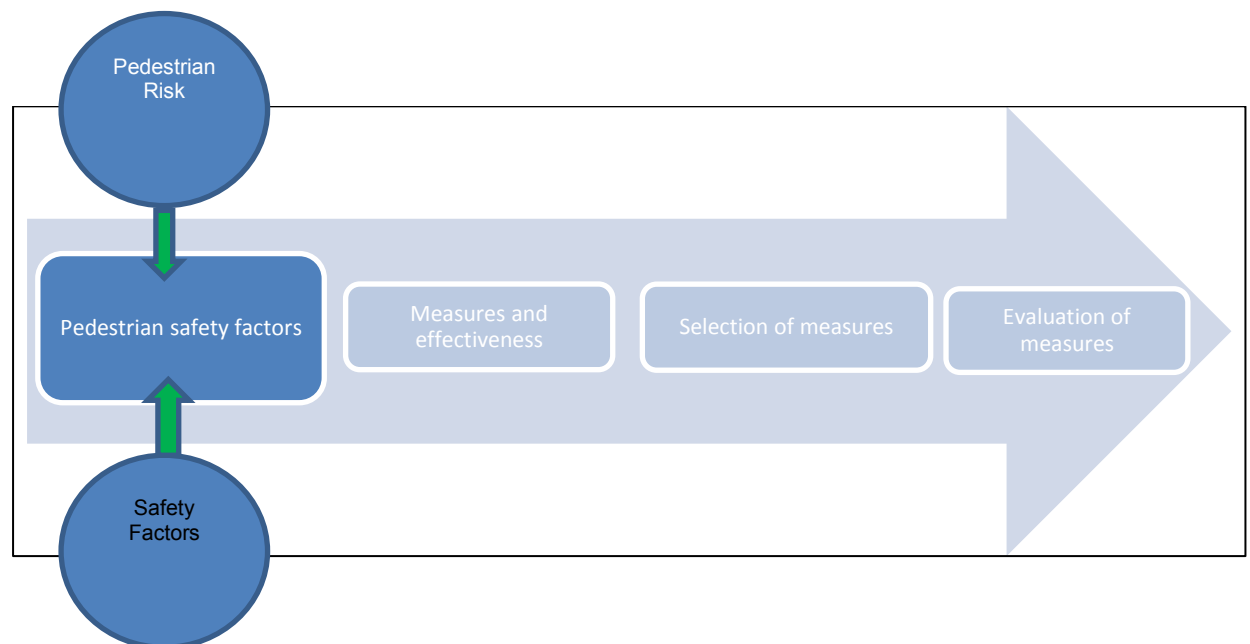
### 2.1 INTRODUCTION

Pedestrian deaths and injuries are often preventable, and proven interventions exist, yet in many locations pedestrian safety does not attract the attention it merits. Successful interventions to protect pedestrians and promote safe walking require an understanding of the nature of risk factors for pedestrian crashes (World Health Organisation, 2013).

Due to the dramatic growth in the number of motor vehicles and the frequency of their use around the world – as well as the general neglect of the pedestrian needs in roadway design and land-use planning – pedestrians are increasingly susceptible to road traffic injury. Pedestrian vulnerability is further heightened in settings where traffic laws are inadequately enforced (World Health Organisation, 2013).

It is essential before proceeding with any project, that the background knowledge and literature is studied. A comprehensive literature review indicates information gaps and surpluses in the research topic. Understanding the research landscape for any topic provides a clear foundation of where to start and which direction to assume. The aim of this literature review is to gather and assess any information that is pertinent to factors affecting pedestrian safety; these include road design elements, adjacent land uses, pedestrian behaviour, etc. factors which can be used to assess pedestrian risk. More importantly this literature review will provide a summary of the state of pedestrian safety in the nation and worldwide and establish the relevance of this research project.

This chapter will therefore elaborate on the first step of the project methodology “Pedestrian safety factors” or understanding the factors that cause pedestrian safety risk.



### 2.1.1 Determining pedestrian risk and exposure

Pedestrian collisions, like other road traffic crashes, should not be accepted as inevitable because they are, in fact, both predictable and preventable. There is a close association between the walking environment and pedestrian safety. Walking in an environment that lacks pedestrian infrastructure and that permits use of high-speed vehicles increases the risk of pedestrian injury. The risk of a motor vehicle colliding with a pedestrian increases in proportion to the number of motor vehicles interacting with pedestrians (World Health Organisation, 2013).

The state of pedestrian safety on the road is measured in terms of exposure and the number of accidents that occur during the exposure period. Exposure is defined as the extent at which people are likely to be involved in an accident. This is influenced by the amount of travel either by vehicle or on foot (km). The amount of travel and the number of accidents associated with an activity or population is used to calculate pedestrian risk (Ribbens, H, Class Notes, 2014).

Risk is used as a way to quantify the level of road safety relative to the amount of exposure; for example, high exposure (km travelled) and few accidents indicates a low risk and vice versa. The literature differentiates between various kinds of such risk such as personal risk, societal risk, individual risk and group risk. The safety level on a road section is determined by the absolute number of accidents or casualties (Ribbens, H, Class Notes, 2014).

Pedestrian safety should be researched from a system point of view to allow for consideration of the many factors that expose pedestrians to risk, such as vehicle speed, poor road design, and inadequate enforcement of traffic laws and regulations. Effective planning for pedestrian safety requires a comprehensive understanding of the risk factors involved. It is difficult to achieve this understanding when research focuses only on one or two risk factors (World Health Organisation, 2013).

## 2.2 SYSTEM PLANNING FOR ROAD SAFETY

“System Planning” is the main emphasis of a new school of thought regarding the road safety problem. The traditional approach to road safety is that the individual road-user is solely responsible for accidents or any other form of conflict on the road. Statements such as, “human error is the cause of approximately 90% of road crashes,” from a WHO 2004 report justify the road user approach (Larsson, 2007). This has resulted in human behaviour, of both drivers and pedestrians, being identified as the sole risk factor for road transport safety. Consequently associated countermeasures have been aimed at altering human behaviour (Turner & Smith, 2013).

“System Planning” evolved from the systems theory approach developed in the 1930’s and 1940’s in response to the limitations of classic analysis techniques and their possibilities to cope with emerging complex socio-technical systems. Socio-technical systems refer to the interaction between society’s complex infrastructure and human behaviour. The road transport system is a complex environment comprising of road-users, vehicles and road components that interact to produce transport of goods and people. The complexity is increased by the open road environment and highly random component interactions. System planning considers the following:

- **Safety as an emergent property:**

Systems theory views safety as an emergent property due to the complex relationships and interactions between the components of the system.

- **System and component performance is variable:**

Performance in any complex system is variable due to the performance variability of the system components and the complexity of their interactions. As a consequence accidents can be seen as a result of the performance variabilities among the components of a system and the complex relationship between them.

- **Systems as hierarchical structures:**

Socio-technical systems can be seen as a hierarchy of levels of organisation with control processes operating at the interface between levels to control processes at the lower processes. To be able to control the system, constraints for these processes must be set, communicated, measured, controlled and enforced at each level (Larsson, 2007).

Vision Zero and Safe System Planning are viewed as adaptations of systems theory. The Vision Zero approach implemented in Sweden is a system approach that is founded on two principles; the system must be adapted to the mental and physical conditions and limitations of humans and the responsibility for road safety must be shared between the road users, road designers and professional operators of the system.

The Safe System Theory approach recognises that humans as road users make mistakes and we are physically vulnerable to certain speeds before serious injury or death occurs. Countermeasures such as infrastructure should take account of human errors and vulnerabilities so that injuries and fatalities can be avoided.

The road transport system in its entirety will be touched on in the literature review for pedestrian safety risk factors in line with the Vision Zero and Safe System Planning.

## **2.3 BACKGROUND TO PEDESTRIAN SAFETY**

### **2.3.1 Why the pedestrian safety issue?**

Information on pedestrian road accidents is typically inadequately captured and under-reported therefore data on pedestrian safety risk on the road network is limited in South Africa (Van Niekerk, 2007). Available sources, despite their limitations, do however paint a picture of the current state of pedestrian safety. Pedestrian exposure was presented in the 2003 and 2013 National Household Travel Survey as the following: approximately 2.3 million or 23% of the workforce indicated that they walk to their working place and 7.5 million or 90.6 % learners and students in rural areas walked to schools and education centres. The large proportion of student pedestrians in rural areas is indicative of the probable risk that this segment is exposed to. This is supported by a CSIR study that concluded that 1 out of 10 pedestrians in crashes are killed on urban roads and 1 out of 3 on rural roads (CSIR, 2009). More people

walk in rural areas than in urban areas thus increasing their exposure to road accidents (CSIR, 2009). In a study of university students in Cairo, Egypt, participants who lived in rural areas were significantly more likely to suffer pedestrian injuries than those who live in urban areas (World Health Organisation, 2013, p. 14).

The number of crashes and fatalities is lower in rural areas compared to urban areas, however, a higher fraction of rural crashes result in death. One reason for such higher rates is that vehicular speeds tend to be higher in rural areas than in urban areas because of the low population density, pedestrian crashes in rural areas are rare events, but remain a concern (Zajac & Ivan, 2002, p. 1).

The RTMC Annual Report 2011/2012 reported that 4 614 pedestrians were killed on the roads, this means that pedestrians accounted for 38% of all road fatalities in 2011/2012 (RTMC, 2011). The fatalities per mode per 100 million veh.km in 2007 for drivers, passengers and pedestrians are provided in **Table 1**. The averages show that pedestrian fatalities accounted for the highest number of fatalities amongst all road users and these are mostly as a result of collisions with buses and taxis. The graph of global road traffic deaths by road users indicates that the fatalities of car occupants are higher than pedestrian deaths (**Figure 6**); this illustrates the South African pedestrian safety problem.

An illustrative comparison in **Figure 7** of annual pedestrian fatalities with other countries illustrates that the South African road safety problem is similar to the developing countries on the list. Developed countries such Japan and the Netherlands have far lower pedestrian fatalities. The number of pedestrian fatalities is affected by traffic mix, for example, Asian developing countries have high motorized two-wheeler fatalities due to their high use of motorcycles and tuk-tuks whereas most African countries cannot afford or are not accustomed to such modes therefore the pedestrian mode will have a greater exposure.

**Table 1: The fatalities per mode per 100 million veh.km:2007 in South Africa (RTMC, 2011).**

<b>Veh type</b>	<b>Drivers</b>	<b>Passengers</b>	<b>Pedestrians</b>
<b>Motorcar</b>	3.15	3.04	3.26
<b>Minibus</b>	3.13	11.34	<b>7.78</b>
<b>Bus</b>	0.94	12.11	<b>8.74</b>
<b>MCycle</b>	14.06	1.40	1.39
<b>LDV's</b>	2.39	3.06	2.76
<b>Trucks</b>	1.95	2.38	3.03
<b>Average</b>	3.06	3.67	<b>4.16</b>

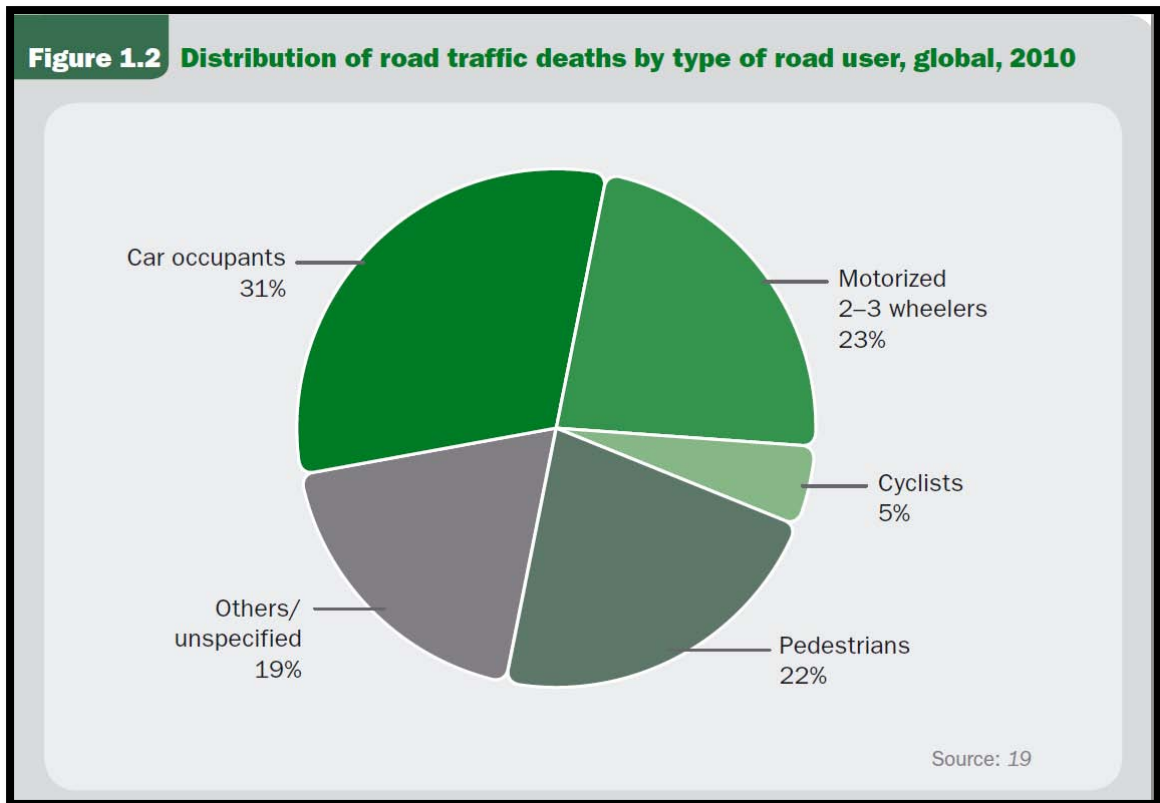


Figure 6: Global road traffic deaths by road users, 2010 (World Health Organisation, 2013, p. 9).

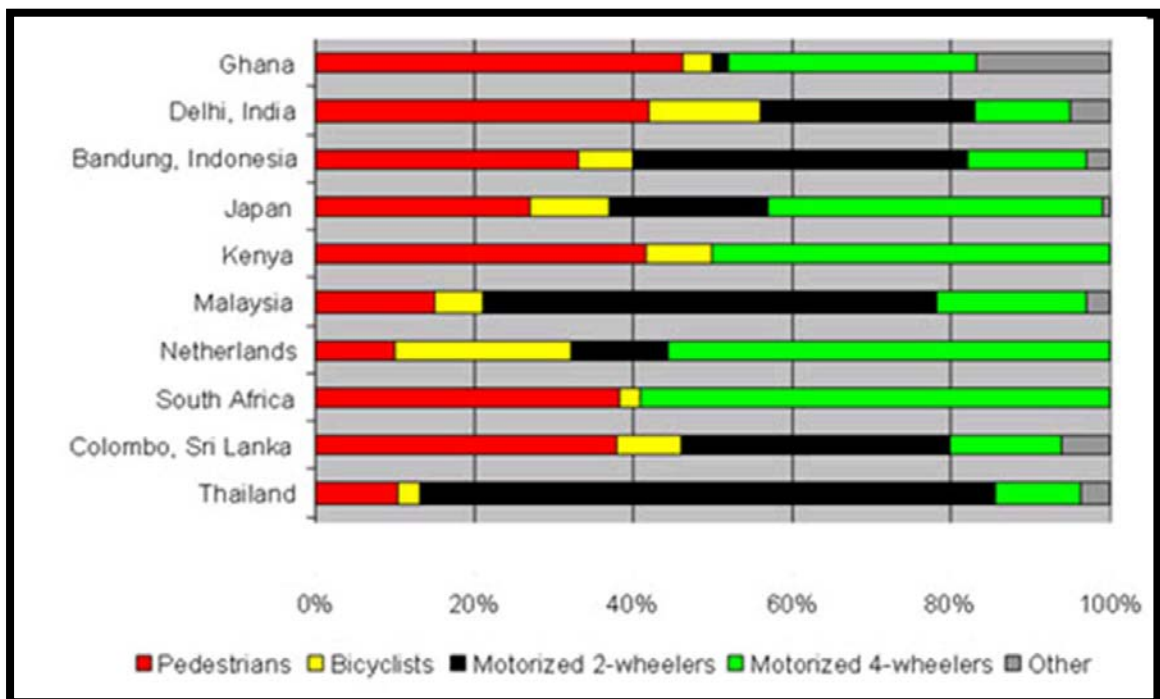


Figure 7: A country comparison of pedestrian fatalities (Ribbens, H, Class notes, 2014).

Pedestrian safety is a problem in South Africa and other developing countries. In South Africa the risk is more acute in rural areas where pedestrian exposure, particularly of minors is very high. **Figures 8** and **9** illustrate the typical daily occurrence of pedestrians making use of higher order roads for access. Based on estimated global road traffic fatalities, about 273 000 pedestrians were killed in road traffic crashes in 2010. This represents around 22% of all road traffic deaths. WHO reports that there is a clear geographic distribution of mortality, with Africa having the highest proportion of pedestrian fatalities than any other region (38%) and South-East Asia being the lowest(12%) (World Health Organisation, 2013, p. 9).



**Figure 8: Rural pedestrian movements in South Africa (Ribbens, H, Class notes, 2014).**

#### What happens in a pedestrian collision?

The usual cause of the most serious pedestrian injuries is a direct impact with the striking car rather than the pedestrian being thrown to the road (World Health Organisation, 2013, p. 16). Pedestrian injuries are illustrated in **Figure 10**. The severity of injuries occurring to the head, brain, thorax, pelvis and extremities is influenced by:

- Car impact speed;
- Type of vehicle;
- Stiffness and shape of the vehicle;
- Nature of the front;
- Age and height of the pedestrians; and
- Standing position of the pedestrian relative to the vehicle front (World Health Organisation, 2013, p. 16).



Figure 9: Rural scholar pedestrian movements in South Africa (Ribbens, H, Class Notes, 2014).

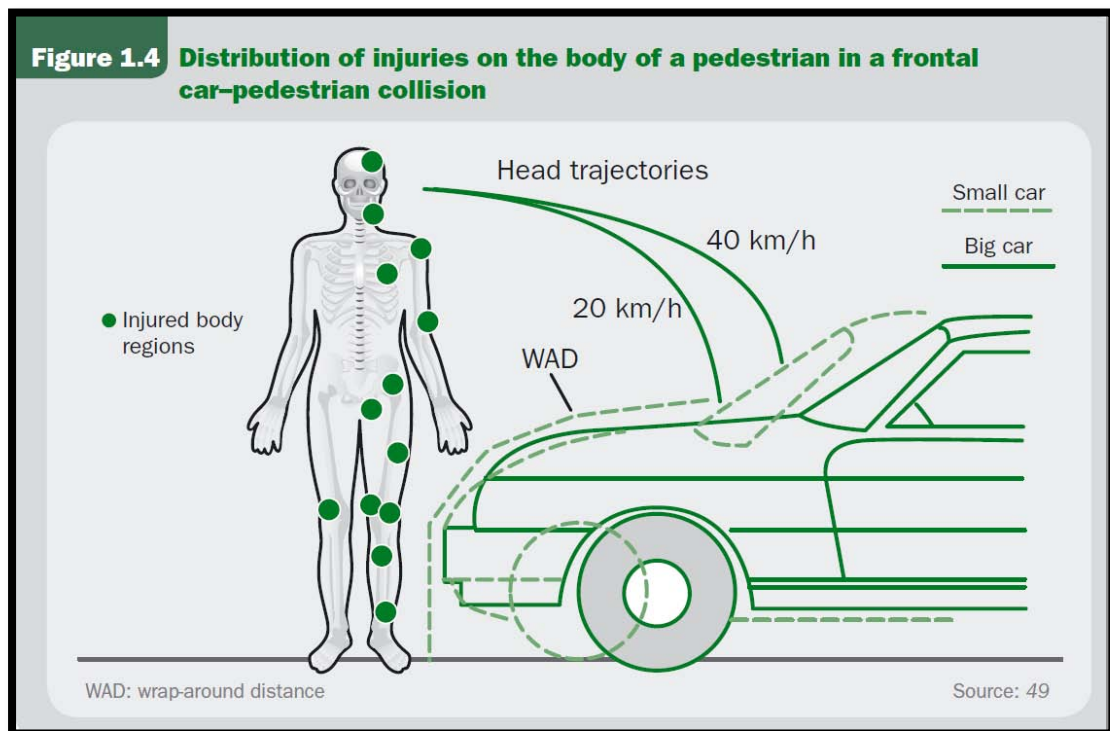


Figure 10: Body injuries that can occur in a frontal car-pedestrian collision (World Health Organisation, 2013, p. 16).

## 2.4 PEDESTRIAN SAFETY RISK FACTORS

The pedestrian safety risk factors discussed in this section influence the type of engineering countermeasures that should be applied in a given context. Detailed information about these factors and their causes provides the necessary guidance to formulate new measures or improve existing pedestrian safety measures so that they can be applied effectively. Knowledge of various pedestrian safety measures also assists in drawing up an assessment methodology that can be implemented when risky locations are identified.

### 2.4.1 Pedestrian behaviour by demographics

The built environment is a composite of the natural environment, infrastructure and people. Therefore engineering measures cannot be effective if the behaviour of the pedestrians and drivers who make use of them is not understood. Transport planners and engineers plan and provide pedestrian facilities according to set guidelines and standards, however, road users often respond quite differently, opposite to what is considered as a safe road environment. Pedestrian behaviour can therefore increase the risk of road collision. The rationale behind pedestrian behavioural patterns will be investigated in this section. There are various human factors that impact on road user behaviour, these are:

- Perception of safety
- Risk taking
- Response times
- Time prepared to wait or be delayed (Ribbens, H, Class Notes, 2014).

Research based on video observations, self-report data obtained from surveys and qualitative interviews or focus groups indicate that road user behaviour imparted by the aforementioned factors can be classified as follows:

- The choice of crossing place
- Non-compliance at designated places
- Crossing speed
- Failure to attend to traffic
- Pedestrian alcohol consumption (Martin, 2006)

The type of behaviour conveyed due to these factors has been observed in certain groups of the population. The groups that tend to stand out; or in other words those people who are more exposed to risk in the road environment, e.g. children, elderly and the disabled will be discussed. Understanding the physical constraints of the different vulnerable road users is vital. The following deductions have been made about their behaviour in the road environment.

#### 2.4.1.1 General population

Research findings show that the general population tends to behave as follows:

- “Pedestrians are more likely to cross anywhere when traffic volumes are light and when they are familiar with the route.

- Many people tend to cross at the provided crossing locations and wait for the Green Man at a traffic signal when traffic volumes are high.
- Research shows that both adults and children become impatient after 30 seconds where after they will try to cross. The probability for a pedestrian to cross the road, when it is unsafe, i.e. motor vehicles still have green or yellow, varies with waiting time. People do not want to wait too long to cross streets. As signal waiting time increases, pedestrians get impatient and violate the traffic signal. This violation places them at increased risk of being struck by a motor vehicle. Thus, reducing the waiting time for pedestrians are likely to decrease the probability of pedestrian crossers being hit by a motor vehicle.
- Researchers evaluated gap-acceptance behaviour of crossing pedestrians at 42 study sites in 7 USA states. Behavioural analysis revealed that pedestrians did not always wait to cross the street when all lanes were completely clear; instead, they anticipated that the lanes would clear as they crossed and used a “rolling gap” to cross the street. Statistical analysis revealed that most approaches had 85th percentile accepted gaps between 5.3 and 9.4 s, with a trend of increasing gap length as crossing distance increased. All 85th percentile accepted gaps were less than the critical gap defined in the "Manual on Uniform Traffic Control Devices" for a walking speed of 1.1 m/s; this indicates that if 1.1 m/s were used as the design criterion, it would be sufficient to serve at least 85% of the observed pedestrians at the study sites.
- Socio-psychological variables induce behaviours such as peer pressure and the probability of compliance. The presence of other people at crossing locations can represent a form of social pressure that can influence behaviour. Adults for example are less likely to cross if others were waiting and vice versa.
- There is less compliance with the law when there is no perceived danger/risk of a collision.
- Time to cross the road depends on road width, walking speed and traffic volumes.
- Lack of observation is the main cause for both adult and child pedestrian accidents.
- The complexity or uncertainty of the crossing situation, competing with turning traffic to cross the road, speeding, etc. makes it challenging and therefore risky for pedestrians to cross.
- Pedestrian alcohol use decreases cognitive awareness” (Ribbens, H, Class notes, 2014).

#### **2.4.1.2 Children in traffic**

Children have limitations that increase their vulnerability to accidents in the road environment. Some of the important differences between children and adult pedestrians are:

- “Children have less experience as pedestrians therefore some may not comprehend or are not fully aware of dangerous conditions on the road.
- They do not drive, and therefore lack the understanding of what a driver’s intentions might be at a junction or crossing point.

- They have shorter attention spans and may grow impatient at crossings causing them to cross under risky conditions. This is typically the reason why they tend to dart into traffic and to dash across streets causing their movements to be less predictable than those of adults.
- Young children still lack visual acuity and peripheral vision to judge speeds of oncoming traffic and adequacy of gaps in the flow of traffic.
- Children are less able to determine the direction of sounds.
- School children are influenced by peer group pressure which encourages them to disobey pedestrian signals.
- Research showed that attention absorbing activities not related to the task of road crossing featured strongly among the under 11's."

Children are short, with a typical eye height of about 1 meter above the ground, their field of vision is different from those of adults and they are difficult to see when reversing as well as if they enter the road during short gaps. The discussed behaviour and physical attributes of children are a challenge for drivers (Ribbens, H, Class notes, 2014). The pedestrian fatalities by age group in **Figure 11** illustrates that the largest affected age groups are young adults (20-45 years) (RTMC, 2011).

#### 2.4.1.3 Elderly persons

Older road users are generally considered to be safe and more cautious however age limitations are pronounced where demands are significant or complex in the road environment. The vulnerability of elderly pedestrians is usually caused by:

- Deteriorating senses resulting in reduced seeing and hearing, impacting on their awareness of risk and the ability to respond appropriately.
- A generally slower reaction time compared to other pedestrians due to impairment associated with medical conditions (cardiovascular, multiple sclerosis, deterioration of motor functioning).
- The pace of walking is slower than the general public, typically less than 1m per second (Ribbens, H, Class notes, 2014).
- Impacts of cognitive impairment (caused by dementia, Parkinson's, Alzheimer's etc.) on behaviour and crash risk. "Crashes involving older pedestrians are more prevalent in complex road crossing scenarios where there is a risk of cognitive and executive function overload. These limitations would affect performance and playing a part in crash causation" (Oxley, Charlton, & Flides, 2005).
- "The elderly feel more vulnerable thus they are more likely to cross at crossing locations and take longer to cross.
- Older people typically require additional green time to cross as compared to the provided time" (Ribbens, H, Class notes, 2014).
- Pedestrians age 65 years or older, increases severity (Zeeger, Stutts, Huang, Zhou, & Rodgman, 1993).

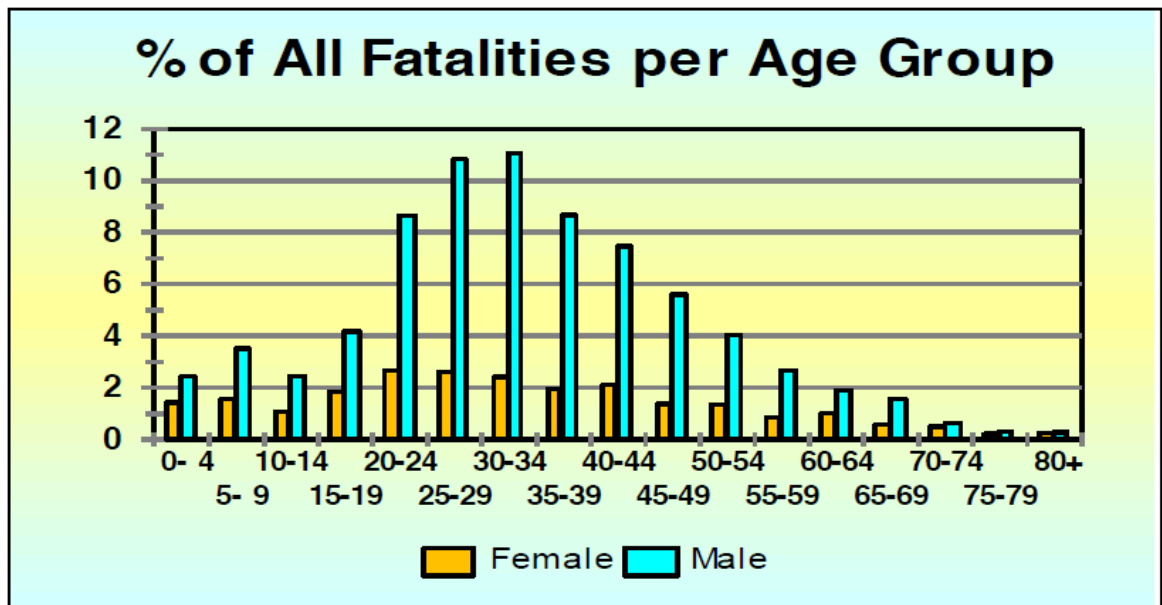


Figure 11: Road victims by age group (RTMC, 2009).

#### 2.4.1.4 Disabled road users

Physical impairment reduces the capabilities of pedestrians in the road environment. Physical or visual constraints increase crossing time and auditory constraints inhibit the awareness of danger (Ribbens, H, Class notes, 2016).

#### 2.4.1.5 Men

Research indicates that men are more involved in accidents than women in all age groups. This is probably due to men's inclination towards risky behaviour. The RTMC 2010/2011 report stated that an overwhelming 75% of the pedestrian fatalities were males while only 25% were females.

- Men take the quickest route to destination - delay is linked closely with pedestrian's propensity to take risks.
- Male children are more likely to cross without waiting for the green signal.
- Limited research findings available in terms of pedestrian alcohol use. A higher proportion of males (40%) were found to be drinking and walking than females (12%). The highest incidence occurs among the 30 – 54 year age group (Ribbens, H, Class notes, 2014).
- Research on the Pedestrian risk exposure at signalised intersections was conducted by Tiwari, Bangdiwala, et al - 2006. Data on pedestrian behaviour at seven selected intersections in Delhi, India involved data collection by placing a video camera at each zebra crossing. It was observed that "the mean waiting time of females is 27% more than for males, while the waiting time of 90% of female pedestrians are 44% more than the corresponding number for males" (Tiwari, Bangdiwala, Saraswat, & Gaurav, 2007, p. 1).

### 2.4.1.6 Collective behaviour of crossing pedestrians

Pedestrians have empirically demonstrated to respond to a wide range of information when crossing the road. Research states that people respond to: social and non-social information. Social information is adopted from the behaviour of other pedestrians crossing the road while non-social information is derived from non-human road elements i.e. traffic speeds, volumes, traffic signals etc. The study conducted by Jolyon J, Faria, Stefan Krause, and Jens Krause, (2010) indicated the following:

- Male pedestrians are more likely to respond to the behaviour of others than females.
- Pedestrians in groups (that started relatively late) were more likely to abort their crossing than pedestrians who were waiting at the crossing alone.
- Pedestrians who followed others across the road are at a relatively higher risk than those who did not for 2 reasons: Following individuals may experience conflicting social and non-social information which may cause uncertainty about when to cross. This confusion may be transmitted to the vehicle driver and both individuals may be more likely to panic and thus cause an accident. Individuals that follow others may be more likely to have made incorrect decisions about the timing of the crossing.
- Pedestrians in groups tended to make a single, or multiple steps, before crossing the road, but then aborted the crossing while some pedestrians walked almost half way across the road and then backtracked to the safety of the roadside from where they had departed. Three possible explanations for this behaviour are provided:
  - Individuals who waited in positions further from the oncoming traffic were no more likely to abort their crossing than individuals closer to the traffic.
  - Individuals who aborted their crossing were late to cross relative to those who did not abort their crossing.
  - Individuals who started to cross relatively later than others would have had a smaller gap in traffic in which to cross than those who crossed earlier.
  - Therefore, from these results, the most likely explanation is that individuals tended to abort their crossing because they changed their decision about when to cross (Faria, Krause, & Krause, 2010).

Pedestrians have to make a trade-off between saving time and avoiding any risk of injuries when crossing the road (Sueur, Class, Hamm, Meyer, & Pele, 2013, p. 1). A study of how culture influences an individual's perception of risks when crossing a street, using survival analysis was undertaken by Sueur, Class, Hamm, Meyer and Pele in 2013. Pedestrian behaviour was observed in two city centres: Inuyama (Japan) and Strasbourg (France). In each city, observations were made at a safe site consisting of a crosswalk and a street light and at an unsafe site (i.e. no crosswalk or street light). At unsafe sites, the time needed by a pedestrian to take a decision ( $T_{dec}$ ) was measured. During  $T_{dec}$ , a pedestrian estimates whether he can ( $T_{safe}$ ) or cannot ( $T_{risk}$ ) cross the road. Using survival analysis, the distributions of these three time variables showed that French pedestrians took more risks than Japanese pedestrians, and that males took more risks

than females. More studies would considerably broaden the understanding on how culture may affect decision-making processes under risky circumstances” (Sueur et al, 2013).

The research provides a summary of the behaviour of different segments of the population as well as their collective behaviour. This must be considered when measures are designed and implemented. Certain crossings are frequented by specific segments of the population i.e. crossings at schools, old age homes, communal soccer fields therefore behavioural considerations are critical.

## **2.4.2 Pedestrian/driver interactions**

Accidents at road crossings often result from a lack of understanding of the relationship between pedestrians and drivers. This is supported by a study by Hine and Russell (1993) that concluded that the lack of knowledge of the relationship between traffic conditions and pedestrians’ behaviour at crossings without signals is a contributing factor to pedestrian risk. The relationship between the pedestrian and the driver depends on many factors, such as the driver’s behaviour, the pedestrian’s behaviour, the pedestrian’s distance from the kerb, the size of the city, the vehicle speed, etc (Himanen & Kulmala, 1998). Research on pedestrian and driver interactions at different locations will be summarised in this section.

### **2.4.2.1 Junctions**

Pedestrians are very vulnerable at road junctions specifically at turning lanes where drivers are often reluctant to allow pedestrians to cross the road first. Pedestrians therefore have to wait and start crossing after the green man phase has expired or look for a gap in the traffic stream or cross away from the junction. Junctions therefore present increased pedestrian risk of being involved in an accident, especially at high traffic volumes and complicated sections where people are prone to cognitive overload (Ribbens, H, Class Notes, 2014).

### **2.4.2.2 Mid-block crossings**

At un-signalised midblock crossings drivers legally have to give way to pedestrians, however the compliance rate is very low. Pedestrians rather cross elsewhere because of this non-compliance of drivers and out of ignorance. The main findings of an observational study of pedestrian behaviour at various types of crosswalks and a user survey to seek perceptions towards crossing types on a divided urban arterials outside Michigan State University - Pedestrian behaviour and perception towards various crossing facilities indicated:

- Pedestrians preferred un-signalised midblock crosswalk treatments (83% reported a preference to cross) and also showed high crossing compliance rates (71.2%).
- The crosswalk location, relative to the origin and destination of the pedestrian, was the most influential decision factor for pedestrians deciding to cross at a designated location (90%) (Sisiopiku & Akin, 2003).

At signalised midblock crossings pedestrians’ push buttons but do not wait for the green man signal, eventually crossing in a traffic gap. Drivers then have to wait at a red signal with no pedestrians crossing resulting in skipping of red lights in the future (Ribbens, H, Class Notes, 2014). A study by Ibrahim et al (2005) shows that, the interaction between pedestrians and

drivers at crossings without signals are very different in developing countries than the interaction in developed countries. Sisiopiku and Akin (2003) study indicated that:

- The availability of pedestrian signals influenced the pedestrians' decisions to cross at a specific location (74% said so). This shows that proper traffic control can further encourage pedestrian crossings at designated locations.
- Moreover, vegetation and concrete barriers influenced the decision to cross of a significant number of pedestrians surveyed (65%) (Sisiopiku & Akin, 2003, p. 1).

A growing body of research shows that community behavioural interventions shape the behaviours of large numbers of persons in health, welfare and safety. Nasar (2003) tested the impact of prompts on drivers. The study hypothesis was that (1) a higher proportion of drivers would stop as a result of hand-held signs and (2) that the effect would generalize downstream to other pedestrians not using the signs. Results showed significant improvements in both cases. Stellenbosch University Class notes refer to a study by Persson, (1988) that also concludes that accidents are reduced by increases in communication between the pedestrian and the driver using various forms of signs. For example, hand gestures by drivers and pedestrians such as: Driver:

- "A flick of the index finger by the motorist to convey that he has seen the pedestrian and the latter must move first" (Ribbens, H, Class notes, 2014).
- A pedestrian raising their arm horizontally to indicate crossing intention can improve communication and as a result safety.

In light of this research a new pedestrian priority rule was implemented in France from 1 January 2011 that states that if a pedestrian or cyclist shows a clear intention to cross the road anywhere (described as "an ostensible step forward or a hand gesture") drivers will be required to stop for them. The only exception is where there is a designated pedestrian crossing less than 50m away" (Ribbens, Class notes, 2014).

### **2.4.3 The road/built environment**

The design of the built environment which comprises transport infrastructure and land use has implications on the safety of pedestrians. These implications will be discussed subsequently.

#### **2.4.3.1 Time of day**

Pedestrian accidents predominantly occur during the morning peak (7:00-9:00) and late afternoon/early evening (17:00-22:00). There are higher incidents on Friday, Saturdays and Sundays (RTMC, 2011). This is illustrated in **Figure 12**. Darkness increases severity and illumination decreases injury severity (Klop & Khattak, 1999).

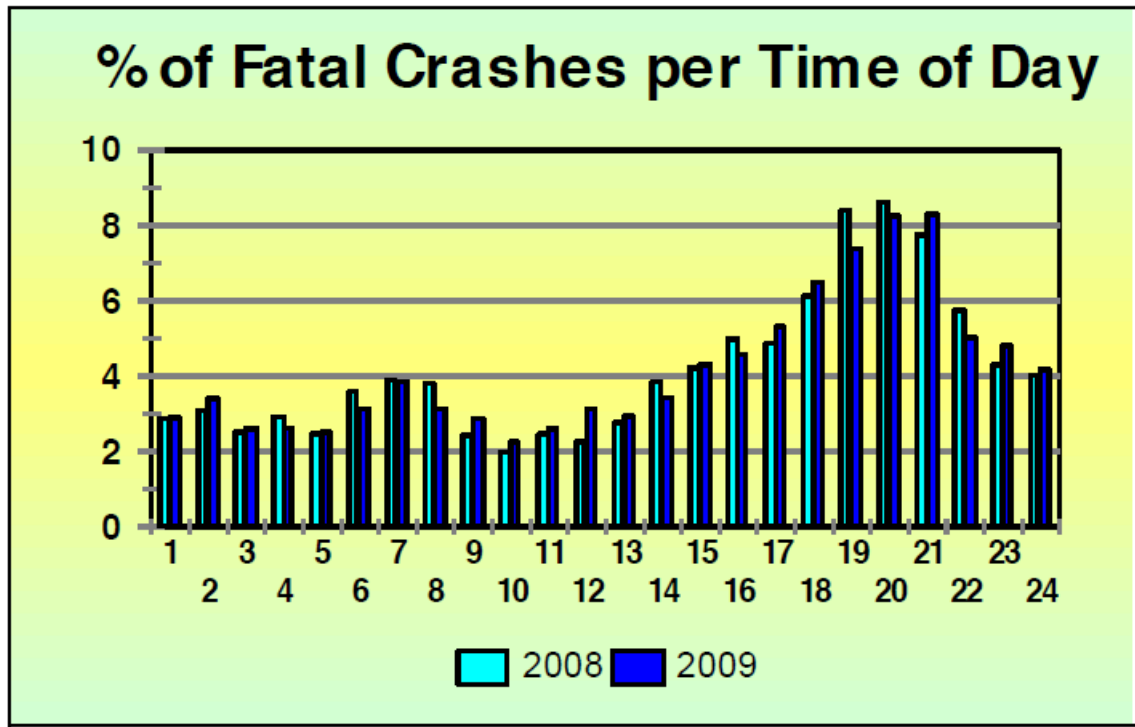


Figure 12: Fatalities at night (RTMC, 2009).

#### 2.4.3.2 Land use planning

Rural higher order roads inevitably extend through villages, where it can be expected that high pedestrian volumes will occur. However, at any given location at or near a village, it is possible that at most one crash may occur in a 10 year period. This low frequency of pedestrian crashes does not necessarily mean that a particular location is safe for pedestrians; it means the factors that influence pedestrian safety need to be studied (Zajac & Ivan, 2002).

The design and use of the broader land can contribute to the occurrence of pedestrian injuries and fatalities; this means that there are specific places at villages where accidents can be predicted. Pedestrian risk increases in the vicinity of high trip generating land use where inadequate pedestrian infrastructure has been provided i.e.:

- Public transport stops and routes
- In close proximity of towns (first 5 km)
- Rural hospitals and clinics
- Schools and educational centres
- Rural commercial and industrial centres
- Intensive agricultural areas (Ribbens, H, Class notes, 2014).

These facilities may be located directly adjacent to the road or further away, but all of them can result in high pedestrian volumes crossing the road or walking parallel to the road. Schools are sensitive facilities especially primary schools. As discussed in section 2.4.1.2, children in that age group have unpredictable behaviour and exceptional care has to be taken when designing crossing facilities for scholars. The location of these facilities needs to be determined in relation to the road as well as where the related crossing points are. The

treatment of pedestrians and the speed limit through these villages has to be different from the rural sections (ITS Engineers, 2009).

Other land use factors that affect pedestrian traffic risk include: population density; land use mix and city structure. The frequency of pedestrian crashes in a given area is influenced by the density of the resident population and the total population exposed to risk. Land-use planning policies and strategies that encourage a greater mix of land-uses and shorter trip distances make walking more feasible, and safer, if measures for safe walking have been considered. There are wide variations in road traffic fatality rates, including pedestrian rates, across cities with different income levels and even within cities with similar income levels, implying that city structure, modal share and exposure of motorists to pedestrians may have a significant role in determining fatality rates, along with road design, vehicle design and income (World Health Organisation, 2013)

Rural areas are plagued by insufficient land use planning that leads to:

- Hawkers encroaching on the road reserve
- No pedestrian linkage to the road network
- Poorly planned public transport operations
- Lack of lay-bys
- Not linked to local street networks
- Inappropriate positioning of public transport stops

Zajac in 2002 stated that area type influences the speeds at which drivers feel comfortable to travelling and therefore the risk of pedestrian accidents. Building height, spacing and distance from the road may influence driver behaviour in the sense that taller buildings close together and close to the road create a narrowing feeling and promote an awareness of possible pedestrian activity as well visual distractions this typically occurs in cities. Whereas open spaces such as villages create a feeling of reduced risk for motorists. The research defined areas as follows:

- Village areas consist of smaller buildings and residences set back from the road. Sidewalks may or may not be present.
- Lower density commercial areas have lower density commercial development than that of medium density commercial areas, and residences are more common. These areas are not likely to have sidewalks or on-street parking.
- Low density residential areas have houses that are spaced far apart and are often not visible from the road. Sidewalks are rare in these areas. Locations with little to development are included in this category. (Zajac & Ivan, 2002).

#### **2.4.3.3 How road design contributes to pedestrian injury**

Roadway design generally caters for the needs of motorized traffic, neglecting the needs of pedestrians. WHO reports that the provision of road elements such as, high-speed roadways, intersections and fast-speed lanes without clear consideration for pedestrian facilities can result in an increased likelihood of injuries and fatalities. Vehicle-pedestrian collisions are 1.5 to 2 times more likely to occur on roadways without sidewalks. (World Health Organisation, 2013, p. 27).

The following are hurdles for pedestrian movements identified on the road network:

- Inadequate or no road crossings
- Lack of sidewalks
- Obstructions on sidewalks-signs, lighting poles, boulders etc.
- Lack of damaged/vandalised road signage and markings
- No barriers (vehicle and pedestrian)
- Poor maintenance of NMT infrastructure
- Poor road and sidewalk drainage systems
- Inadequate street lighting (World Health Organisation, 2013).

An assessment of roads in low-middle income countries in Asia, eastern Europe and Latin America revealed that 84% of the roads surveyed had no pedestrian footpaths though they carried motor vehicle traffic moving at 40km/h or more. The WHO report states that there has been a recent effort to improve roadway design to cater for the safety needs of pedestrians in some countries (World Health Organisation, 2013) however more still needs to be done.

The surrounding road network should therefore be studied and a high level road hierarchy should be determined. This will be necessary in order to decide which roads are important routes that need to have access points to the major route. It will also make it possible to decide which accesses or intersections can be closed to improve the spacing between intersections and to reduce the conflict points along the route (ITS Engineers, 2009). Specific aspects of roadway design that are likely to influence pedestrian safety are discussed below.

#### **2.4.3.4 Traffic mix**

The risk of pedestrian injury is high when pedestrians share the road with vehicles travelling at high speeds. WHO reports that such cases are associated with increased injury severity and death for pedestrians and cyclists. Mixed use of the road space is common in both urban and rural areas in low-medium income countries. Improving pedestrian safety in such environments may require the use of several measures such as sidewalks, raised crossings, reduced posted speed limits and road narrowing (World Health Organisation, 2013, pp. 29-30). Pedestrian sidewalks parallel to the roadway can be separated from vehicles, depending on the available cross section. If adequate space is available, the walkway should be located far from the road with a recovery area for vehicles in between. The distance between the edge of the road and the sidewalk should increase if the design speed is higher (ITS Engineers, 2009).

#### **2.4.3.5 Traffic volumes**

Studies have found that road environments with high traffic volumes and inadequate attention to pedestrian safety may exacerbate pedestrian collisions. For example, traffic volume influenced the probability of a pedestrian collision with a left-turning vehicle, while another study showed that high volumes of traffic, the presence of bus stops and high volumes of pedestrians crossing all led to increased collision risk for pedestrians. This relationship is not always linear, crash rates relative to exposure may actually decline with higher traffic volumes, and the severity of injury may also decline (World Health Organisation, 2013, pp. 33-34). This

is supported by Klop and Khattak, 1999 who found that increases in AADT decrease severity of pedestrian accidents.

#### **2.4.3.6 Sight distance**

Sight distance is dependent on the design speed of the road. Stopping sight distance is based on the driver reaction time and the time required for braking safely in front of a stationary object. When high pedestrian volumes are present, the aim should not be to provide the minimum required stopping sight distance, but as much as possible (ITS Engineers, 2009).

#### **2.4.3.7 Horizontal and vertical curves**

Curves increase the driver work load in steering the vehicle, and the driver should therefore not be confronted, in the ideal situation, with additional conflict from pedestrians. Curves generally result in shorter sight distances and hence reduced driver reaction time. Pedestrian facilities and especially crossings should therefore be avoided at small horizontal and vertical curves as far as possible (ITS Engineers, 2009).

#### **2.4.3.8 Cross section: number of lanes per direction, width**

Road widening increases pedestrian injury risk. A wider road requires longer crossing time for the pedestrian and increases the duration of the conflict period within the road. A walking speed of 1.2 m/s is typically used to design for pedestrians crossing a road. Road widths of 4 lanes (2 per direction) or more should be provided with a median to provide the pedestrian with a refuge island midway as walking times become too long. This is especially applicable in village areas where there are high volumes of pedestrians (ITS Engineers, 2009). Reducing the number of lanes also appears to improve traffic safety, particularly for pedestrians and cyclists. Vehicles travel more slowly on single lane roads or when streets are narrow. "Drivers may drive less aggressively and generally feel less safe and thus drive more cautiously on narrow streets" (World Health Organisation, 2013, p. 31).

#### **2.4.3.9 Speed: design speed, posted speed limit, operating speed**

There is a well-documented relationship between the risks of crashes and the speed on the road. Higher speeds change the survival rate of pedestrians; this is shown in **Figure 13** which illustrates that the probability of death increases as speed increases. Pasanen (1992) states that the risk of fatal injury at a collision speed of 50 km/h is almost eight times than that of 30 km/h. "Road design speed is the initial speed limit for a section of road at the planning stage. Factors considered when determining design speed are sight distance, radius, elevation and friction of the road. The design speed is determined before the road is built, implying that it may have to be adjusted to take into account the actual conditions when the road becomes operational, for example, adjacent land-uses and traffic mix" (World Health Organisation, 2013, p. 31). This is done on many higher-order rural roads in South Africa, in rural sections the posted speed limit can be 100 to 120km/h and then through villages can be reduced to 60 or even 50 km/h. The challenge with this measure is that many drivers do not adhere to this change in speed limit through villages, with the resultant reduction in safety for pedestrians (ITS Engineers, 2009).

Wider lanes tend to encourage the increase of motor vehicle traffic speed, which increases pedestrian risk. "Wider roads with more traffic lanes and higher traffic speeds are also more dangerous for pedestrians to cross" (World Health Organisation, 2013, p. 31). Increases in speed limit increase accident severity.

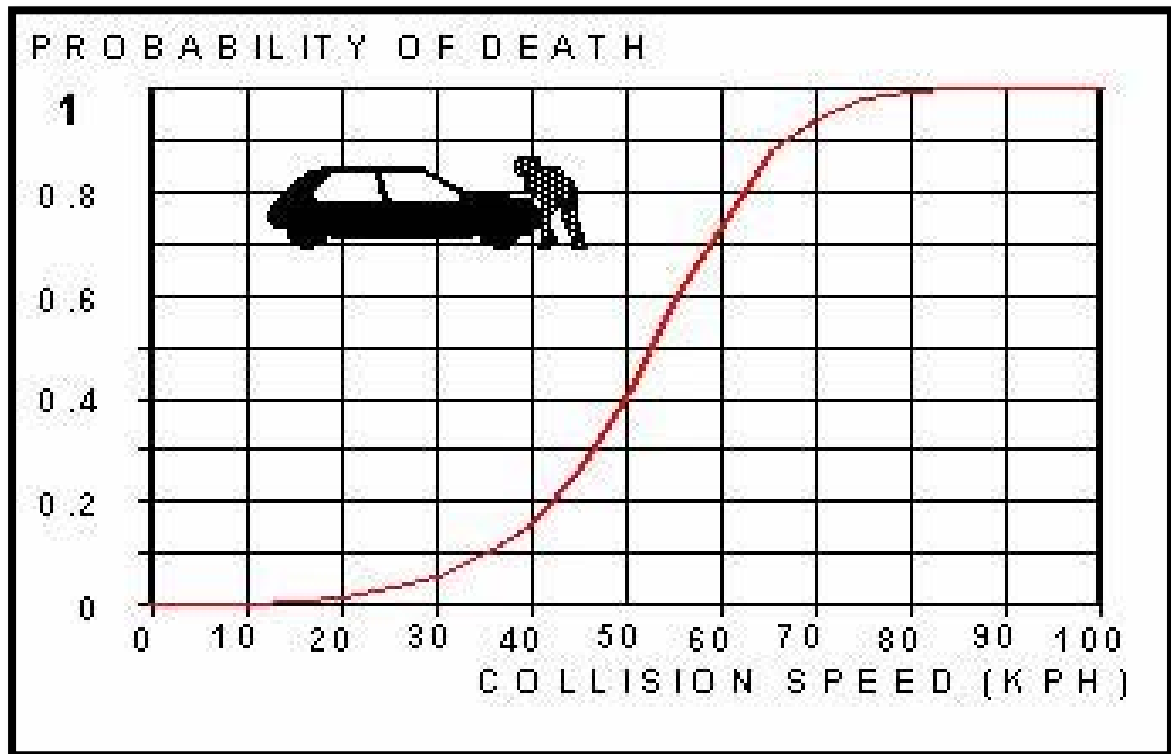


Figure 13: The impact of vehicle speed on pedestrian casualties (City of Helsinki, Finland-Traffic/Pedestrian Death Study).

#### Stopping distance for emergency braking

The effect on crash risk comes mainly via the relationship between speed and stopping distance. The higher the speed of a vehicle, the shorter the time a driver has to stop and avoid a crash, including hitting a pedestrian. Taking into account the time needed for the driver to react to an emergency and apply the brakes, a car travelling at 40 km/h will stop in 27 metres (World Health Organisation, 2013, p. 17). Pedestrians typically misjudge high speed vehicles, causing a false sense of safety which results in the pedestrian being struck (World Health Organisation, 2013, p. 18).

#### Junctions

The negative behaviour of pedestrians and drivers at different types of junctions was discussed in the prior sections. Certain design factors may be the cause of this behaviour.

- Intersection timings and phase sequencing
- Signage and traffic calming location
- Stop signs and other intersection controls
- Accommodation of pedestrians (walking and crossing) at intersections
- Complex intersections

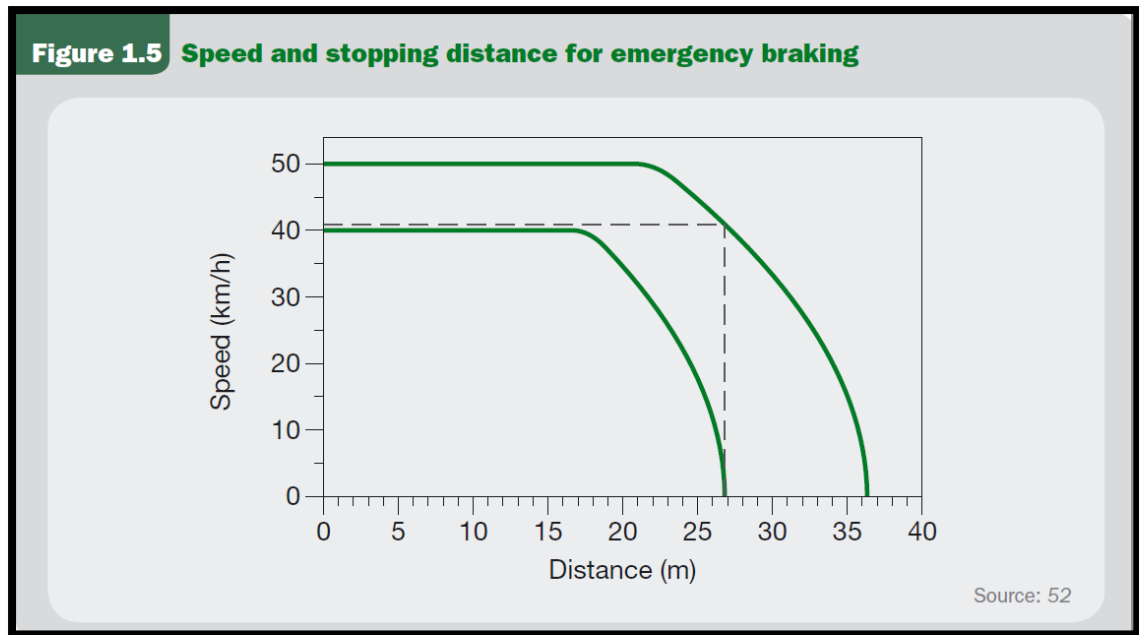


Figure 14: Speed and stopping distance for emergency braking (World Health Organisation, 2013, p. 17)

#### 2.4.4 Challenges facing NMT users in the road environment

The behavioural and design factors that can lead to pedestrian risk have been discussed. The literature review indicates that the needs of pedestrians are not particularly understood or they are simply not really considered. Some of the risky behaviour is a result of attitudes and others are simply because pedestrians are not catered for. The needs of pedestrians should be thoroughly understood when assessing pedestrian safety problems as well as when solutions are being implemented.

##### 2.4.4.1 Pedestrian needs

The needs of pedestrians impact their behaviour. Safety and security are the most fundamental of all needs, for example, pedestrians will not use a facility if there is a real or perceived security /safety problem or excessive time delay- this leads to increased risk & exposure to accidents. The Pedestrian and Bicycle Facility Guidelines, DoT, 2003 characterizes the needs of pedestrians as accessibility, convenience and comfort -(Ribbens, H, personal communication, December 10, 2014).

##### 2.4.4.2 Accessibility

Pedestrian facilities should be accessible to all users, regardless of age or ability. People with special needs such as those on crutches, wheelchairs and with guide dogs require modified facilities e.g. larger access dimensions, ramps, way-finding for pedestrians who are blind or who are visually impaired etc. to accommodate mobility. Continuous pedestrian walkway facilities are required on travel corridors e.g. across driveways and roadways.

### 2.4.4.3 Convenience

A variety of pedestrian and cyclist facilities should be available and be convenient to use. Convenience is defined by quick, direct and convenient routes to chosen destinations. Detours and delays deter the use of facilities. Pedestrian infrastructure must form a coherent unit that links origins and destinations. Routes must be continuous and be of a consistent standard – there should be no gaps in a route. Pedestrian (and bicycle) facilities should be integrated with other transportation systems.

### 2.4.4.4 Comfort

Pedestrian (and cyclist) facilities must be easy and comfortable to use. The following aspects are particularly important: topography affects pedestrians and may have a considerable effect on route selection. Grades more than 5% are undesirable, especially if fairly long. Preference should be given to gentle road gradients. The pavement should be fairly smooth and well maintained, without potholes and other undulations, which make it difficult for pedestrians to use. Walkways must be properly cleaned and not covered by debris, dirt, leaves and other loose matter which can be hazardous for both pedestrians and cyclists. Walking is not an all-weather transport mode and many people will be discouraged from walking in extreme weather. Shelters are required in areas with very high and frequent rainfall or where very cold weather prevails for long periods (Ribbens, H, Class notes, 2014).

### 2.4.4.5 Pedestrian problems in the South African context

The pedestrian challenges published by Labuschagne and Ribbens (2014) echo the sentiments of the needs discussed in the previous section. The list also highlights issues on institutional planning and maintenance processes that hamper improvements for pedestrian access.

- “The NMT road environment is inadequate, lacking infrastructure to provide safe passage of roads or moving alongside roads. Generally there is a limited or no space for pedestrians on the road network.
- NMT infrastructure is not continuous. Many examples exist where networks are incomplete, leaving pedestrians and cyclists stranded along roads.
- Transport and land use planning processes do not always take NMT user needs into account, and more often than not give priority to the needs of private car users.
- Funding is limited to provide for and to maintain NMT infrastructure.
- Crossing of freeways, urban arterials and major road junctions present major challenges to NMT road users, predominantly pedestrians.
- Intermodal transport planning practices are deficient, particularly with regard to NMT infrastructure at, vicinity of, public transport facilities, including railway crossing facilities.
- Many NMT users sense a lack of security in the road environment, because of inadequate street lighting on roads, in subways or footbridges: and poor vegetation management.
- NMT infrastructure is poorly maintained, making it inconvenient to use.

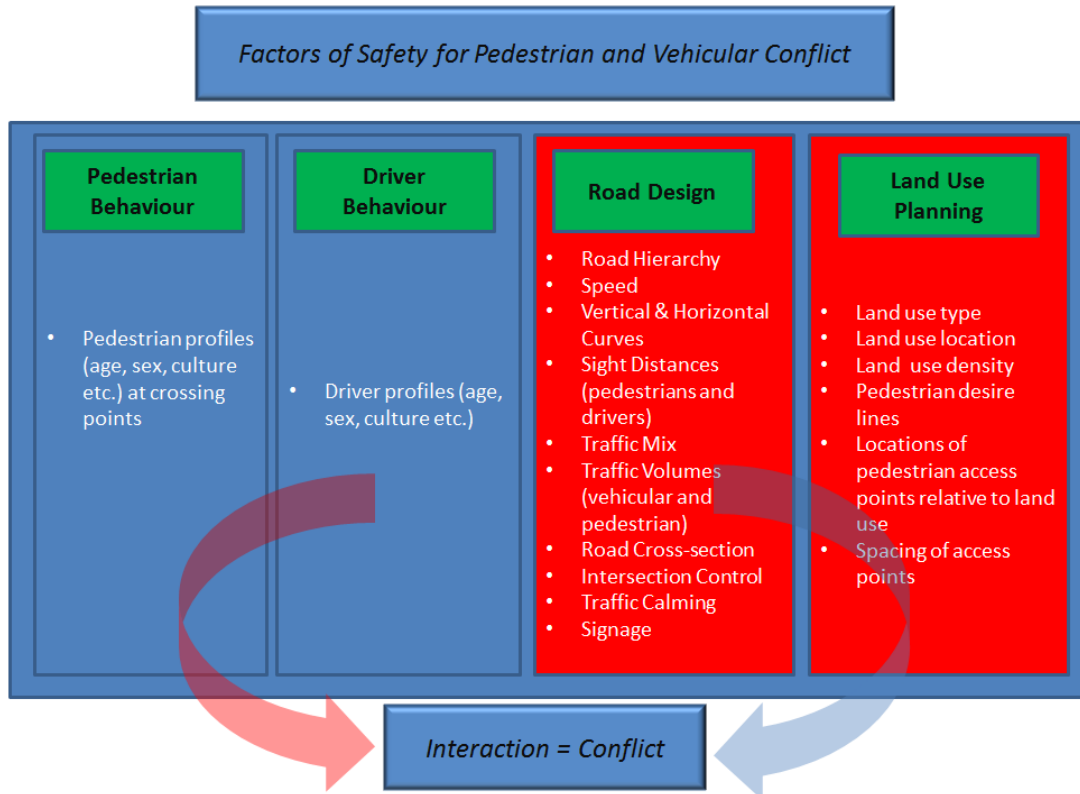
- Universal design principles are generally not applied and consequently disabled users, elderly pedestrians and children find it difficult to freely move around within the road environment.
- The challenge however is not just about the provision and maintenance of accessible, convenient and safe NMT infrastructure. As traffic volumes and traffic density increase NMT users find it more difficult to cross roads and to share the road; and as a result higher number of casualties is experienced on the road network. The Road Traffic Management Corporation (RTMC) reported that currently pedestrians account for just below 40 per cent of all road fatalities in South Africa (RTMC, 2013).” (Labuschagne & Ribbens, 2014, p. 2)

Labuschagne and Ribbens (2014) suggest that a shift in the paradigm is required in the planning, implementation and operation of NMT-relevant infrastructure. A paradigm refers to the basic assumptions used to define a problem and to evaluate solutions: a shift in the paradigm would force practitioners to examine their basic assumptions and analysis methods. (Labuschagne & Ribbens, 2014).

## 2.5 A SUMMARY OF PEDESTRIAN SAFETY RISK FACTORS

The pedestrian safety risk factors on rural roads discussed in this literature review are summarised as follows (**Figure 15**):

- **Pedestrian behaviour** (Pedestrian/vehicular conflict at crossings, Talking and walking, Reduced reaction time and walking speed for the elderly, Inability of children to gauge vehicle speed and other relevant information, Lack of supervision of children who are too young to make safe judgements, walking under the influence of alcohol).
- **Driver behaviour** (Driver attitudes, unsafe driving practices and driver distractions, e.g. cell phone, advertising, Driver fatigue, speeding, driving under the influence of alcohol).
- **Road Design** (Design and posted speed, sight distances, curve radii, intersection control, pedestrian facilities, lighting and visibility etc.).
- **Land use** (unregulated building encroachment, land use and transportation integration, access management etc.).



**Figure 15: Summary of pedestrian safety factors.**

These risk factors have numerous sub-categories; they are simply the core or summary of the factors discussed in this chapter. When addressing pedestrian safety on rural higher order roads, the chance exists that one can enter into the detail problems too soon and not understand the bigger picture or fail to evaluate the higher level causes of the problem. A macro level or high level assessment of a road section should therefore be carried out to understand the bigger picture. This summary of the possible pedestrian safety risk factors is a first step to clearly identifying problems.

## 2.6 ASSESSING PEDESTRIAN SAFETY RISK

A higher level assessment of a road environment (greenfields or existing) is required before any interventions/solutions can be selected and applied. One of the aims of this research report is to assess the pedestrian safety risk on the R71 therefore it is important to determine a methodology from the literature to do so.

The WHO report states that a situational assessment constitutes an essential step to facilitate understanding of the local pedestrian safety situation. This information is used to make decisions on priority areas, to select the best approaches to improve pedestrian safety, and to strengthen existing plans and programmes or develop new initiatives (World Health Organisation, 2013, p. 43).

A situational assessment of pedestrian safety has the following activities:

- “Describing the magnitude, trends and patterns of pedestrian fatalities and injuries;
- Analysing risk and protective factors for pedestrian injuries and fatalities;

- Examining the times and places where pedestrian injuries and fatalities occur;
- Describing the modes of transport involved in conflicts with pedestrians;
- Identifying and assessing existing pedestrian safety programmes and institutions to identify gaps and areas to improve as well as those to maintain; and
- Identifying contextual factors related to politics, environment, economics and capacity that may facilitate or hinder the implementation of pedestrian safety measures” (World Health Organisation, 2013, p. 44).

A similar “Project Level Assessment” is stipulated in the South African NMT Facility Guidelines published in 2014. The recommended steps are as follows:

- “Status Quo Assessment,
- Situational Assessment,
- Needs Assessment
- Prioritization Subject to budget constraints
- Development of programmes; and
- Development Plans” (UCT and SMEC, 2014, p. 21)

The minimum data set includes information on the what, where and why dimensions of pedestrian injuries. In addition; it is important to have background information on population, transport and socio-economic indicators of the setting under investigation.

## **2.6.1 Pedestrian accident statistics**

An assessment can commence with the analysis of available accident data to identify known problem areas. Pedestrian accident statistics provide historical data on the actual risk at specific locations. They however do not predict accident risk in green field’s projects nor do they provide guidance on the type of solution that should be applied. Another problem is that the current state of road accident statistics in South Africa are not reliable and can almost be discarded. Accident data cannot always provide an indication of why accidents occur at a location. Sample sizes are often small and not collected often, resulting in gaps in the data. Data quality is affected by poor accident reporting and capturing (Ribbens, Class notes, 2014). If available, accident statistics should be evaluated together with all the other sources of information, such as input from the community and others that will be mentioned in this section.

### **2.6.1.1 Visual assessment of the study area and identifying pedestrian safety factors**

Visual surveys of pedestrian movements often provide a better understanding than doing extensive expensive counts of pedestrian movements. By talking to various community role players problem areas can be identified. These can be verified by visual observations for a few hours. Counts can be done if there is any doubt whether an expensive facility, such as a pedestrian bridge is warranted. The pedestrian safety factors discussed in the previous section can be identified using this method. Visual assessments of traffic operations indicate the conflicts as discussed in the prior chapter (ITS Engineers, 2009).

### 2.6.1.2 Models and analysis systems

Numerous models, systems and procedures have been devised to assess pedestrian safety risk; noteworthy examples are the Haddon Matrix and Pedestrian Conflict Analysis, these are discussed in the following paragraphs.

#### 2.6.1.2.1 Haddon matrix

William Haddon developed the matrix (**Table 2**) in 1980 to identify risk factors before the crash, during the crash and after the crash relative to the person, vehicle and environment (physical and social). The matrix is an analytic tool to identify all risk factors associated with a crash, when to implement traffic countermeasures, for planning crash-related data collection and identifying organisations for collaboration efforts.

The three phases listed below are provided in Table 2.

- Pre-crash phase: Countermeasures that prevent the crash from occurring.
- Crash phase: Countermeasures that prevent injury or reduce its severity.
- Post-crash phase: All activities that reduce the adverse outcome of a crash after it has occurred.

The matrix provides potential issues that can be addressed using the 4 E's; Education, Enforcement, Engineering, and Emergency response solutions (The Haddon Matrix, 2011).

The risk factors uncovered in the literature review are covered in the pre-crash phase of the Haddon Matrix, particularly for the human and physical environment factors. The other phases are important however the focus of this report is on preventative transportation engineering measures, this is largely impacted by human behaviour and the built environment. The crash and post-crash phases are largely related to car design, incident management and emergency services planning. The Haddon matrix reinforces that the choice of pedestrian safety factors uncovered in the literature review are supported by other research.

**Table 2: The Haddon Matrix for determining pedestrian risk and exposure (The Haddon Matrix, 2011)**

Not Applicable	Human	Vehicle/ Equipment	Physical Environment	Socioeconomic
<b>Pre-Crash</b>	Poor vision or reaction time, alcohol, speeding, risk taking	Failed brakes, missing lights, lack of warning systems	Narrow shoulders, ill-timed signals	Cultural norms permitting speeding, red light running, DUI
<b>Crash</b>	Failure to use occupant restraints	Malfunctioning safety belts, poorly engineered air bags	Poorly designed guardrails	Lack of vehicle design regulations
<b>Post-Crash</b>	High susceptibility, alcohol	Poorly designed fuel tanks	Poor emergency communication systems	Lack of support for EMS and trauma systems

#### 2.6.1.2.2 Traffic conflict study technique

A traffic conflict is an undesired event in the traffic stream, such as a near-accident or a violation of a traffic rule. A few hours or days of observations would often reveal undesirable

driver, pedestrian and cyclist behaviour which could lead to traffic accidents. The Traffic Conflict Study technique is a method according to which potential accidents and causes of accidents can be identified without the use of accident data.

“Serious conflicts are in the same way as traffic accidents, the result of a breakdown in the interaction between the road user, environment and vehicle. The similarity between accidents and serious conflicts is striking; accidents can be avoided by circumventing conflict” (Department of Technology and Society Lund University , p. 5).

There are between 3 000 and 40 000 conflicts for each accident reported by the police. This ratio depends on the type of conflict and the severity of the conflict. The random variation is less of a problem, as the number of conflicts based on a few days study outnumbers the number of accidents over several years. It has therefore been demonstrated that conflict studies give a better estimate of the average number of accidents than accident statistics. This means that 3 days of observations already give (normally) better estimates than waiting for three years of accident data.

Estimating the expected number of accidents, or even expected number by type, is not sufficient for traffic analyses. Risk estimates are required, as a basis for good comparisons. A combination of conflict studies and volume counts enables detailed risk estimates” (Department of Technology and Society Lund University , p. 7).

## 2.7 CONCLUSION

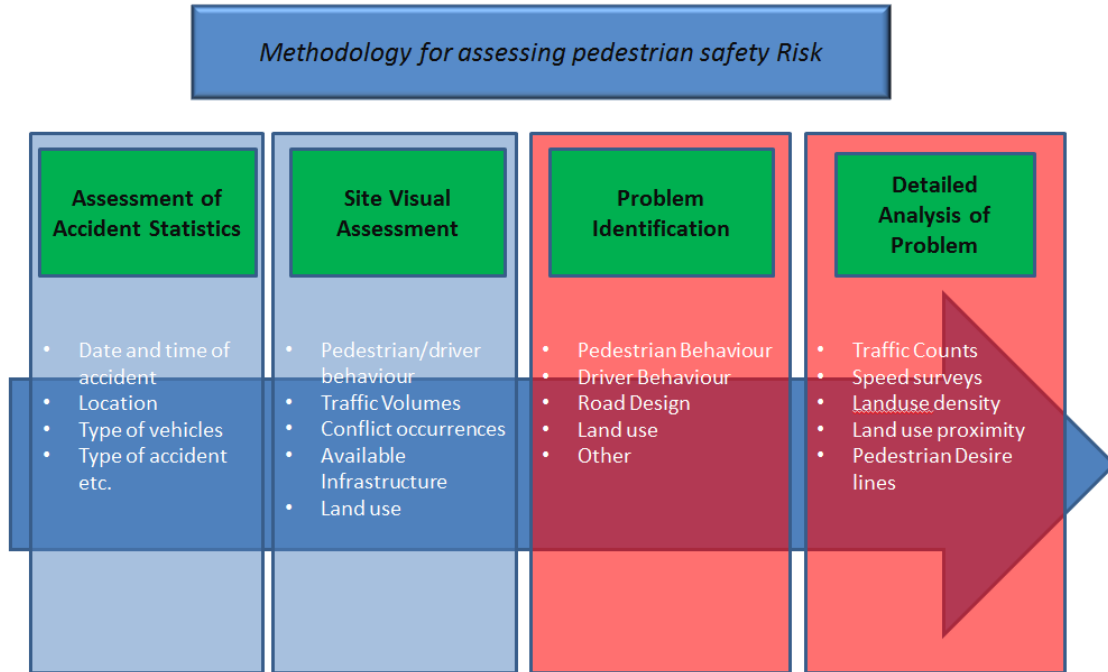
The research has defined pedestrian risk as the number of pedestrian accidents per certain kilometres travelled in an area. This is a broad and absolute way of defining risk, which is useful for higher level planning. Understanding the root cause of pedestrian accidents on high-order rural roads and identifying countermeasures requires a clear analysis methodology which begins with understanding the bigger picture, identifying the pedestrian safety risk factors and then embarking on detailed analysis. The literature provides methodologies for assessing this risk, these have been summarised in the figure below.

Pedestrian safety risk can be loosely broken down into the identified risk factors/contributing factors of risk. Risk can therefore be expressed as a function of the following:

Pedestrian Safety Risk = **a**(pedestrian behaviour)+**b**(driver behaviour)+**c**(road design)+**d**(land use)+ (accidents\*km travelled) + **E**

- **a,b,c** and **d** being regression factors
- **E** being other factors which have not been included i.e. vehicle condition etc.

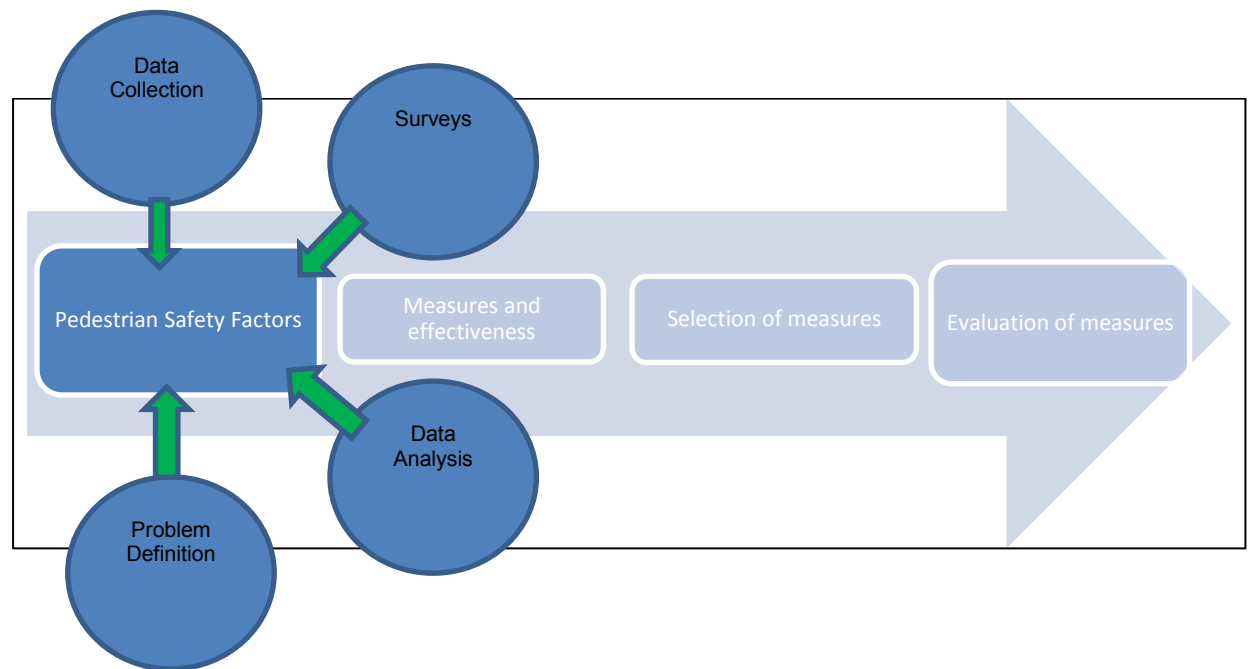
It can be loosely concluded that the greater the factors at a specific location the greater the risk. The proposed methodology for assessing pedestrian safety risk will be applied to the R71 Polokwane case study to determine the risky locations in the study area.



**Figure 16: Proposed methodology for assessing pedestrian risk on high-order roads.**

### 3. STATUS-QUO

The status-quo analysis of pedestrian safety on the R71 study area will be assessed in this chapter. The methodology for assessing pedestrian safety risk – deduced in Chapter 3, **Figure 16** and summarised in the schematic below- will be followed. The chapter will commence with a macro-level assessment of contextual factors.



#### 3.1 POLICY AND PLANNING DOCUMENTS

The status-quo of legislature and policy should be examined to ascertain government's stand on the pedestrian safety issue. Legislature and policy govern the gravity and direction with which the issue should be pursued since the issue itself is a public one. Prevailing national, provincial and local transport policy and legislation underpin the provision of sustainable transport and highlight the need for improving and integrating NMT facilities within the transport network. Given the fact that the vast majority in Polokwane (71%) walk to work and school, NMT is an essential daily transportation mode. Policy indicates that government is aware of the urgent need to integrate and develop NMT facilities to provide access to all key destinations (Polokwane, 2012). Policy relevant to the research will be discussed in the next paragraphs.

##### 3.1.1 National Land Transport Act (NLTA)

The National Land Transport Act (NLTA) emphasises that transport services and infrastructure must be designed to integrate different modes of transport to be cost efficient, to achieve service quality, to use available resources optimally, to use the most cost-effective modes and to do the least possible harm to the environment. The document

highlights the importance of accommodating marginalised users and meeting the needs of special categories of passengers (such as learners and people with disabilities). These needs can be met by better integration of Non-Motorised Transport (NMT) modes, i.e. bicycles and pedestrians (as the preferred types of NMT transport). All these principles should be applied on the R71 (DoT, 2009).

### **3.1.2 Polokwane Integrated Transport Plan and non-motorised plan**

The Integrated Transport Plan (ITP) identified walking as the main mode of transport in the Polokwane Municipality. A Non-Motorised Transport Plan was prepared to promote the use of walking, bicycles and animal-drawn vehicles. The plan was based on a survey of key pedestrian and bicycle desire lines and infrastructure improvements were prioritised according to short, medium and long term timeframes. Pedestrian movements were noted along the R71 and should be accommodated. This approach addresses the vision statement of integrating modes, the need for improved NMT facilities and more importantly, its positive impact on the overall efficiency of the transport system (Polokwane, 2012).

### **3.1.3 Sanral Road Safety Management System**

The SANRAL Road Safety Management System provides a general overview of the processes for managing the SANRAL Road Network to improve safety for all road users. SANRAL is working towards ensuring that road safety is a central consideration in every decision made about construction, maintenance, operation and the management of its road network. SANRAL supports the integrated approach to road safety and believes that the discipline of engineering, education and enforcement each play a vital role in reducing the carnage on the road. The road authority is therefore open to a holistic approach of solving rural highway pedestrian safety risk.

### **3.1.4 SANRAL pedestrian road safety and cycle strategy**

The SANRAL Pedestrian Road Safety and Cycle Strategy approach is based on the SANRAL Road Safety Management System. The strategy has the following key measures:

- **Reactive measures:**

SANRAL states that a more sustainable approach is one that finds solutions that address the core of the road safety problem. It is therefore important to provide solutions for known areas of pedestrian/ vehicle conflict points. This approach increases the chance of providing the most appropriate infrastructure needs, backed up by the most relevant education and enforcement activities. Transport and road safety needs are then addressed simultaneously.

- **Proactive measures:**

Consideration should be given to the needs of pedestrians with all new infrastructure provided. SANRAL must have influence on what happens adjacent to the Road Network with respect to developments that generate pedestrian trips.

- **Direct interventions on the National Road Network**

Pedestrians make use of the National Road Network; the challenge is to make sure they use it in a responsible manner, by providing appropriate infrastructure supported by the following activities:

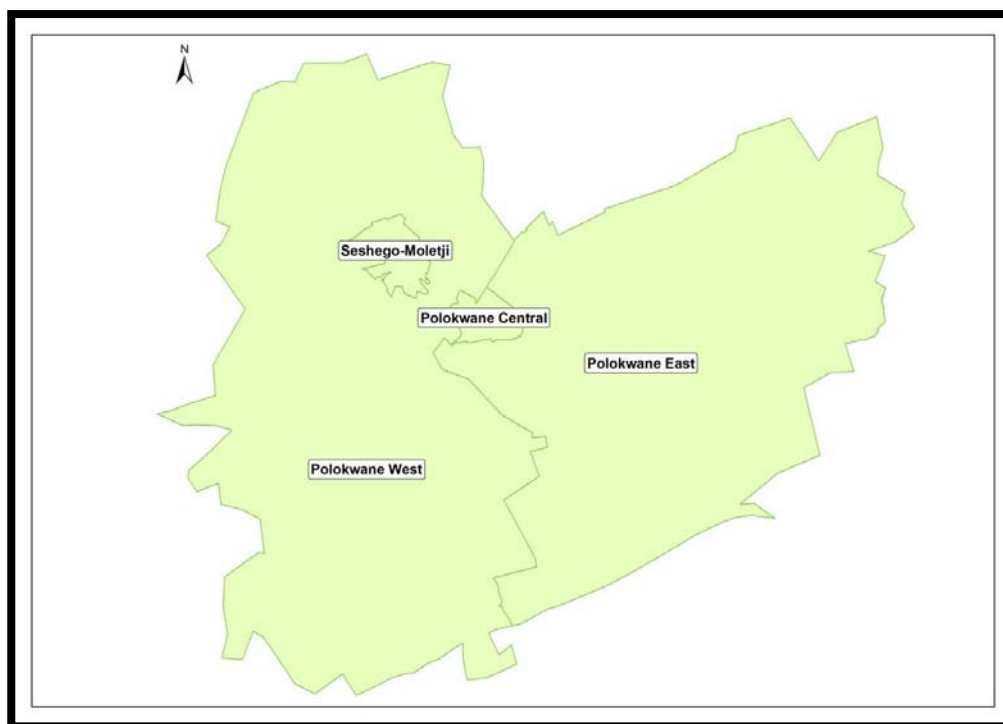
- Road Safety Audits;
- Road Safety Education and Training;
- Law Enforcement;
- Advertising; and
- Engineering Solutions

The current legislature is in agreement with ensuring that pedestrian safety is prioritised on highways. The traditional paradigm of motor-vehicle focus is shifting and government has given the green-light to providing integrated and holistic pedestrian safety countermeasures. The countermeasures that are recommended on the R71 will be in accordance to that (SANRAL, 2006).

### **3.2 TRANSPORT SOCIO-ECONOMIC DATA**

Transport status-quo information was obtained from the 2013 National Household Travel Survey (Statistics South Africa, 2013). The Polokwane Household Travel Survey would have been the ideal travel statistics source –given the number of traffic analysis zones surveyed when conducting municipal surveys- however it was not complete when the project was undertaken.

The commuter and education trips were prioritised as they typically comprise the largest and most frequent movements in human settlements. The modes of transportation used for work and education trips were analysed for all the regions in the Polokwane Municipality. The R71 study area is located in Polokwane East, the regions or “home areas” in which the municipality was divided for the purposes of the survey are mapped in **Figure 17**. The transport status-quo varies in accordance with the socio economic profile of the area/region.



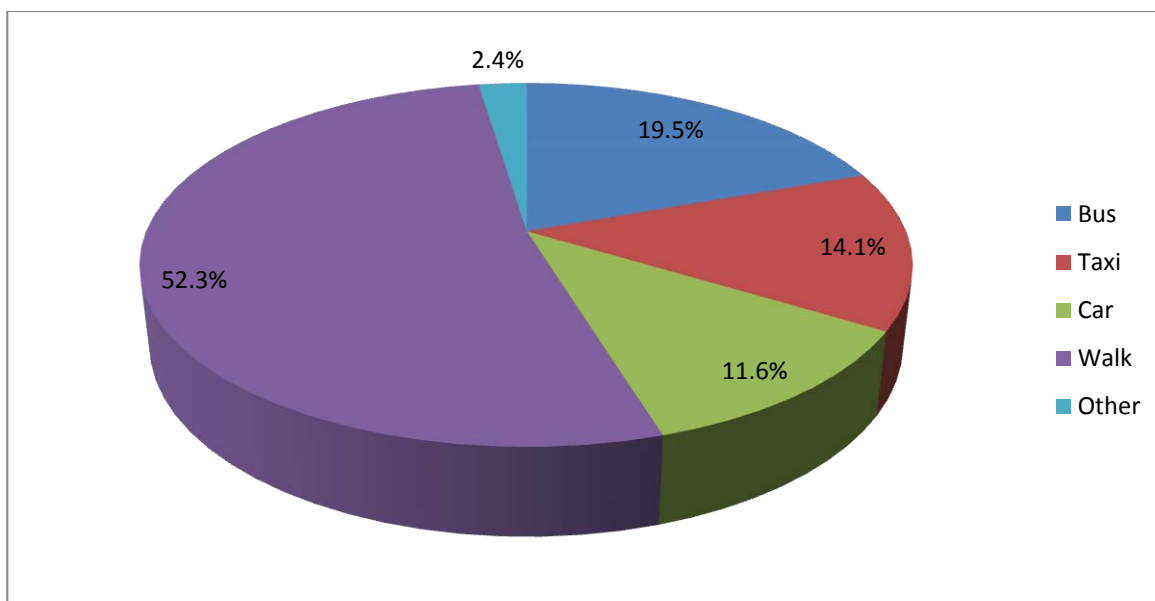
**Figure 17: Polokwane regions included in the National Household Travel Survey (Statistics South Africa, 2013)**

The following tables and pie-charts indicate the modal split for work related trips. **Table 3** indicates that Polokwane East had the highest volume of work trips in the municipality. Work trips were predominantly made via walking and public transport (particularly the bus mode). Walking trips to work in the region are the highest in Polokwane.

**Table 3: Modal split for work trips in Polokwane (Statistics South Africa, 2013)**

MAIN MODE TO WORK ( % of trips)							
Home Area	Nr of trips	Bus	Taxi	Car	Walk	Other	TOTAL
Seshego/Moletji	23 064	14.7%	55.1%	16.6%	12.9%	0.8%	100%
Polokwane Central	14 605		6.3%	82.9%	7.9%	3.0%	100%
Polokwane East	24 890	19.5%	14.1%	11.6%	52.3%	2.4%	100%
Polokwane West	19 024	13.6%	26.7%	20.2%	37.7%	1.9%	100%
<b>TOTAL POLOKWANE LM:</b>	<b>81 583</b>	<b>13.3%</b>	<b>27.3%</b>	<b>27.7%</b>	<b>29.8%</b>	<b>1.9%</b>	<b>100%</b>

The pie-chart (**Figure 18**) illustrates the work mode split in the study area. Walking comprises of more than half of the work trips in the region, followed by buses and taxis respectively. Work car trips in the region are minimal.



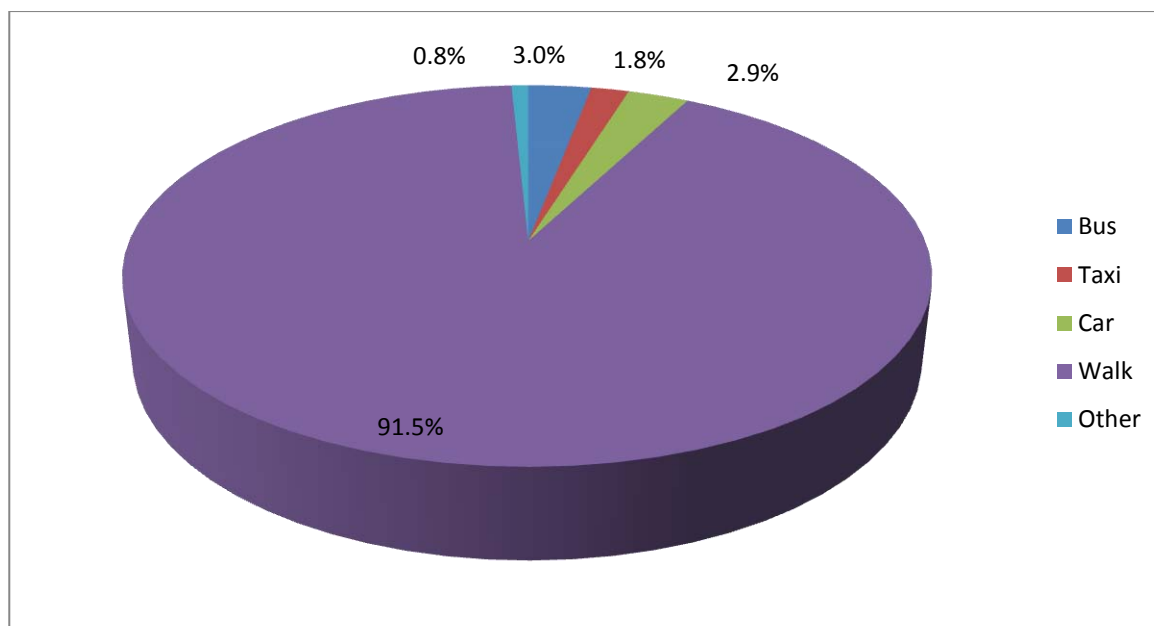
**Figure 18: The work modal split in Polokwane East (Statistics South Africa, 2013)**

Trips to places of education are summarised in **Table 4**. A resounding majority of educational trips are made in Polokwane East, this is attributed to the University of Limpopo located in Mankweng. Educational facilities throughout the municipality are accessed via walking. The data indicates that at least 80% of trips are walking trips for four out of the five regions. At 91.5%, Polokwane East has the highest number of pedestrians walking to and from educational facilities.

A comparison of the main modes of transport for educational trips in Polokwane East is illustrated in **Figure 19**. Walking trips are the overwhelming majority of educational trips, followed by minimal bus, car and taxi trips respectively.

**Table 4: Modal split for educational trips in Polokwane (Statistics South Africa, 2013)**

MAIN MODE TO EDUCATION ( % of trips)							
Home Area	Nr of trips	Bus	Taxi	Car	Walk	Other	TOTAL
Seshego	37 028	5.9%	9.8%	3.7%	80.5%		100%
Polokwane Central	9 426		12.4%	57.6%	28.9%	1.2%	100%
Polokwane East	124 479	3.0%	1.8%	2.9%	91.5%	0.8%	100%
Polokwane West	43 454	0.5%	4.6%	2.7%	91.3%	0.9%	100%
<b>TOTAL POLOKWANE LM:</b>	<b>214 387</b>	<b>2.9%</b>	<b>4.2%</b>	<b>5.4%</b>	<b>86.8%</b>	<b>0.7%</b>	<b>100%</b>



**Figure 19: Polokwane East school trips (Statistics South Africa, 2013).**

The survey results indicate that there is a high non-motorised and public transport dependency in Polokwane East. The R71 is the largest corridor in Polokwane East, linking the region to Polokwane CBD and Tzaneen, the survey results are thus applicable to the R71 study area. In general the percentage of school trips by walking are substantially higher than is the case for work trips. Polokwane East also has higher population percentages of walking than the National averages of 23% workers and 90.6% learners (Statistics South Africa, 2013). Pedestrian movements should be prioritised and their needs investigated and accommodated in line with the policy and planning documents and pedestrian needs discussed in **Chapter 2**.

### 3.3 DATA COLLECTION

#### 3.3.1 Summary of accident statistics

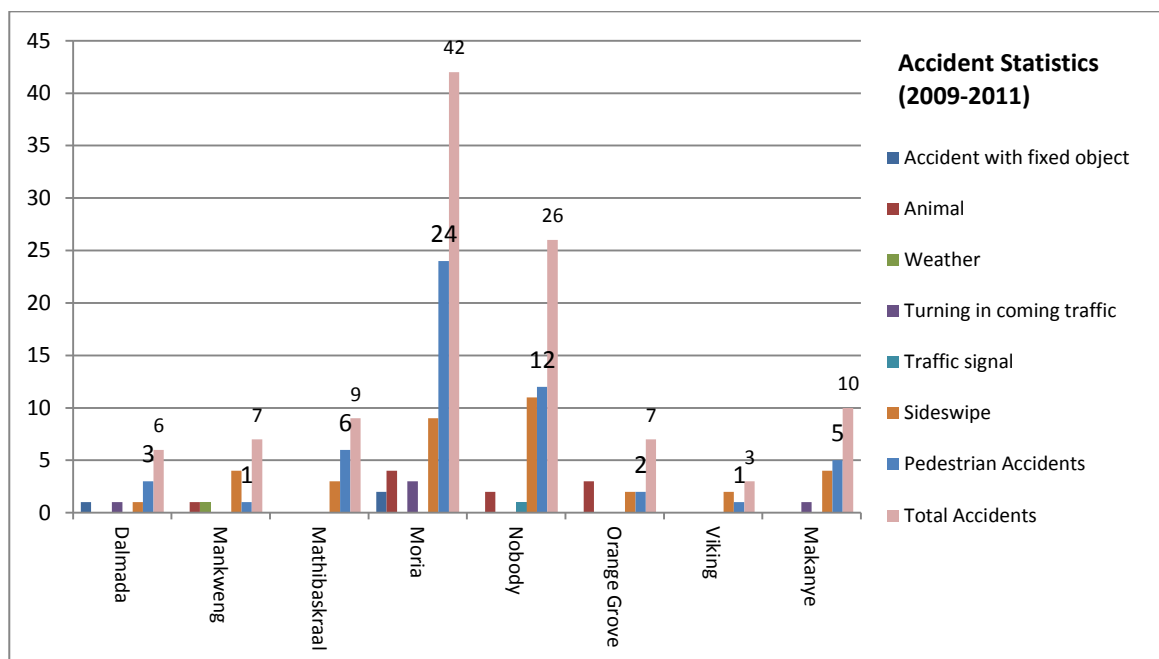
Accident statistics provide a good indication of where safety problems exist, however, the quality and availability of accident statistics in South Africa is usually incomplete, inaccurate and unreliable. Despite these inadequacies, the information highlights problem areas.

Incident data was collected from the Limpopo Roads Department. The accident statistics were compiled from 2009 to 2011 (3 year period). The data was categorised according to date, time, accident cause, area and vehicle type. The statistics were unfortunately not disaggregated according to the number of people involved and the seriousness of the incident, i.e. the number of fatalities and serious injuries per area are not disclosed. The exact location of accidents – i.e. co-ordinates - was also not provided and the reason for accidents with pedestrians was only stated as “pedestrian in roadway”. No pedestrian characteristics i.e. age, sex were available.

The data summary is illustrated in **Figure 20** which is a graphical comparison of the different types of accidents that occurred in the study area. The villages of Moria and

Nobody had the highest number of pedestrian incidents during the 2009 to 2011 period whilst Mankweng and Viking had the lowest.

The accident statistics per area are ranked in descending order in **Table 5**. The table indicates that almost half of the pedestrian accidents in the study area occur at Moria. The pedestrian accidents are 49% (nearly 50%) of all the accidents that occur in the study area. This is higher than the national average. In South Africa, pedestrian accidents account for approximately 33% of all road traffic accidents (RTMC, 2011). The drawings of mapped accident statistics are provided in the **Appendices**.



**Figure 20: Accidents in the R71 study area from 2009-2011.**

The pedestrian accidents per 100 million vehicle kilometres travelled are provided in **Figure 21**. Moria and Nobody have the highest number of incidents.

### 3.3.1.1 Accidents by settlement type

Analysis of the areas where accidents occur indicated that the majority -81%- occurred in villages (Moria and Nobody etc.), 13% in farming areas (Dalmada) and the remaining 6% in urban areas (Mankweng). A graphical summary of the analysis is provided in **Figure 22**. The accident numbers based on settlement type seem to reflect that underdeveloped, low population contexts have higher accident prevalence than the opposite. This may have some merit since more and better pedestrian facilities are provided in Mankweng as opposed to Moria. The settlement nature i.e. sparse building density in village settings may not create an adequate awareness to drivers of the transition from rural to village, thus defer speed reduction at village crossings. The accidents by settlement type indicate that greater intervention is required in village settings.

Table 5: Incidents per township on the R71 Polokwane.

Place	Pedestrian Accidents	Total Accidents	% of Pedestrian Accidents per area to total accidents	% of Pedestrian Accidents to Total Accidents
Moria	24	42	44%	57%
Nobody	12	26	22%	46%
Mothibaskraal	6	9	11%	67%
Makanye	5	10	9%	50%
Dalmada	3	6	6%	50%
Orange Grove	2	7	4%	29%
Mankweng	1	7	2%	14%
Viking	1	3	2%	33%
<b>Grand Total</b>	<b>54</b>	<b>110</b>	<b>100%</b>	<b>49%</b>

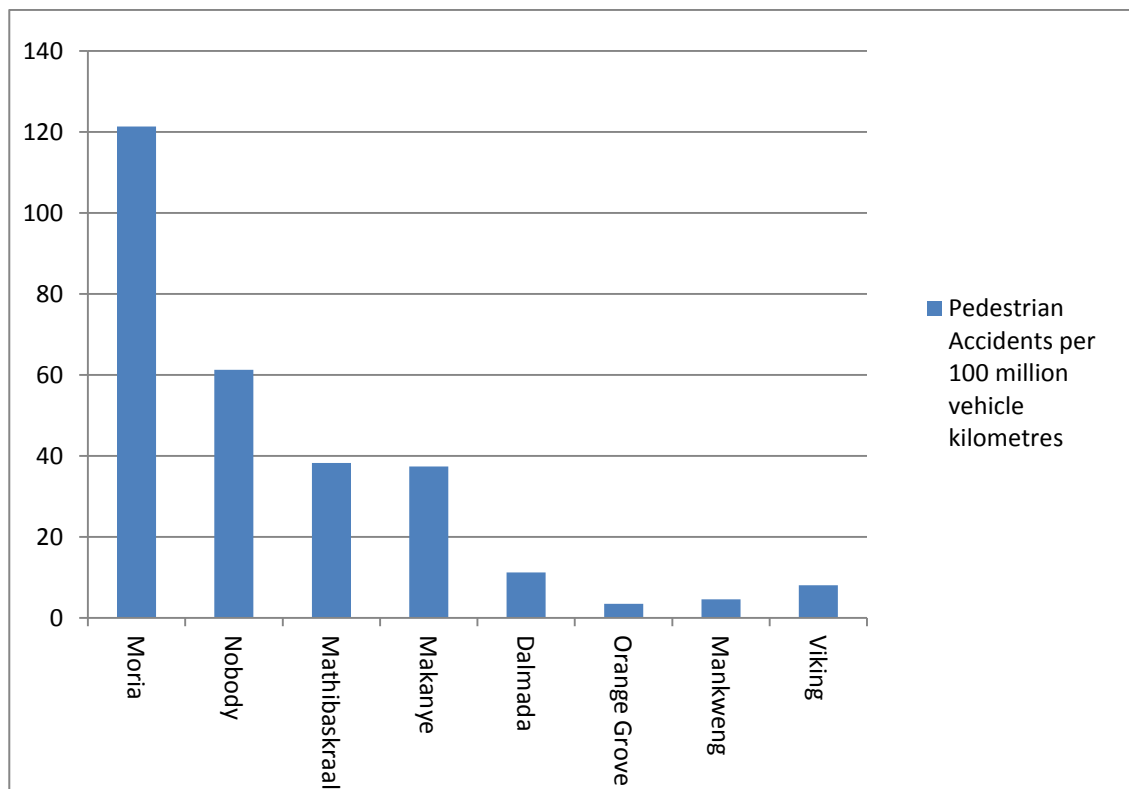
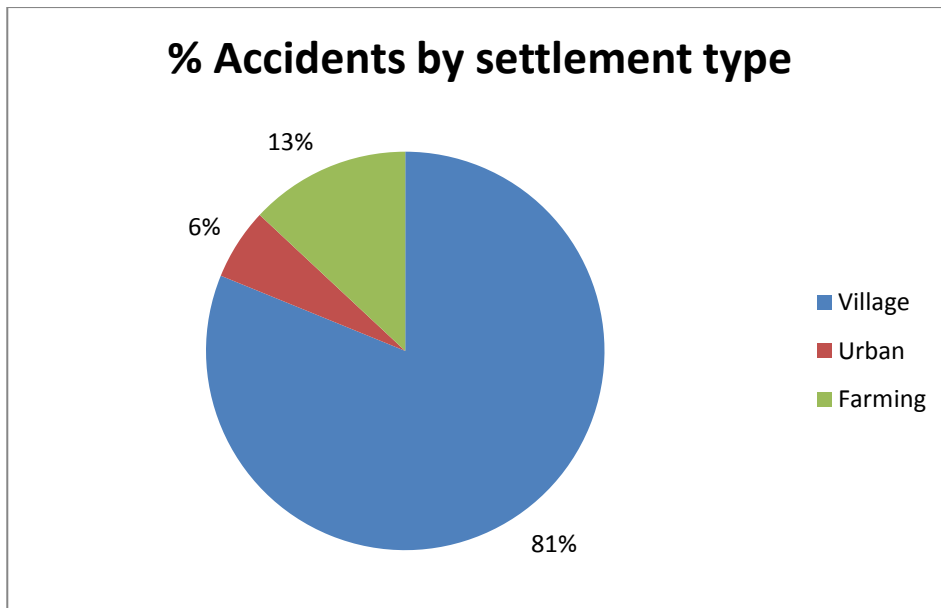


Figure 21: Pedestrian accidents per million vehicle kilometres travelled per settlement.



**Figure 22: The percentage of accident by settlement type.**

### 3.3.1.2 Accidents by time of day

Analysis of the time of day of incidents (**Figure 23**) revealed that 59% of accidents occur in the evening, 25% in the afternoon and the remaining 16% in the morning. The time periods were categorised as follows:

Morning 00:00-11:59  
 Afternoon 12:00-17:59  
 Evening 18:00-11:59

The results of the analysis corresponds with the literature. The number of evening and morning trips (particularly commuters) should be approximately the same therefore it may be possible that the visibility/lighting along the R71 may be an issue, particularly in the summer months when the sun rises early and sets late in the afternoon, allowing better visibility in the mornings compared to the winter months. A majority of the afternoon movements are made by scholars; this may be a gross assumption however the afternoon statistic could be attributed to scholar accidents.

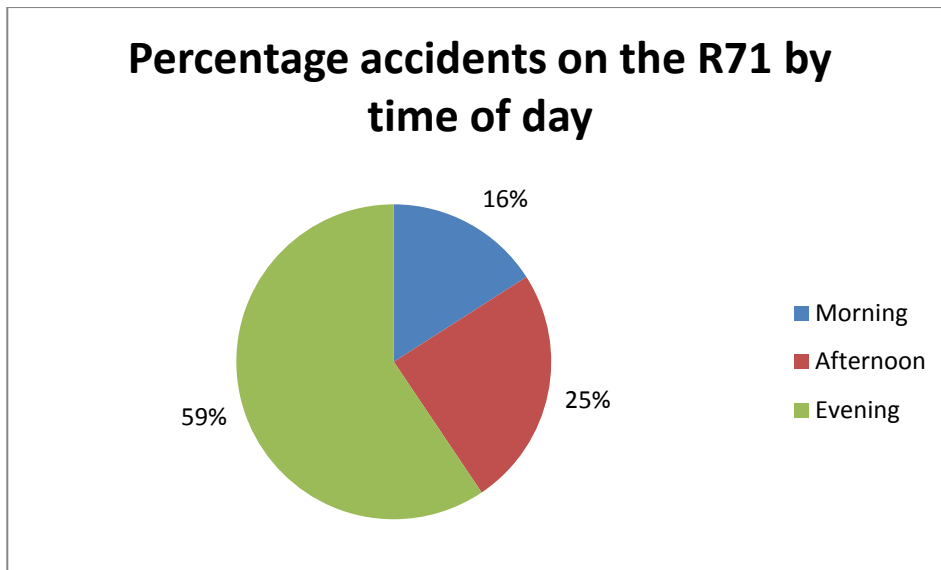


Figure 23: The percentage of pedestrian accidents by time of day

### 3.3.1.3 Accidents by month of the year

The percentage monthly accidents were assessed for 2009, 2010 and 2011 (**Figure 24**). The first two years have a similar trend which indicates that many pedestrian accidents occurred in April. This coincides with the Zion Christian Church pilgrimage in April. The third year has most accidents occurring in May; a particular reason for this could not be established. The graph illustrates that pedestrian accident spikes occur throughout the year, however higher peaks are experienced during the first half of the year.

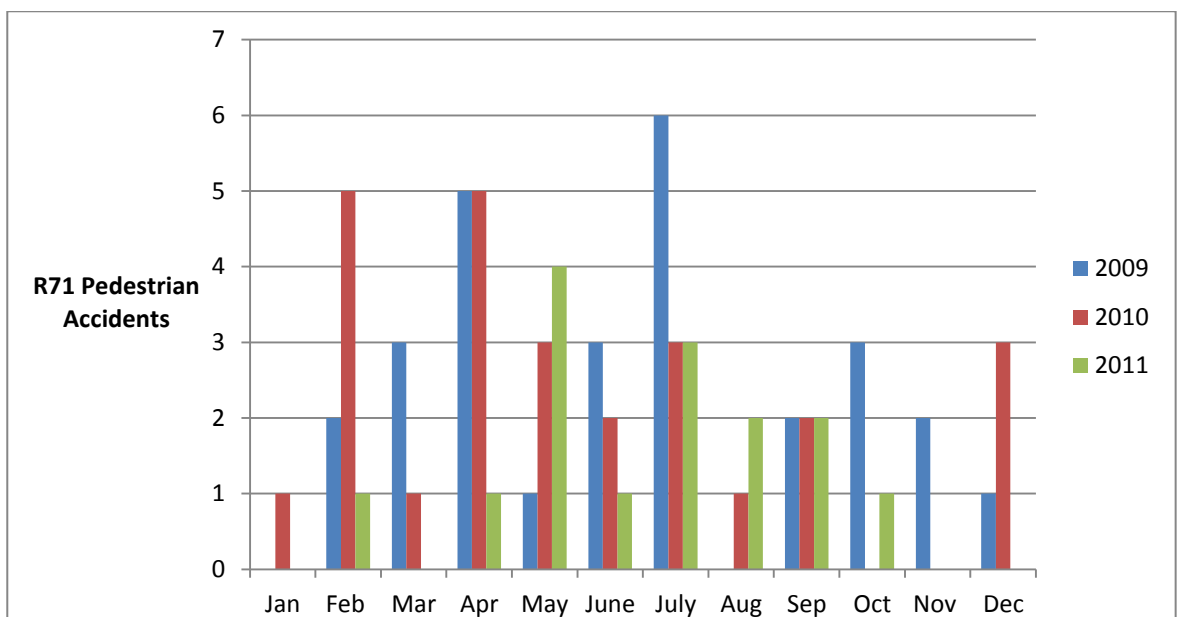


Figure 24: Pedestrian accident trends for 2009-2011.

Pedestrian accidents are caused by a variety of issues; pedestrian and driver behaviour, and land use and roadway elements etc. many of these factors could not be analysed due to the limited detail and quality of the data. Firstly, the accident data only describes the cause of pedestrian accidents as “pedestrians in the roadway” the circumstances that govern the pedestrians’ behaviour are not indicated. If the location of the accident were known, i.e. at a formal crossing or at a link, then the pedestrian could have had right-of-way and other factors could be the cause or in the latter circumstance the driver would have right-of-way and other factors would be at fault. In the absence of pedestrian age and gender, it is difficult to determine detailed interventions that are custom designed for the specific pedestrian profile.

What was gathered from the data is that the pedestrian accidents in the study area were 49% of total accidents which is greater than the national average of 33%. The numbers of accidents were grouped per area revealing areas with high, moderate and low pedestrian accidents. A resounding majority of accidents occurred in villages and the least in urban settings such as Mankweng, indicating that access to adequate pedestrian facilities may be a problem and speed transition between rural and village sections may not be discernible. Time of day indicated that pedestrian accidents mostly occur in the evenings which is supported by the literature; month of year analysis revealed that pedestrian accidents peaked in the first half of the year, particularly during the Easter period.

In the absence of data, the literature can be used to understand the cause of accidents. In general pedestrian accidents are attributed to the following:

- Many roads are not designed for pedestrian usage, features such as side-walks and pedestrian crossings and/or fences are often non-existent;
- High levels of alcohol abuse result in drunken people walking on the roads. 70% of adult pedestrians who are killed on our roads are drunk;
- Lack of visibility of pedestrians is an issue;
- Due to a lack of public transport in some areas, people walk for long distances to reach buses or taxis;
- Informal, unplanned housing and even formal suburbs are often separated from schools, shops, clinics or places of recreation by highways; and
- Vehicle speeds. “At impact speeds of over 30km/h, pedestrians and cyclists risk sustaining life-threatening injuries. At 60km/h, death is virtually certain” (SANRAL, 2006).

Identifying the root cause of incidents is the first step to reducing pedestrian accidents.

### **3.3.2 Site visits and surveys**

Being physically present for site observations provides service providers with invaluable information about site conditions, the behaviour of the inhabitants of a study area and feasible solutions to the problem. To gain this insight, site visits and surveys were conducted from 6:00 to 18:00 on Wednesday 13<sup>th</sup> March and Thursday 20<sup>th</sup> June 2013 respectively. These days were found to be a fair representation of the normal traffic patterns for pedestrian and vehicular transport since they were normal days with no special events taking place.

The site visits and surveys were taken as an opportunity to engage the community on their experiences using the R71 and how it has impacted their lives. It was also taken as an opportunity to observe vehicle and driver behaviour in the study area particularly at locations that were identified as having many pedestrian accidents. Observations were centred on primarily

- Assessing pedestrian and driver behaviour
- Assessing pedestrian-vehicular conflicts or near-accidents
- Assessing the existing infrastructure

### **3.3.2.1 Community concerns**

The Chairman of The Road Safety Council in Limpopo, Ngate Kgorutle was available for consultation. His vast experience with road safety issues in Polokwane and his hands-on consultations with the community make him an ideal representative for the community stakeholders. Mr Kgorutle identified the R71 as a major threat to pedestrian safety in Polokwane. He gave ITS Engineers a guided tour of the study area and singled out all the pedestrian accident hot spots on the route.

He stated that the community had on numerous occasions expressed their concerns about the accidents that occur on the R71 in Mothibaskraal, Nobody, Viking and Moria. They complained that scholars were the worst affected by the accidents as well as drunk pedestrians who often weren't visible in the evenings. Speeding was also said to be an issue in the study area. They requested that those responsible please hear their pleas as nothing effective had been done to resolve the issue (personal communication, June, 2013).

### **3.3.2.2 Visual assessment**

The sites that were visually assessed were selected from the problem areas identified in the accident statistics analysis as well as those singled out by the community. The following were observed and recorded at the different sites:

- Public transport facilities,
- Intersection control,
- Road geometry,
- Pedestrian behaviour,
- Land use,
- Near accidents/conflicts, and
- Any other noteworthy information.

The list is based on the methodology for assessing pedestrian safety risk illustrated in Figure 16. A summary of the site observations is provided:

## Public transport

Formal and informal public transport stops were available at intersections. Formal stops are characterised by long laybys that can accommodate a bus. A formal taxi facility was provided at Piladi Mall in Mankweng however none were provided at schools en-route the R71.



## Intersections



Intersections on the route were very wide. Most of them had 4 approach lanes, two through lanes and one left and right turning lane. Intersection controls were mostly one-way stops with priority for the R71, the R71 traffic was required to yield to pedestrians at transverse crosswalks provided at the intersection. Traffic signals were provided at intersections in Mankweng, only one of which had a pedestrian phase which was not operating.

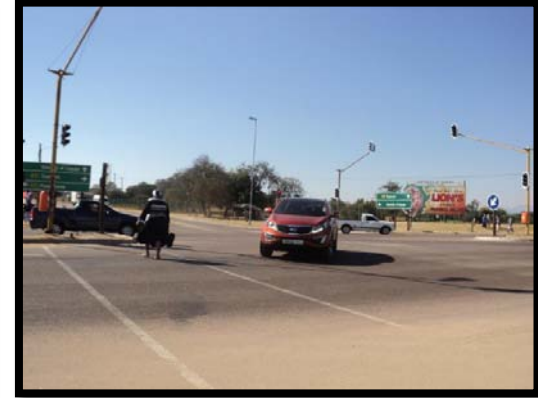
## Road geometry



The R71 can be characterised as a dual carriageway with exception to Moria and Viking. The road also has a minimal paved shoulder/ recovery area. The terrain can be described as mostly gentle with a few rolling sections. The road therefore has mild to moderate vertical and horizontal curves. Sections with pronounced gradients are Moria and Viking. Based on geometry, sight distances on the route are adequate. Visibility issues could occur around the bend at the Moria intersection. Pedestrian facilities such as sidewalks were not provided on the route.

## Pedestrian observations

Observations showed that where crossing facilities are available most pedestrians did not make use of them. They preferred to cross along the links. This could be due to the fact that at yield controlled intersections, vehicles hardly yielded for pedestrians and at most signalised intersections a separate pedestrian phase was not provided therefore turning vehicles made it difficult to cross safely. Pedestrian desire lines also seemed to be located further away from the intersections. Crossings were witnessed at numerous locations along the R71 links.

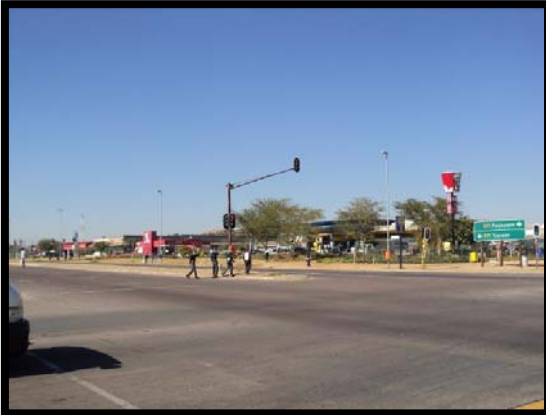


Pedestrians and public transport have not been catered for at schools, this has resulted in illegal taxi u-turns on the R71 and random and unsafe crossings by students. Lack of sidewalks and road shoulders cause students to walk in the road.

### R71 land use

A variety of land use is situated adjacent to the R71. These include clinics, liquor restaurants, hardware stores, shopping centres, fuel stations, educational institutions such as schools and a university etc. A majority of these are accessed illegally on the R71, no pedestrian facilities are provided for these land uses. The large number of liquor restaurants/lounges that are located along the road, are a concern, particularly because the R71 is used as the main access to the facilities.





Near accidents or conflicts were observed at intersections. At yield-controlled intersections where drivers failed to yield for pedestrians and at traffic signals where pedestrians conflicted with turning movements. Pedestrians illegally crossing up or downstream of intersections frequently ran across the road to avoid on-coming traffic. Crossings along links had minimal near-accidents when observations were made. Perhaps this was affected by the time of day of observations as this was done in the late morning and early afternoon.

The visual assessment indicated the following areas of concern:

- Unsafe intersection crossings for pedestrians.
- Limited vehicular yielding or slowing down at intersections.
- No pedestrian facilities.
- Numerous adjacent land uses and lack of access to them.
- The location of liquor restaurants along the R71.
- Limited public transport facilities.
- No pedestrian and public transport facilities at schools.
- Wide intersections and thus pedestrian crossings consisting of crossing four approach lanes.
- A minimal road shoulder causing pedestrians to walk in the road.
- Minimal lighting along the route only provided at large intersections.

The R71 is a typical mobility road with a well maintained pavement, wide lanes and wide intersections, this possibly makes it difficult for motorists to slow down and yield for pedestrians particularly because there is no clear transitions between rural and village sections on the road.

### 3.3.3 Data assimilation and analysis

Qualitative and quantitative raw data was obtained for the study area based on the problems identified in the site observations and the accident statistics. The data was processed and presented graphically in order to provide a visual guide on the status quo conditions for the R71. The data collected for the study is discussed individually in the preceding sections, all processed data is analysed to investigate its impact on the safety of the R71. Status-quo maps are provided in the **Appendices**.

#### 3.3.3.1 Traffic counts

Manual traffic counts are typically characterised by inaccuracies due to human error. SANRAL's Comprehensive Traffic Observations (CTO) for the R71 were used to determine the general traffic patterns in the study area. The survey period spanned from 1<sup>st</sup> January 2011 to 13<sup>th</sup> June 2011, it was then extrapolated to 31<sup>st</sup> December 2011. The data is summarised in **Table 6**.

The AM and PM peaks correlate with those obtained in the manual count survey. The AM peak (7:00-8:00) also coincides with the school starting time (7:20) in the study area. The traffic volumes in Moria during the Easter pilgrimage are significantly higher than the survey volumes. This is represented by the occurrence of the highest hourly volume in

April 2011 (during Easter), however, Church pilgrimages are limited to a hand-full of weekend occurrences during the year.

Table 6: CTO for the R71 (SANRAL, 2011).

CTO Data : Site 1370 R71 Polokwane	
Average Daily Traffic	17199
Percentage Trucks	6.3%
Highest hourly volume on the road	(2011/04/21) 2255
30 <sup>th</sup> Highest volume on the road	(2011/03/22) 1815
Typical AM Peak	7:00-8:00
Typical PM Peak	17:00-18:00

Unclassified intersection counts (AM and PM) were conducted along the R71 on Thursday 20 June 2013 at intersections in areas that have pedestrian accidents. Traffic was manually counted by 31 enumerators sourced from the local community. The counts took place under normal conditions from 6:00 to 9:00 and 15:00 to 19:00. The surveys were conducted at the 8 counting stations indicated in **Figures 25-27**.

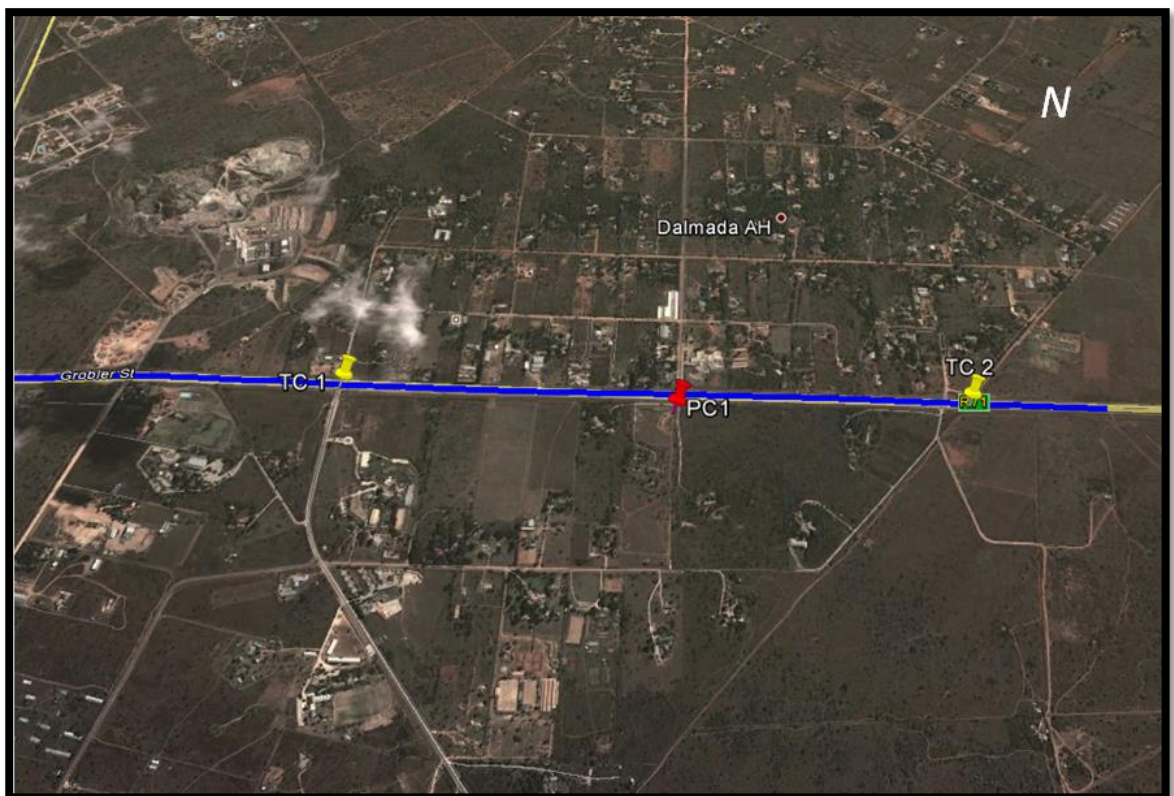


Figure 25: Traffic and pedestrian count locations in Dalmada (Google image).

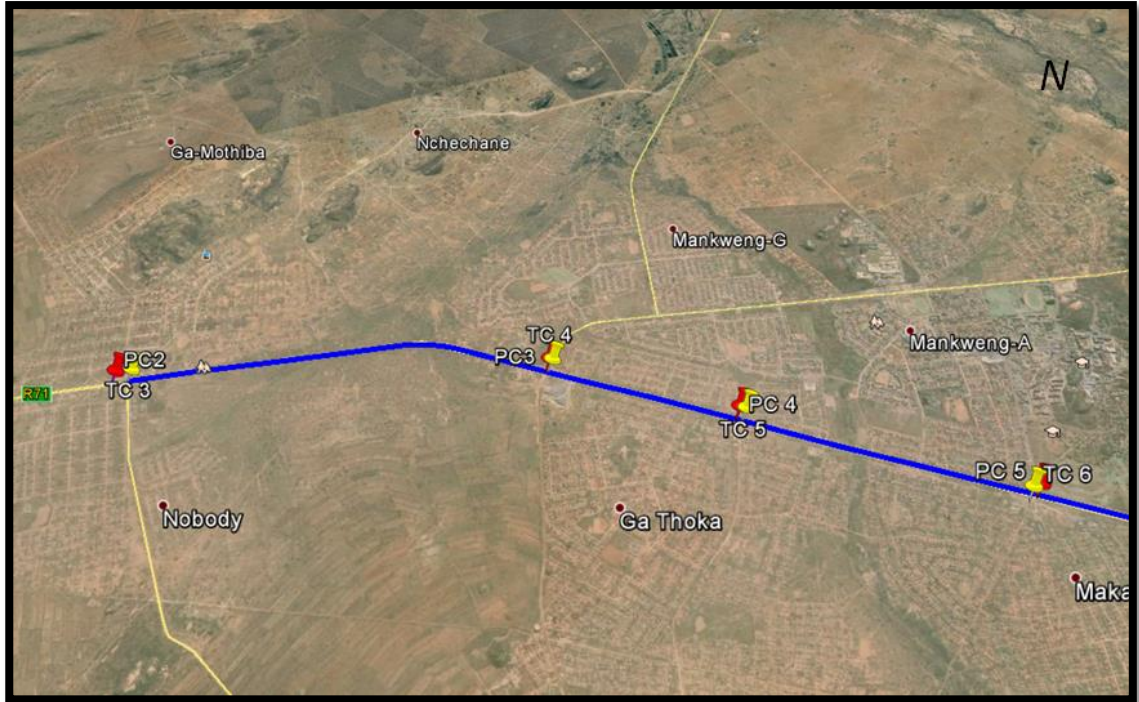


Figure 26: Traffic and pedestrian count locations at Nobody and Mankweng (Google Image).

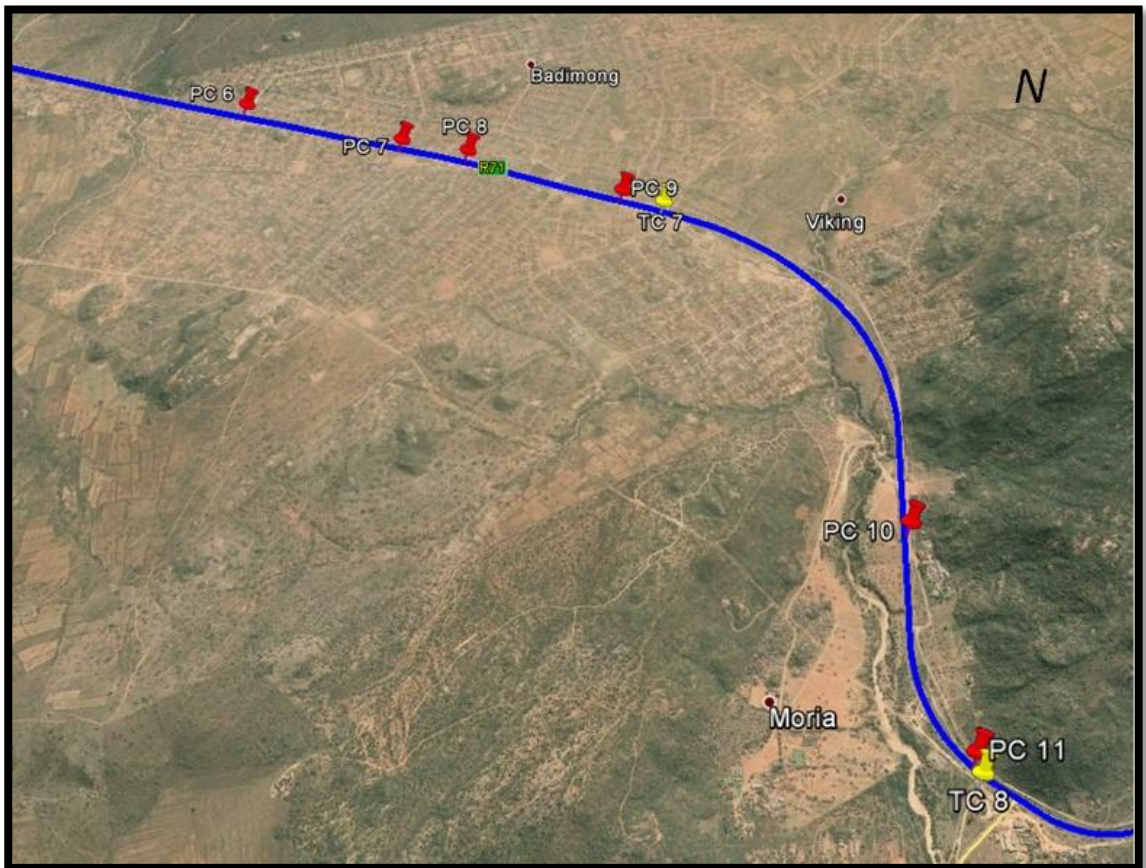


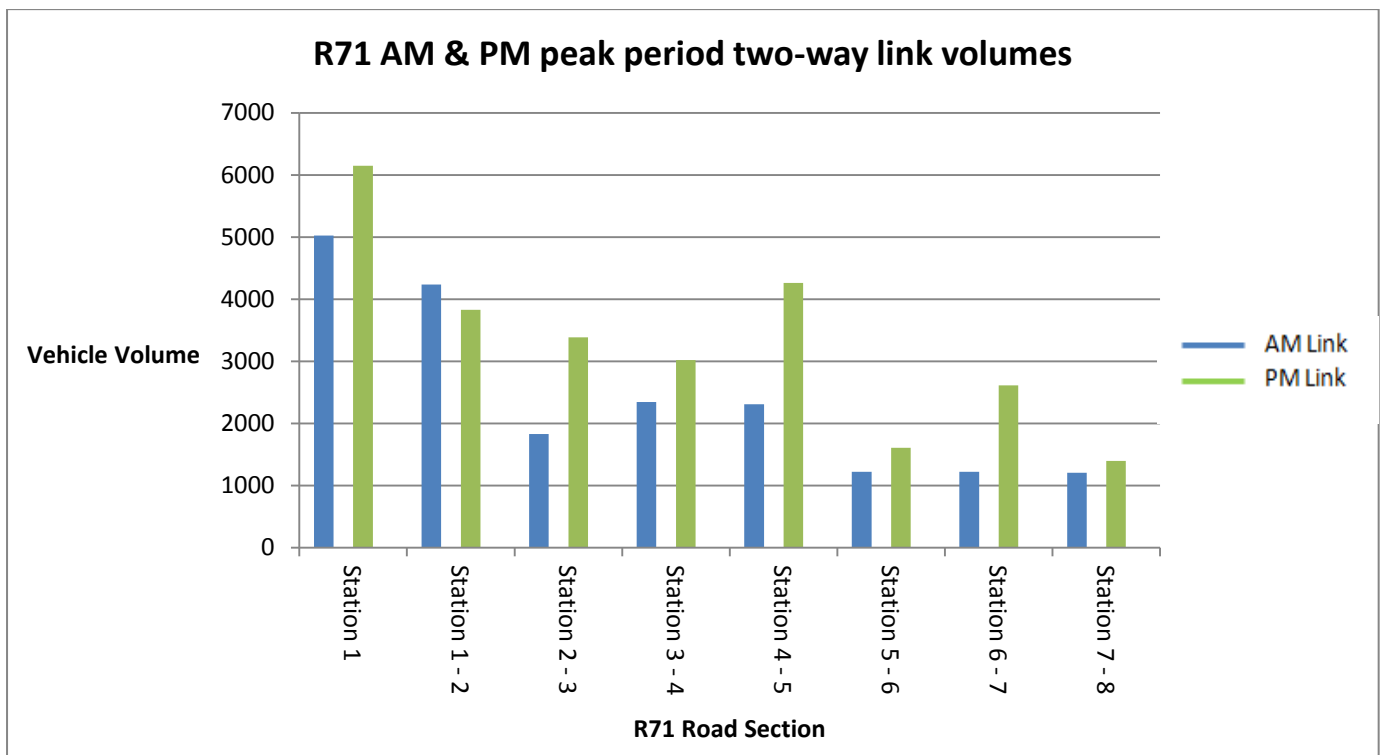
Figure 27: Traffic and pedestrian count locations at Badimong, Viking and Moria (Google Image).

Link volumes along the R71 were extracted from the data to provide a vehicular volume profile along the study area that illustrates the locations with the highest traffic volumes. The total link volumes for the AM and PM periods are summarised in **Table 7**. Drawings of mapped link volumes are included in the **Appendices**.

**Table 7: The link volumes on the R71 study area.**

Link Volumes			
Station Number	Township Name	AM (6:00-9:00) Link Volumes	PM (15:00-18:00) Link Volumes
Station 1	Dalmada	5027	6149
Station 1 - 2	Dalmada	4236	3831
Station 2 - 3	Nobody/Ga-Mothiba	1830	3385
Station 3 - 4	Mankweng	2347	3019
Station 4 - 5	Mankweng	2310	4261
Station 5 - 6	Mankweng	1224	1608
Station 6 - 7	Viking/Badimong	1224	2613
Station 7 - 8	Moria	1208	1398

The survey results indicate that Dalmada, Mankweng and Nobody have the highest link volumes in the study area. The locations along the R71 with the lowest traffic volumes are Moria and Viking. The link volume variation in the study area is illustrated in **Figure 28-30**.



**Figure 28: AM and PM two-way link volumes in the R71 study area.**

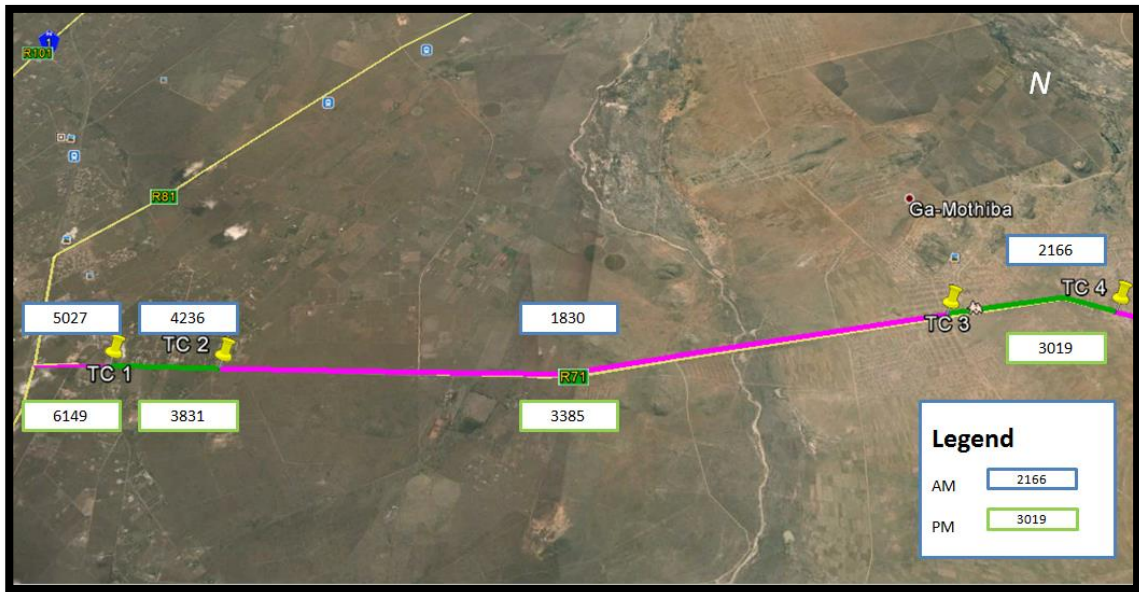


Figure 29: AM and PM link Volumes on the R71.



Figure 30: AM and PM link Volumes on the R71.

The traffic volumes in the study area are low. The design hour vehicle capacity per lane for dual carriageways is 1400 vehicles, some road sections had less than this for the entire 3 hour AM period. A comparison of the traffic counts and the number of accidents per area does not show any correlation except for that the SANRAL CTO highest hourly traffic in April that coincides with the spike in pedestrian accidents in April. Moria and Nobody have the highest number of incidents however their volumes fall within the lowest

of all volumes in the study area. With the exception of the ZCC pilgrimage, traffic volumes do not seem to have any relationship to the number of accidents that occur in an area.

### 3.3.3.2 Speed surveys

Speed limits are the maximum speed (in good conditions) that people can legally drive along a section of roadway. They are set to promote safety and provide a balance between safety and mobility. A comparison of the posted and actual speeds provides information on driver behaviour/ compliancy rates and indicates high risk locations. Higher order rural roads have the challenge that in rural sections, the posted speed limit can be 100 to 120km/h, and then through villages can be reduced to 60km/h. Many drivers do not adhere to this change in speed limit through villages, with the reduction in safety for drivers and pedestrians. A report by SANRAL states that more than 33% of accidents on rural roads occur at at-grade intersections (SANRAL, 2009).

Posted speeds in the study area were recorded during a site visit and average speeds (85<sup>th</sup> percentile speeds-the speed at which 85% of vehicles travel) were obtained from TOMTOM, a company providing vehicle navigation solutions. The average speeds were extracted from historical traffic data for the R71 spanning from 2009 to 2012. The average speeds are mapped in **Figures 31 to 33** and on the Route Status-Quo drawings provided in **Appendix A** for the study area. A speed profile, which is a graphical representation of the 85<sup>th</sup> percentile speed achieved along the length of the highway segment and the posted speed are provided in **Figure 34**.

The figures illustrate that the speed limit is adhered to only in Mothibaskraal and Nobody. The highest speeds were recorded in Dalmada, Mankweng, Badimong, Viking and Moria ranging from 80km/h to 110km/h with a posted speed limit of 80km/h-100km/h, in these areas the 85<sup>th</sup> percentile speed exceeds the posted speed limit. The speeding was recorded along the links and at intersections in the aforementioned areas.

The CTO data indicates that the overall average speed in the study area is 100 km/h and 51% of all vehicles on the R71 are exceeding the speed limit (SANRAL, 2011). As stated in **Section 2.4.3.9**, at impact speeds of over 30km/h, pedestrians risk sustaining life-threatening injuries and at 60km/h, death is virtually certain.

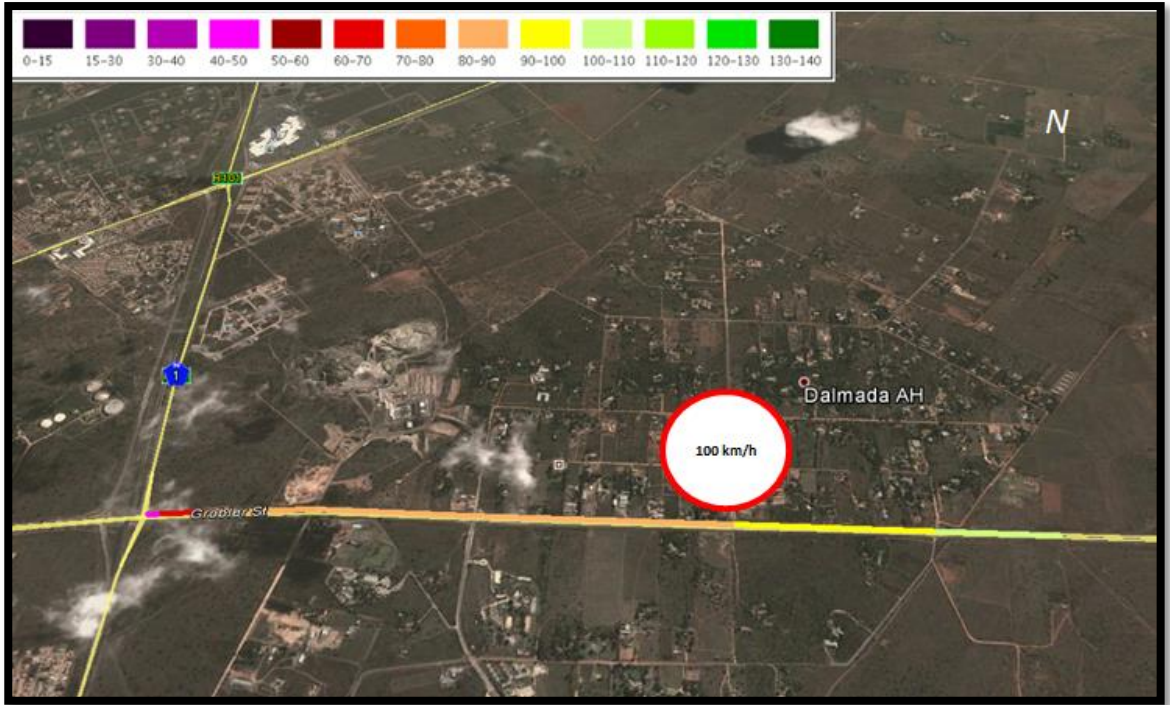


Figure 31: Actual average speeds in Dalmada (TOMTOM, 2012).

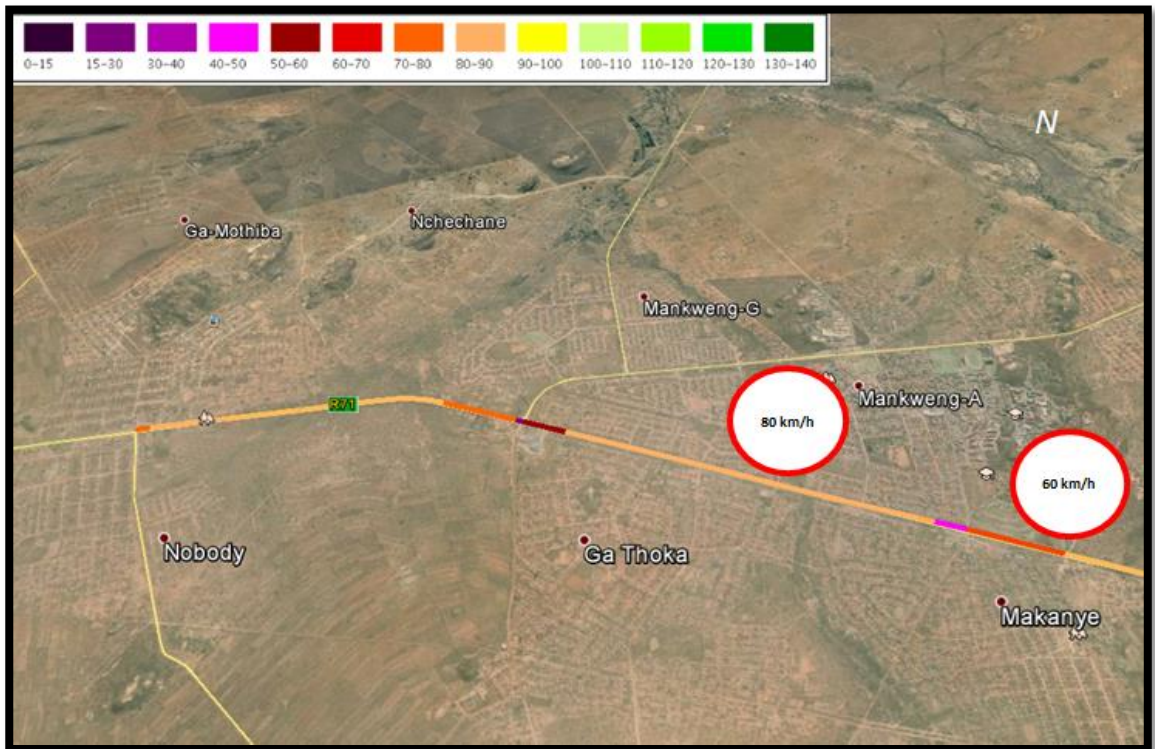


Figure 32: Actual average speeds in Mothibaskraal, Nobody and Mankweng (TOMTOM, 2012)

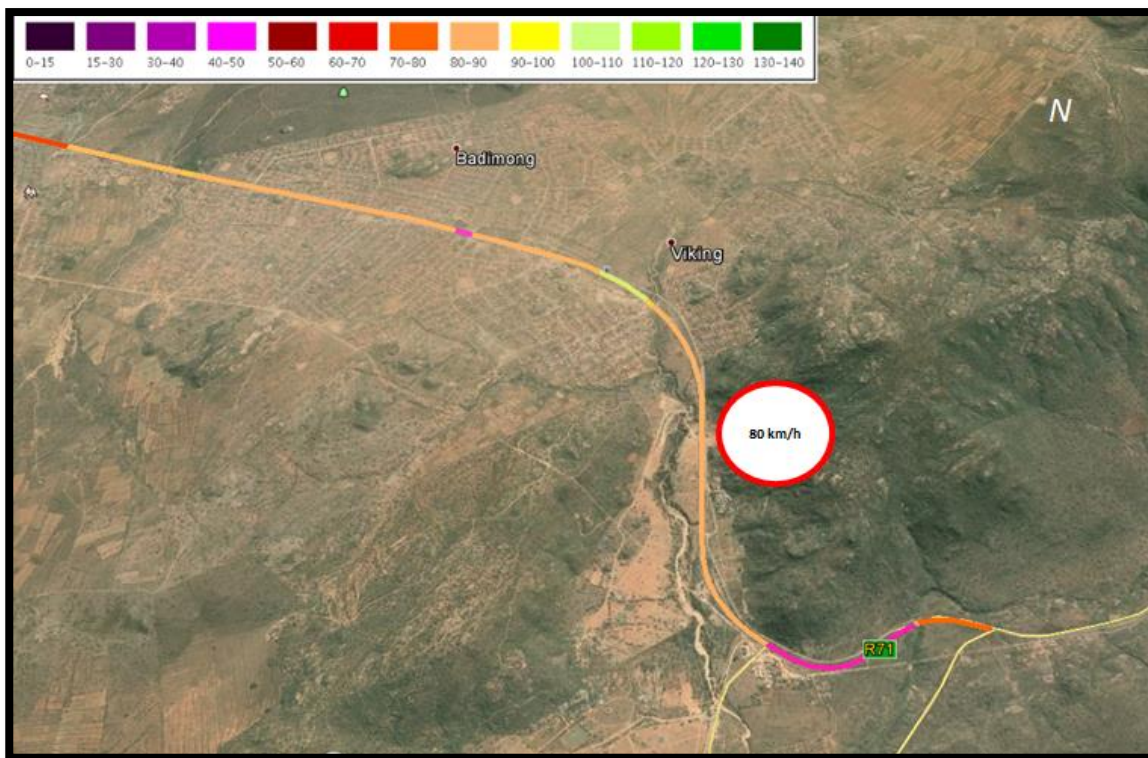


Figure 33: Actual average speeds in Badimong, Viking and Moria (TOMTOM, 2012).

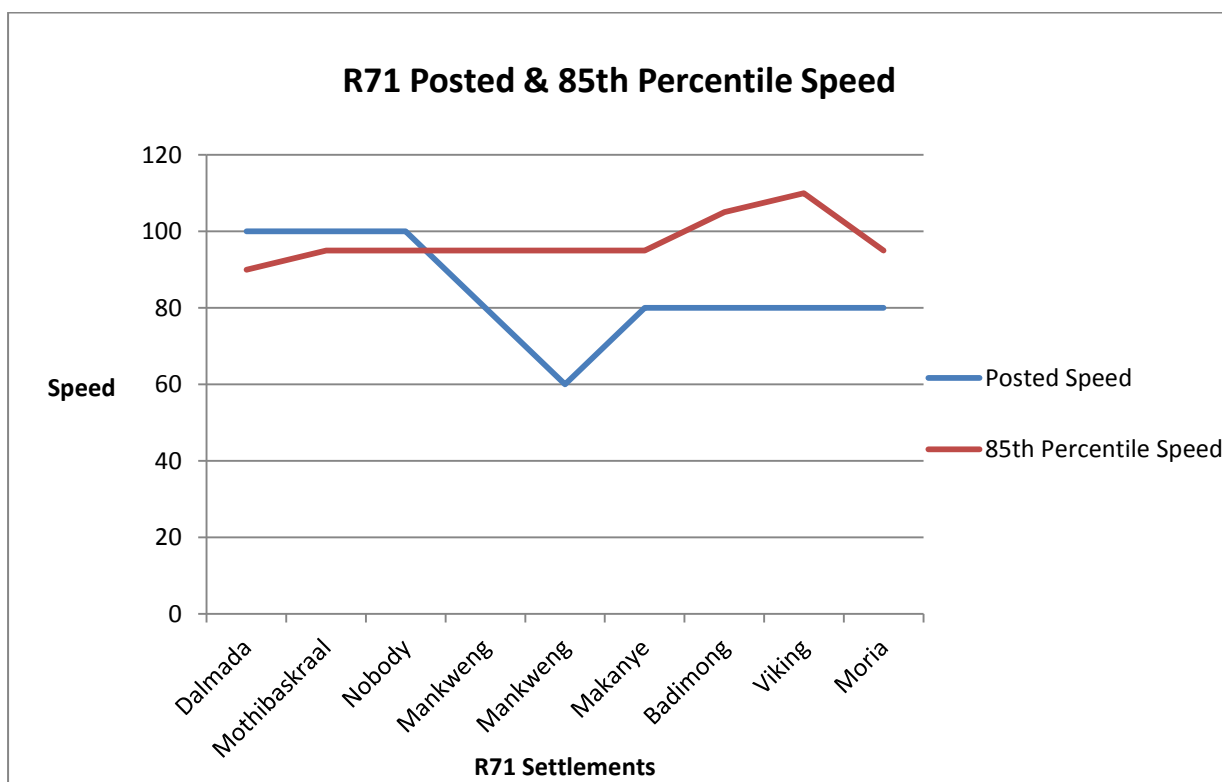


Figure 34: A speed profile of the posted and the 85<sup>th</sup> percentile speeds in the study area.

From this analysis it can be concluded that the 85 percentile speed exceeds the posted speed in many areas along the R71. The problem is more acute at intersections particularly because they are located in built up areas and they are the primary access for pedestrians and vehicles in the settlements. Problems associated with high speeds at intersections are a higher probability of non-compliance of traffic controls caused by vehicles not being able to stop which creates unsafe access and crossing conditions for pedestrians and vehicles particularly at yield and stops controlled intersections. The current speed reduction measures used are posted speed signs that advocate speed reduction as drivers approaches intersections and warning signs that indicate the presence of pedestrians. These measures are clearly not effective. The reasons for this could be due to poor signage placement that is not conducive to gradual speed reduction; poor sight distances, the lack of physical measures that safely enforce speed reduction etc.

The following is required:

- Understanding the average speed and its impact on safety at intersections
- In light of this, determining the reasonable speed reductions that can be achieved to make intersections safer.
- Changing the road environment to clearly inform drivers of the transition between rural and village sections
- Creating homogeneous speed reductions at villages along the route.

The speed limit was also being exceeded along links. This may be indicative of a mismatch between the posted speed and the geometric character of the road. Speed infringements were noted at these locations (**Table 8**):

**Table 8: Summary of speed infringements**

Area	Link	Intersection
Dalmada	X	X
Mankweng		X
Badimong	X	
Viking	X	X
Moria	X	x

### 3.3.3.3 Location of land use

Movement is driven by the need to access land use; the size, type and location of which dictates where people will travel. Land use such as shopping centres, education institutions, churches and hospitals generate the largest pedestrian volumes. Their location and access management has a large impact on the surrounding road network and

the community at large. The higher the number of such land uses near a road the greater the number of pedestrian crossings and the higher the risk of pedestrian accidents.

The land use locations in the study area were presented on maps (**Appendices**). The maps indicate the following:

- The schools within 2km of the R71;
- Attractions (shops, clinics, liquor restaurants) along the R71;
- Household density;
- Public transport facilities;
- The density of built-up areas along the R71;
- and Access points along the R71.

Every area in the study has schools within 2km of the R71. Mankweng has the highest density of schools and Viking has the least. The schools in Makanya, Moria and Dalmada are located at the edge of the road reserve all of which use the R71 as their main access. School starting times coincide with the R71 AM peak discussed in section 6.5. Section 6.1 Socio-Economic data states that 91.5% of scholars in the study area -Polokwane East-walk to their education institutions. Peak traffic volumes coupled with walking scholars that do not have any pedestrian facilities increases the possibility of conflict. The risk of scholar pedestrian accidents on the R71 is substantially higher at these locations. Safety interventions in these areas should consider the behaviour and needs of scholars.

A large number of university students live off-campus in Mankweng and the neighbouring villages and many of the administration staff use public transport that drops them off at the R71 intersection. Accidents in the area are minimal however the area has the potential of becoming a high risk. Pedestrian volumes at this intersection need to be understood to address the possibility.

High densities of attractions are found in Mankweng, Nobody and Dalmada. The Attractions that typically generate substantial pedestrians include shopping centres and health facilities such as clinics, these facilities are available near intersections in Mankweng and Nobody. Liquor restaurants are also located along the road, mostly in Mankweng near the University of Limpopo. These typically generate evening pedestrian trips. Intoxicated pedestrians have impaired judgement which increases the risk of pedestrian accidents in the vicinity of the facility.

Households are concentrated along the R71 with Mankweng having the highest household densities compared to the other areas. Household density and thus population density doesn't seem to be an issue in terms of pedestrian risk in the study area this is because Mankweng already has a higher number of formal crossing locations and the urban environment may have an impact on the behaviour of motorists.

Formal public transport laybys are provided at intersections on the R71 because the route is a public transport trunk. The majority of the access roads within the areas – except for Mankweng and sections of Moria – are unsurfaced which deters public transport operations. Pedestrians therefore have to walk to the R71 to get public transport.

Informal public transport facilities are located at some intersections but mostly along the links in proximity of land uses such as schools. Taxis also stop illegally anywhere on the R71 to service the available demand. Many intersections on the R71 are also utilised as taxi holding areas, particularly in Mankweng and Badimong. Informal holding areas and taxi stops at intersections reduce sight distances and result in poor intersection operations. Illegal stopping and u-turns on the links can be fatal for other motorists and pedestrians making use of the service. Other drivers do not expect the abrupt taxi stop and unanticipated pedestrian movements on a higher order road. Mankweng, Dalmada and Nobody have the highest density of public transport stops on the R71.

Illegal accesses are prevalent through the study area. A majority of legal and illegal accesses were surveyed in Mankweng and Badimong/Viking. Illegal accesses, u-turns and right-turns are caused by the dynamic of seeking economic opportunities, uncurtailed poor land use planning and poor internal access road provision and maintenance. The R71 is therefore the only current access option for adjacent land use. The impact of illegal accesses on pedestrian safety is the possible conflict that may occur between pedestrians and vehicles illegally entering and exiting the road. If unprotected sidewalks are provided these operations will create unsafe walking conditions, the safety implications on the R71 may be far worse.

At the time of the surveys proposals were submitted for constructing a shopping centre along the R71 in Dalmada and the Department of transport had completed an operational plan for a Rapid Transit System on the R71 comprising of a trunk route with a public transport interchange in Mankweng. Both these developments are high pedestrian generators and their proximity to the R71 poses a high risk for pedestrians in the future.

Land use have different characteristics that affect the type of traffic and the times that this traffic is generated. Shopping centres have high Friday and weekend trips while clinics may have particular days for immunisations etc. that affect the peak.

The study area can be characterised by ribbon developments en-route the R71 that have been induced by the quest for economic opportunities as well as the lack of access roads. Internal/access roads have poor riding quality and infrequent maintenance, therefore communities and businesses favour access onto the surfaced roads R71 (Henderson). Over the years development has occurred along the R71 based on ease of access. Examples of this are the construction of schools across the road from the school feeder population. Lack of planning has resulted in easy access for the teachers but the positioning of the schools requires pupils to either walk on the R71 or to cross it. No provision was made for the safe movement of learners to the school.

Land use planning along the R71 has been neglected, and the location of government services has not been co-ordinated and as such has resulted in road safety aspects being ignored in the development of infrastructure. Unregulated landuse make it near impossible to provide effective interventions, i.e. new desire lines develop and formal crossing points become redundant. Land use attract pedestrians and public transport and increase safety risks.

### 3.3.3.4 Pedestrian origins and destinations and volumes

Manual pedestrian counts (AM (6:00- 9:00) and PM (15:00-18:00)) were conducted at eleven sites in the study area on the 20<sup>th</sup> of June 2013. The counts were conducted by 11 enumerators sourced from the study area. Refer to **Figures 25-27 in Chapter 3.3.3.1** for pedestrian count station locations. The locations were selected according to the following:

- **The density of pedestrian desire lines at the R71** – The thicker a pedestrian desire line/ informal pedestrian pathway, the greater the pedestrian demand at that location.
- **The proximity and density of land use near the R71** i.e. schools, shops and retail, liquor restaurants, churches, clinics, public transport facilities, etc. The aforementioned land uses are examples of primary trip generators. Primary land use is typically characterised by high pedestrian volumes that create dense pedestrian desire lines.
- **Access roads/ intersections.** Access roads serve the function of local collectors. In townships they are used by both pedestrians and vehicular traffic to access larger order roads. Public transport is generally located at the intersections of local collector roads and higher order roads.
- **Pedestrian Accidents**  
Pedestrian counts were done in areas with pedestrians accidents.

Enumerators were strategically located in these positions to capture dominant pedestrian movements across the R71.

### 3.3.3.5 Pedestrian count analysis

A map of the detailed pedestrian count analysis is provided in the **Appendices**. The pedestrian count analysis revealed that the highest volumes of pedestrians were crossing at Mankweng, Nobody and Moria and the least were recorded at Badimong and Dalmada (refer to **Figure 35 and Table 9**). Peak pedestrian volumes were observed between 6:15 to 9:00 and 15:30 to 18:45 during the morning and afternoon periods respectively. Pedestrians in Mankweng, Nobody, Viking and Moria are predominantly characterised by school children.

**Table 9: Pedestrian count analysis for the R71 study area.**

Settlement	Count Station	AM	PM	Total	AM Peak	Peak Hour	PM Peak	Peak Hour	Pedestrian Type
Mankweng	10	1912	273	2185	1177	6:45-7:45	140	16:15-17:15	Mostly children
Nobody	2	585	825	1410	306	6:45-7:45	378	16:15-17:15	Mostly children
Mankweng	11	556	507	1063	398	6:45-7:45	286	16:30-17:30	Mostly children
Moria	8	504	488	992	216	6:15-7:15	231	15:30-16:30	Mostly children
Mankweng	9	330	458	788	202	6:30-7:30	268	16:15-17:15	Mostly children
viking	6	331	216	547	217	7:30-8:30	98	16:15-17:15	Mostly children
Badimong	3	204	298	502	97	7:45-8:45	132	16:45-17:45	All
Moria	7	217	156	373	115	8:00-9:00	74	16:30-17:30	All
Badimong	4	154	208	362	81	7:15-8:15	105	16:00-17:00	All
Dalmada	1	150	124	274	98	6:15-7:15	54	16:45-17:45	All
Badimong	5	120	113	233	68	6:30-7:30	85	15:30-16:30	All

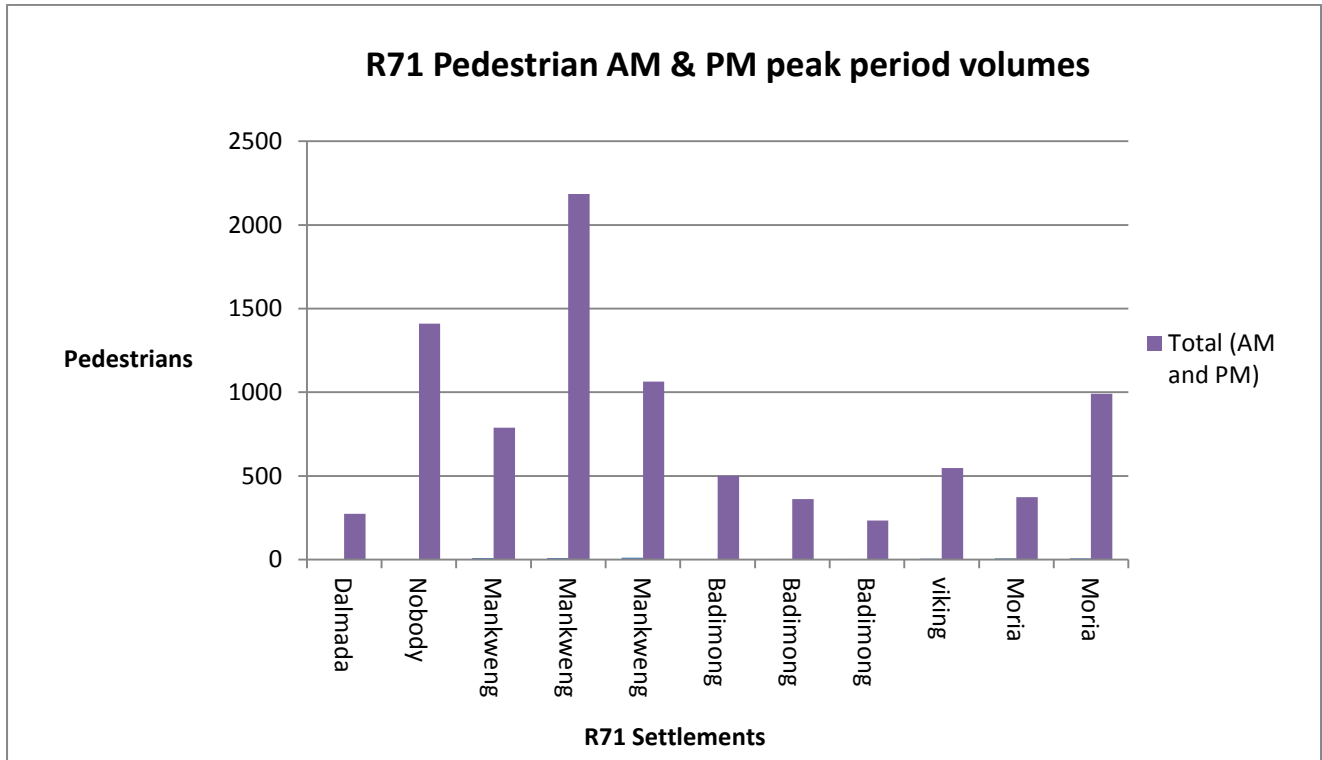


Figure 35: The total pedestrian volumes per area along the R71.

High pedestrian accident areas discussed in **Section 3.3.1** were Moria, Mothibaskraal and Nobody and Mankweng and Viking were the lowest. The relationship between accidents and pedestrian volumes seems to be directly proportional, the higher the volumes the higher the accidents. However, this doesn't apply to urban areas such as Mankweng where volumes are high but accidents are low because higher level interventions have already been applied. The peak hourly pedestrian volumes in the entire study area should be assessed to determine the appropriate pedestrian facilities to mitigate accidents.

### 3.4 SUMMARY OF STATUS QUO

The Status Quo analysis was based on the Situational Assessment Guidelines discussed in Chapter 3. These are: Assessment of Accident Statistics, Site Visual Assessment, Problem Identification and a Detailed Analysis of the problem. Limited data made it difficult to conduct detailed analysis, particularly for pedestrian and driver behaviour. However some deductions have been made.

Pedestrian safety is a concern in the study area. The accident data indicates that the number of pedestrian accidents account for 49% of the total accidents in the study area. This is greater than the National average of 33%.

The most apparent of all analysis from the status-quo is the relationship between settlement type and the number of pedestrian accidents. Accidents occurring in the village and rural sections, agricultural and urban settlements were 81%, 13% and 6% respectively. Analysis of accident times indicated that 59% of all accidents occurred in the

evening, 25% in the afternoon and 16% in the morning. A summary table of the status-quo analysis is provided:

**Table 10: A summary of high risk areas on the R71.**

<b>Risk Factors</b>	<b>High Risk Areas</b>
Pedestrian Accidents	Moria and Nobody
Link Volumes	Dalmada, <b>Mankweng</b> and Nobody
Speed	Dalmada, Viking and Moria
Density of Schools within 2km of R71	<b>Mankweng</b>
Points of nearest interest	<b>Mankweng</b> , Nobody and Dalmada
Illegal Accesses	<b>Mankweng</b> and Badimong
Public Transport stops	<b>Mankweng</b> , Badimong and Nobody
Pedestrian Volumes	<b>Mankweng</b> , Nobody and Moria
High Risk Areas	Dalmada, <b>Mankweng</b> and Moria

Mankweng was consistently counted among the settlements with the highest risk factors in the study area. It had the highest number of vehicular and pedestrian volumes, the highest density of schools within 2km of the R71, the highest number of points of interest etc. However, contrary to this perceived risk, Mankweng has the lowest number of pedestrian accidents in the study area. Settlement type seems to play a pivotal role in the reason for this.

Mankweng is an urban area located amongst villages. The site visual assessment indicated that Mankweng has better infrastructure as compared to the rest of the areas i.e. paved access roads with a clearly defined hierarchy, a higher number of formal crossing opportunities (intersections), signalised intersections with a pedestrian phase at one, lighting etc. The provision of such infrastructure contributes to the low number of accidents in the area.

The urban nature of the settlement also contributes to the higher safety. Land use density, advertising, high pedestrian and vehicular volumes may lead to a reduction in speed particularly within the settlement. The gradual land use transition between rural areas and Mankweng may also prompt drivers to slow down as they enter Mankweng.

An analysis of the villages indicates that pedestrian accidents are directly proportional to all the risk factors assessed in the status-quo. Moria and Nobody consistently scored as

areas with some of the highest risk as well as having the highest number of pedestrian accidents. The overarching problem in rural areas and villages is the non-existent land use planning, inadequate access provision, non-existent pedestrian infrastructure provision and poor design of speed transition zones between rural and village sections.

The function for a Pedestrian Safety Risk Index can only be assessed when a comprehensive data set is provided, this is particularly important when calculating the weights for the different risk factors. The lack of descriptive accident data necessitates for an in-depth data collection exercise in the future. Multi-criteria analysis is a tool that can be used when the data is available to assess the pedestrian safety risk at different locations in the study area.

Pedestrian Safety Risk = **a**(pedestrian behaviour)+**b**(driver behaviour)+**c**(road design)+**d**(land use)+ **e**(accidents\*km travelled) + **f(F)**

- **a, b, c, d, e** and **f** being weighting factors
- **F** being other factors which have not been included i.e. vehicle condition etc.

A simplified method to calculate risk was used to identify the high risk areas in the settlement. Locations that frequently scored highly in the status-quo risk factor assessment were identified as high priority locations. The areas that appear in **Table 9** were identified as one of the highest in each status-quo category. These are thus considered as high risk areas. High risk areas were identified (based on Table 9) as Mankweng, Badimong, Nobody, Dalmada, Moria and Viking. It is crucial that these areas be provided with adequate safety interventions.

The R71 is a Class R2 road; its function is to provide regional connectivity between Tzaneen and Polokwane. RCAM states that pedestrian access on a Class R2 should be isolated. The traffic volumes, posted speeds, number of lanes, road geometry, limited access and vehicle right of way make it extremely difficult for pedestrians to cross safely. The accidents that occur in the study area are a testament to the problem. The safety issues on the R71 are a symptom of the following underlying causes:

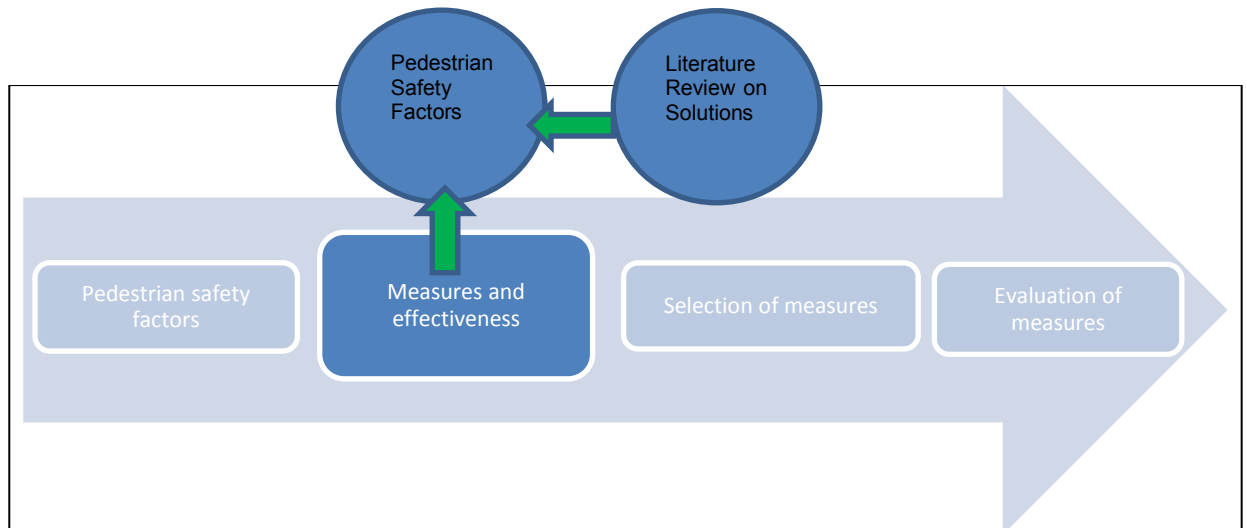
- Disintegrated land use and transport planning;
- Lack of pedestrian infrastructure.
- Poor design of speed transition zones between rural areas and villages and urban areas.

Finding appropriate solutions to the aforementioned causes is crucial to improving pedestrian safety on the R71.

## 4. MEASURES AND PROVEN EFFECTIVENESS

### 4.1 INTRODUCTION

The literature review is a composite of local and international engineering solutions for pedestrian safety problems. Solutions which possibly address the risk factors discussed in the status quo analysis are investigated in this chapter. In the past, pedestrian safety solutions were solved by simply addressing one of the three E's (Engineering, Education, Enforcement) in isolation (ITS Engineers, 2009). Role players in the road safety arena (Engineers, law enforcement, designers, planners, educators, and citizens) have realised that they should all be involved in identifying and implementing effective countermeasures for improving pedestrian safety. The engineering solutions in this project will be matched with complimentary measures – education and enforcement etc.- that will provide a holistic and therefore effective solution. The methodology for this section is summarised in the schematic below.



### 4.2 COUNTERMEASURES

Countermeasures for improving pedestrian safety can reduce fatalities and injuries by causing changes in behaviour, attitudes and knowledge. Retting, Ferguson and McCartt (2003), describes the typical engineering solutions/modifications to the built environment that can reduce pedestrian risk in three broad categories:

- Separation of pedestrians from vehicles by time and space (control of crossings- gap acceptance, traffic signal control-) (pedestrian bridge, alternative routes, walls preventing pedestrians to enter the road reserve),
- Measures that increase the visibility of pedestrians (lighting, warning signs and road markings to improve the alertness and reaction time of the driver.), and
- Reductions in vehicle speeds (signs, law enforcement, physical measures – speed humps, raised pedestrian crossing (ITS Engineers, 2009).

Separation countermeasures reduce the exposure of pedestrians to potential harm both on the roadside and when they are crossing streets. In many pedestrian crashes the driver reportedly does not see the pedestrian before the accident; measures are needed to increase the visibility of pedestrians. As discussed in Chapter 2, higher vehicle speeds are associated with a greater likelihood of crashes involving pedestrians as well as more serious pedestrian injuries Retting et al (2003).

Literature on the effectiveness and functionality of measures will be presented in this chapter.

### 4.3 ROAD DESIGN MEASURES

Pedestrian safety cannot be addressed in isolation of the rest of the road design elements as well as the planned or prevailing land uses in an area. When decision-makers, engineers and planners routinely consider pedestrian safety as part of integrated roadway design and land-use planning, pedestrian safety is built into the transport and urban system. An integrated “built environment” focus is required for the holistic success of any project. Ways to improve the different components of the built environment (pedestrians and drivers, land use and the road network) will be discussed.

Roads are designed around the following basic criteria:

- Road class and function,
- Access management,
- Land use served and planned,
- Geometric design (design speed determining sight distances, alignment),
- Demand and hence capacity and cross-section (number of lanes per direction),
- Constraints (terrain, budget, etc.).

Decisions made on the basis of these criteria should incorporate the needs of pedestrians. Introducing pedestrians on a higher order road presents a compromise situation where vehicular mobility has to be constantly weighed against pedestrian safety. The types of measures that can be applied to address pedestrian safety issues arising from the road design criteria will be discussed.

A basic principle that should be applied throughout is the hierarchy of road safety design. The aim should be to prevent a conflict situation by proper design rather than reverting to warning signs. Mitigation of the impact of an accident should therefore be considered on all elements of the road. The following steps can be employed to make sure that pedestrian safety is incorporated into road design:

- Prevent: All aspects of the design should be to such a design standard that accidents/conflicts are prevented from an engineering perspective – adequate radii, sight distances, limited conflict points, etc. should be provided.
- Warning: where changes in the road or dangerous situations occur, the driver should be provided with adequate warning to react. This is typically done with road signs or markings.

- Mitigate: on any section of the road accidents will occur. The impact of this should be mitigated through road design– wide enough shoulders and recovery areas, no or limited hazardous objects within the road reserve, etc. (ITS Engineers, 2009).

#### 4.3.1 Road class and function

The R71 is classified as a Class R2 rural major arterial the primary characteristics of which are to provide mobility by predominantly and continuously serving inter-regional through traffic over long distances between:

- Smaller cities and medium to large towns,
- Class 1 and 2 routes, and
- Important regions, transport nodes and commercial areas that generate large volumes of freight and other traffic.

The ideal pedestrian safety situation for mobility roads is to completely separate pedestrians and vehicles in space with no at-grade crossings, however, with Class R2, pedestrians are allowed in the road reserve. The dual role of the Class R2 is achievable in low pedestrian volume areas. The situation becomes complex at developing villages and semi urban areas such as the R71 study area. The mobility function of the R71 is compromised by the allowance of full access for developments along the road resulting in a direct conflict between mobility and access functions (COTO, 2011).

#### Modified highway cross-sections

In the rehabilitation of an existing Class R2 road, specific attention should be paid to reducing the conflict points between vehicles and pedestrians. The following separation should be part of the design to ensure the minimum number of conflict points between pedestrians and vehicles:

- Pedestrian facilities need to be part of the cross-section for each road classified according to the road hierarchy. Pedestrian facilities are ideally not required on mobility roads but where pedestrian volumes are high mobility roads must acknowledge specific pedestrian requirements such as crossing major intersections or freeways. Pedestrian facilities should preferably be some distance away from the edge of the road or physically separated using kerbs, guardrails etc. to avoid mixing the two modes. Where volumes are low pedestrians can make use of the road shoulder. Paved shoulders can reduce “walking along the road” pedestrian crashes as well as “run-off road” and “fixed object” crashes involving motor vehicles.
- Walls are required to concentrate movements to dedicated crossings as well as to reduce the number of conflict points.
- Access for vehicles can be limited by fences as well as providing barriers in the median of the road (ITS Engineers, 2009).
- Walls and fences are effective and functional only when adequate crossing points are provided and further sprawl is prevented.

A new school-of-thought is to ensure that all transport projects and programmes, from the planning, design, construction to maintenance stages, favour pedestrians first, then public transport passengers, cyclists, and lastly cars. In addition, street design conducted in a manner that supports context and modal priorities and is not limited by rigid engineering standards (Labuschagne & Ribbens, 2014).

### Self-explaining roads

To promote safety in pedestrian zones on higher order roads the “self-explaining road” concept can be used. This method is based on designing roads in built up areas that induce motorists to operate their vehicles in ways and at speeds that are appropriate for passage through urbanized areas. Self-explaining roads recognise that it is in these areas that they have the biggest conflicts between the purpose of roads for moving people and the value of roads in providing for exchange and access. Self-explaining roads are quickly understood, and easy for users to act on (NCHRP, 2012). Principles of self-explaining roads:

- Monofunctionality of roads as either through roads, distributor roads, or access roads in a hierarchically structured road network
- Homogeneity of mass and/or speed and direction
- Equality of speed, direction, and mass at moderate and high speeds
- Predictability of road course and road user behaviour by a recognizable road design
- Road environment and road user behaviour that support road user expectations through consistency and continuity of road design
- Forgivingness of the environment and of road users
- Injury limitation through a forgiving road environment and anticipation of road user behaviour
- State awareness by the road user
- Ability to assess one's capacity to handle the driving task (Bekiaris & Gaitanidou, 2011).

### **4.3.2 Enforcing access management guidelines**

A corridor access management approach involves seeking an appropriate balance between the safety and mobility of a roadway facility with the access needs of adjacent land uses. Access management should be considered as part of all projects, that involves new construction or reconstruction, as well as on major rehabilitation or roadway widening projects, especially facilities with moderate to heavy daily traffic volumes. Areas where effective access management has been implemented have experienced:

- “A 5-23% reduction in all crashes along two-lane rural highways, and
- A 25-31% reduction in severe (injury/fatal) crashes along urban/suburban arterials” (US DoT, Federal Highway Administration, 2014, p. 1).

Class R2 roads are rural highways, therefore at-grade intersections giving priority to through movement are allowed at strict spacing requirements. Occasionally grade separated intersections are found on Class R2 roads. Access to property as seen on the

R71 is prohibited unless the property is sufficiently large to warrant its own interchange and there is no present or future need to provide a public road intersection. Service stations and sometimes low volume (less than 10 vehicles per day) farm gates or tourists facility accesses are also permitted.

The minimum spacing requirements for full intersections on Class R2 roads is 5km. Where a road identified as a mobility road also serves an access function such as the R71, a check must be made to determine whether retrofit measures can be introduced to restrict accesses and activities along the road or whether alternative provision can be made for local land access. The separation measures discussed in the previous section should therefore take cognisance of the minimum spacing requirements (COTO, 2011).

### 4.3.3 Geometrics

#### Stopping Sight Distance

At intersections, designers should provide no more than the minimum required intersection sight distance on each approach. Excessive intersection sight distance can lead to higher vehicle speeds that reduce the safety of the intersection for all road users (NCHRP, 2012).

#### Pedestrian facilities

Pedestrian facilities must be designed with the most challenged users in mind – pedestrians with mobility or visual impairments- and the resulting design will serve all users.

- Intersection corners must be free of obstructions to provide enough room for pedestrians waiting to cross.
- Adequate lines of sight between drivers and pedestrians must be maintained on intersection corners and in the crosswalk.
- The road environment must indicate the actions that pedestrians are supposed to take at intersections. For example, crosswalks must clearly indicate where crossing should take place.
- Geometric design features and traffic control must be coordinated (ITS Engineers, 2009).

### 4.3.4 Reducing vehicle speed

Speed management is much more than setting and enforcing appropriate speed limits. It employs a range of measures in engineering, enforcement and education with the aim of balancing safety and efficient vehicle speeds on the road network. The engineering approach to speed management consists of a number of measures, system-wide speed reductions and traffic calming. Observations of driver behaviour revealed that the strongest indicator of operating speed was posted speed limit. Design speed appeared to have minimal impact on operating speeds unless a tight horizontal radius of a low k value was present (NCHRP, 2012).

### System-wide speed reduction

There is a growing effort to implement system-wide lower speeds for entire geographical areas instead of focusing on individual streets. System-wide speed reductions are typically implemented near and at intersections on higher order roads. However speed transitions need to be designed carefully to prevent extreme speed differentials amongst vehicles and to ensure that vehicles will in fact be able to slow down or achieve the posted speed limit.

Each driver chooses a speed at which they feel safe driving. Speed choice is based on a variety of factors:

- Highway characteristics (alignment, curves, grades, width, number of intersection, etc.)
- Weather and environment (rain, darkness etc.)
- Traffic (volume of vehicles, level of congestion etc.)
- Vehicle characteristics (age, condition, performance)
- Purpose of travel (commuting on familiar roads, vacationing, working etc)

Where drivers are unsure of an appropriate speed, large variations or speed differentials can develop. This results in less consistent traffic flow, increased driver uncertainty and /or frustration and increased crash risk.

Speed limits should be set so that they include the behaviour of the majority of drivers and provide an appropriate maximum speed. The normally careful and competent actions of reasonable drivers should be considered legal. This means that travelling at the speed limit should feel that it is truly a maximum or it's not an effective limit. Setting an appropriate speed limit increases speed limit compliance and reduces speed differential, resulting in reduced crash risk.

It is good practice to periodically review speed limits. Over time, changes to vehicle technology improvements to the highway, or development can result in speed limits that are out of step with driver behaviour.

The 85th percentile speed represents the speed at or below which 85% of vehicles travel. It is the predominant factor used in setting speed limits in North America (British Columbia Ministry of Transportation and Infrastructure, 2014).

### High-speed to low-speed transition zones for rural highways

As rural and other high-speed highways approach built-up areas, there is usually a transition zone where drivers are encouraged and expected to reduce their speed to one suitable for the environment they are entering. Design standards and policies exist for both the high-speed and low speed environments, but differences between the two make design of the transition zone a problem. Speed transition zones are designed as gateways to communities that safely and effectively prepare the driver to adjust to the different road environment.

A transition zone is defined to be a section of road that is continuous and connects a road section with a high posted speed limit to a section with a lower posted speed limit. The

transition zone should not be considered as a specific point along the roadway where a speed change is to occur, rather, it extends over a length of roadway. Designs that encourage gradual speed reductions over the length of a transition zone are preferred to designs that bring sudden reductions in speed at the downstream end.

The design of speed transition zones is related to the basic concepts of intersection treatments and traffic calming. The basic principle is that motorists are provided with warning signs devices and psychological measures early in the transition zone, and are then presented with physical measures closer to the community. The transition zone comprises of the following areas:

#### Rural Zone

“The rural zone is defined as a high-speed, rural roadway outside of a developed community. It has a high design speed (>72km/h), little roadside development, few access points, and is designed to facilitate high-speed, longer distance travel. There are relatively few features or potential conflicts that require driver attention in this zone. The design in this zone should be consistent with the high design and posted speeds.

#### Transition Zone

Located between the rural zone and the community zone, the transition zone is the area in which the community zone, the transition zone is the area in which drivers are expected to complete the necessary speed reduction to facilitate safe travel in a more developed area. The theoretical location and length of this zone are determined by a series of physical, operational, and safety characteristics. It may include a section that has similar characteristics to the rural zone. It may also include the edge of the developed community. It should however, have elements that differentiate it from the other two zones and inform and assist drivers in making the appropriate speed reduction. The two areas that make up the transition zone include the following:

#### Perception-Reaction Area

The portion of the transition zone where drivers are made aware of an impending need to change their speed and driving behaviour. The general physical and operational characteristics of this area are similar to the rural zone; however some elements should begin to change. Drivers in this area should have clear lines of sight to signs as well as other warning signs and or psychological devices that alert them to the changes ahead. These devices may be physically located in either the perception-reaction area and or the deceleration area, depending on the device and design criteria. Some deceleration may occur in this area, but the primary objective is to mentally prepare drivers to adjust their driving behaviour and speeds in the deceleration area.

#### Deceleration Area

This area is the portion of the transition zone where the driver is expected to decelerate to a safe operating speed for entering the developed area. Driver behaviour and awareness should adjust with the change in environment. The

roadway and roadside characteristics as well as the land use and access are generally beginning to change in this area. The deceleration area may include physical measures to reinforce the needed speed transition. The length of the deceleration area is determined by factors such as the design speed profile, lines of sight, and design criteria for any physical features introduced in the area. The boundary between this area and the community zone should be set based on safety, roadway, traffic operations, and land-use criteria.

### Community Zone

The community zone is that portion of roadway serving the more developed community area. This zone requires slower travel speeds for safety and community reasons. It typically has very different design characteristics from the other zones, including some or all of the following: lower design speeds, increased traffic control, on-street parking, sidewalks, curbs and gutters, higher land use intensity, street trees, pedestrian and bicycle activity, narrow lanes, and turn lanes. This zone may extend through the community to the transition zone on the other side. Traffic calming measures may be implemented within this zone to maintain lower speeds.

### Transition and community thresholds

The transition threshold is the upstream boundary for planning and designing the entire speed transition zone. It should be far enough upstream that all roadway geometry and line of sight issues can be addressed. It may, for example, be the point at which drivers first observe downstream signs or features that begin to alert them to upcoming roadway and speed changes. The community threshold defines the downstream end of the transition zone. At this threshold the 85 percentile speed should be consistent with the posted speed limit for entering the community. It should typically be set near the edge of development for the community as defined by land-use density, the number of access points, and changes in the roadway and roadside design. For safety reasons, a setback of approximately 30m may be appropriate between the edge of the community and the transition zone. For a growing community, it may also be necessary to set the community threshold far enough away from the current development to allow for near-term growth. However, if this threshold is set too far from the dense development drivers may not maintain the desired lower speeds through the community” (NCHRP, 2012, pp. 51-52).

### Traffic calming measures

Traffic calming is not permissible on Class 2R roads and can create an even more dangerous situation on urban and rural mobility roads. Speeds humps and four way stops should be avoided as traffic calming measures. These ineffective solutions seldom achieve anything other than traffic aggravation, adding to road rage and disobedience of signs and can even increase the number of collisions due to different speeds and reactions of drivers, both at the restriction and elsewhere (COTO, 2011).

Implementing traffic calming on highway links is illogical and a serious safety risk, however mild traffic calming with sufficient warning signs can be effective at designated

intersections with high pedestrian activity. The WHO report provides a list of measures that can be applied at arterials that may be worth assessing (**Table 11**).

Traffic-calming measures can vary from a few minor changes, through modifications of local streets, to area-wide changes and major rebuilds. Physical treatments to roads as well as perceptual treatments and speed limit reductions aimed at reducing vehicle speeds and sometimes traffic volume. Their efforts include moderate speed reductions and street design changes, with various degrees of success in reducing pedestrian crashes and traffic volume.

The traffic calming measures which may be applicable to Class 2R intersections are highlighted in **Table 11**. The rest of the solutions pose a serious safety concern and may drastically reduce speed and cause bottlenecks on a highway.

**Table 11: Traffic calming measures appropriate for arterials (modified from (World Health Organisation, 2013, p. 77)**

<b>Speed Reduction Measures for Arterial Roads</b>	<b>Impact on Traffic Volume</b>
Speed table	Possible
<b>Raised crosswalk</b>	<b>Possible</b>
Raised intersection	Possible
<b>Textured pavements</b>	<b>Possible</b>
Speed cushion	Possible
<b>Rumble strips</b>	<b>No</b>
<b>Roundabout</b>	<b>Not likely</b>
Realigned intersection	Possible
Tight radii	Possible
Centre island narrowing	Possible
Chokers	Possible
Road diets (lane reduction)	Yes
<b>Speed limit</b>	<b>No</b>
<b>Speed alerts and enforcement</b>	<b>No</b>
<b>Perceptual design</b>	<b>Possible</b>
<b>Warning signs</b>	<b>No</b>
Half closure	Yes
Diagonal diverters	Yes
Lateral shift	No
Median barriers	Yes
<b>Gateway treatments</b>	<b>No</b>
Traffic signal coordination	No
Vehicle-activated signs	No

### Rumble Strips

Rumble devices on roads are intended to alert the driver to the need for caution ahead. Rumble devices produce a rumbling sound which the driver will hear within the

vehicle, accompanied by a vibration which he will feel. They can be installed on the approaches to stop intersections and other hazardous locations such as curves, traffic circles, steep descents and railway level crossings (Jobson, Dehlen, & Wium, 1973). The idea is that having been alerted by the rumble installation on the road, the driver will see the roadside messages and do the right thing.

Type 2 intermittent rumble surfaces are recommended in advance of rural stop intersections on high speed rural roads. Studies in California by Kermit and Hein on the impacts of Type 2 rumble surfaces on the approach to a rural stop intersection showed that deceleration took place over a greater distance and was consequently much more gradual. A reduction of 22% was found in the average deceleration rate over the last 137m of the approach length. The guidelines for selecting rumble devices are provided in **Table 12**.

A negative consequence of rumble strip implementation is the noise outside the vehicle. This could give rise to complaints from occupants of buildings in the vicinity of the installation. This can be countered by the choice of rumble installation type and coarseness of surfacing materials used. In certain cases it might require a cost-benefit analysis between road safety and an acceptable noise climate (Jobson et al, 1973).

Crash data on roads treated with centreline rumble strips or shoulder rumble strips revealed noticeable crash reductions on all classes of roads (rural and urban two-lanes roads and freeways). Shoulder rumble strips placed as close to the edge line as possible maximise safety benefits (NCHRP, 2012, p. 68).

#### **4.4 INTEGRATED LAND USE AND TRANSPORT PLANNING**

Integrated land use and transport planning is achieved by providing safe and convenient access for land uses while staying within the bounds of road access management guidelines. Ribbon developments such as those that occur on the R71, where numerous accesses for land uses along the road lead to high rates of pedestrian and vehicular crossings can be solved by a number of measures such as safely applying minimum intersection spacing's (Section 5.3.2) as well as internal access roads etc. Measures for integrated land use and transport design will be discussed in this section.

##### **4.4.1 Development of supporting access roads**

Class R2 is part of the primary road network and in rural areas and villages the secondary and tertiary road system is poorly developed if at all provided resulting in Class R2 being used as an access road. The development initiatives for such areas, should as part of the overall ITP/IDP of the area, duly address this aspect of road infrastructure development. The road authorities in conjunction with the ITP/IDP should ensure that the transport infrastructure within the area is progressively developed to complete the road network and hierarchy. This development philosophy will lessen the burden on policing and maintenance units as the last tier to resolve critical road safety problems that require massive interventions (CSIR, 2009).

Table 12: Guidelines for the selection of rumble strips (Jobson et al, 1973, p.30).

Average Approach Speed (km/h)	Reduced speed desired (km/h)	Rumble installation length (m)	Recommended type of rumble installation		
			Urban streets	Peri-urban Streets	Rural highways
60	0	83	Continuous rumble surface		
80	60	57	Continuous rumble surface	Intermittent sets of rumble strips	
	50	79			
	40	96			
	0	140			
100	80	75		Intermittent sets of rumble strips	Intermittent rumble surfaces
	70	103			
	60	132			
	50	154			
	0	215			
112	80	135		Intermittent sets of rumble strips	Intermittent rumble surfaces
	70	162			
	60	192			
	50	214			
	0	275			
120	100	125			Intermittent rumble surfaces
	80	200			
	70	223			
	60	257			
	50	279			
	0	340			

#### 4.4.2 Pedestrian facilities

It is ideal to provide pedestrian access where the demand is warranted i.e. locations where dense pedestrian desire lines exist, however, road function and access management should be considered. A balance of the distance between the preferred crossing point and the safer crossing location in terms of access management can be obtained by providing a desirable (safe and aesthetically appealing) walking environment and appealing crossing locations.

##### Sidewalks

Studies show that pedestrian walkways improve pedestrian safety and increase walking:

- “Pedestrian crashes decrease where there are sidewalks and raised medians. A study conducted in the United States found that pedestrian crashes were more than twice as likely to occur at locations without sidewalks than would be expected on the basis of exposure.

- The presence of a sidewalk has a strong beneficial effect on reducing “walking along the roadway” pedestrian crashes. A study in the United States found that sites were 88% less likely to be pedestrian crash sites than those without sidewalks.
- Walking increases where sidewalks are provided.

To maximise the benefits of footpaths/sidewalks to pedestrian safety, they should:

- Be part of every new and renovated roadway;
- Be provided on streets that currently do not have sidewalks, including providing shoulders on rural roads;
- Provided on both sides of the road;
- Link to all land use along the road;
- Consist of a hard level surface;
- Be separated from other vehicles with a kerb, vegetation such as hedges, bufferzone or both;
- Be continuous and accessible to all pedestrians;
- Be adequately maintained;
- Have adequate width;
- Include kerb ramps at at-grade intersections;
- Be free from obstruction” (World Health Organisation, 2013, pp. 70-71)
- Include demarcations by road user type when shared by pedestrians and cyclists.
- Be lit;
- Have emergency push buttons or community policing presence.

Retting et al (2013) refer to a study by Knoblauch et al of streets with and without sidewalks at 495 locations in 5 cities (16 hours of exposure data collected at each site); showed that in residential areas, pedestrian crashes were more than two times more likely to occur at areas without sidewalks on the basis of exposure. Residential areas with no sidewalks had 23% of all pedestrian-vehicle crashes and only 3% of exposures; Commercial areas with no sidewalks were only slightly more hazardous than commercial areas with sidewalks (Retting et al, 2003). Sidewalks should not be segregated to create a feeling of safety for pedestrians (Renfro, 2007).

#### Pedestrian channelization

Pedestrian channelization is often used where the safe direction of pedestrian traffic is required. This countermeasure can also be used as a safety barrier to separate vehicles and people. The problems that this countermeasure typically addresses include: pedestrians not using crosswalks, pedestrians trapped in the middle of a street, pedestrians failure to yield and pedestrians not waiting for signals/acceptable gaps (Pulugurtha, Vasudevan, Nambisan, & Dangeti, 2012).

Channelization is achieved by providing barriers and fences, which are designed to channel pedestrians along walkways to safe crossing areas and prevent them from running into traffic. At intersections pedestrians can be channelled by strategically aligning walkways with kerb ramps and separating these facilities and the road with

guardrails etc. Intersection treatments will be discussed in subsequent sections in this chapter. This measure has been found to reduce midblock crossings and substantially decrease crash rates (ITS Engineers, 2009). Channelization is made effective by the correct placement of crossing locations. Incorrect crossing locations will be underutilised therefore planned channelization will not materialise.

### Overpasses and underpasses

Pedestrian overpasses and underpasses are bridges and tunnels that allow for uninterrupted flow that is separate from vehicular traffic. This measure is used primarily in areas with high pedestrian volumes. Pedestrian bridges are often regarded as the ultimate solution for reducing pedestrian/vehicle conflict. The level of use depends on convenience, security and walking distances compared with alternative crossing locations. Pedestrians generally do not use these facilities if a more direct route is available. Experience has however shown that careful consideration has to be given to the specific site before implementing a pedestrian bridge. The following should be considered:

- Pedestrians have a resistance against vertical inclines. Overpasses are suitable when the topography allows for a structure without ramps, for example, an overpass over a below-grade freeway. Overpasses with multiple stairs are not user-friendly for the elderly or disabled pedestrians. Ramps must be designed to accommodate pedestrians in wheelchairs.
- Pedestrians will break openings through fences to avoid climbing up stairs or ramps in order to cross the road.
- Experience has shown that the only effective fence to channelize pedestrians to utilize a pedestrian bridge is to build a solid wall or install clear-vu fencing. Concrete or steel palisade fences have proven to last only a few months at the most before holes are made in these (ITS Engineers, 2009).
- The effectiveness of such features depends on their location relative to desired pedestrian travel and nearby destinations. The presence or lack of alternative crossings also plays a role. The type of barrier being traversed influences the number of alternative crossing opportunities as well as the distance from a particular bridge. Bridges crossing surface streets typically compete with alternative crossings. Surface streets may or may not have treatments discouraging at-grade crossings. Observed treatments discouraging crossings include concrete centre dividers, signage, or no measures.
- Pedestrians consider not only the bridges location but with respect to logical walking , they also consider the distance and travel time associated with accessing the bridge structure itself, and weigh this against the perceived risk of crossing at-grade if physically possible. Bridges with easy and convenient access provisions have greater potential for attracting users.
- The AASHTO pedestrian guide cites conclusions drawn by the 1998 ITE study that: 70% of pedestrians would use an overpass if the travel time equalled the at-grade crossing travel time

- Very few pedestrians would use an overpass if the travel time were 50% longer than the at-grade crossing travel time.
- The WSDOT design manual states that “a structure might be underutilised if the additional walking distance for 85% of the pedestrians exceeds 400m (Renfro, 2007).

Pedestrian bridges work best when the barrier being crossed is depressed below the natural ground line. Bridges situated level with surrounding streets and paths minimise the need for access ramps to overcome vertical elevation. On the other hand bridges located above natural ground lines are challenged with providing access for multiple users while offering a reasonable level of convenience e.g. minimising real or perceived out-of-direction travel. The planning and design of future highways should include this consideration whenever possible.

Overcrossings should include the components necessary to enhance user comfort, safety and security. Wider structures not only facilitate easier travel by minimising user conflicts they also minimise the perception of isolation. Bridges and access ramps should be designed with appropriate landings, railings, fences and lighting to promote user safety and comfort.

Bridges can be architecturally designed to serve as visual icons and community gathering places. Bridges with aesthetically pleasing elements not only have the potential to attract bicyclists and pedestrians, but they can also attract visitors using the bridge as a destination in and of itself (Renfro, 2007).

Underpasses need to be designed in such a way as to offer a sense of being open and accessible. These structures can be affected by flooding, and may quickly become dirty without regular maintenance. Underpasses are often dark, secluded places. They may be targeted by gangs or other perpetrators of interpersonal violence, and, for this reason, people who perceive a high risk of assault avoid them. Overpasses should be well-lit and secure, to maximise personal security and therefore utilization.

Bridges are expensive to construct and maintain. They require high capital costs and ongoing maintenance however when designed well bridges can remarkably improve pedestrian safety. A study by the Japan Road Association, assessed the before and after pedestrian-vehicle conflicts at 31 intersections, 6 months before and after the interventions were introduced. The number of pedestrian-vehicle crashes decreased by 91% within 100m of the structures and 85% within 200m of the structures (Retting et al, 2003).

#### At-grade pedestrian crossing treatments

At-grade pedestrian crossings on Class R2 roads should only be provided at intersections. Mid-block crossings are not permitted on mobility roads (COTO, 2011). The literature indicates that various intersection treatments can be applied to make pedestrians crossings at intersections safer.

### Intersection traffic control

Intersections can be controlled by traffic signals, stop and yield signs or traffic circles. Factors to consider for implementing controlled intersections are pedestrian and vehicle volumes, the substantial volumes of elderly pedestrians and safety concerns such as sight distance (San Francisco Planning Department, 2008).

#### Traffic signals

One study reported that the installation of traffic signals substantially reduced conflicts occurring at high-speed intersections where previously no signals were present and pedestrians had difficulty crossing. The installation of a traffic signal at a high-speed intersection reduced the risk of pedestrian-vehicle conflict by roughly half (Gardner). At intersections with traffic signals, exclusive traffic signal phasing's - which stop all traffic for part or all of the pedestrian crossing signal - have been shown to significantly reduce conflicts. A comparative analysis of intersections with and without exclusive pedestrian signal phasing's reported that the risk of pedestrian-vehicle crashes at intersections with exclusive timing was approximately half that at intersections with standard pedestrian signals (Retting et al, 2003). Separate pedestrian signal phasing's can adequately separate pedestrians and vehicles in time. Providing separate phasing at signalized intersections for right-turning vehicles reduces right-turn vehicle crashes involving pedestrians, and right-turn crashes involving vehicles going straight.

Adequately timed yellow and all-red clearance signals are necessary at traffic signals to ensure that drivers have sufficient time to clear the intersection before the display of pedestrian walk signals. One study showed that combined changes in the duration of yellow and all-red signal timing reduced the risk of pedestrian and bicycle crashes at intersections by 37% relative to control sites. A randomised before and after study with controls at 40 urban intersections over a three year period showed a 37% reduction in pedestrian and bicycle crashes due to changes to traffic signal interval timings (Retting et al, 2003).

Automatic pedestrian detection, which can be used at traffic signals in lieu of pedestrian push buttons to automatically detect pedestrians and display a walk signal, have been reported to significantly reduce conflicts (Redmon, 2011). This technology also can extend crossing time to allow slower pedestrians to finish crossing (Retting et al, 2003).

Pedestrian countdown signals illustrated in **Figure 36** show the time remaining for pedestrians waiting or crossing at intersections. These traffic signals improve the safety of walkers by reducing the number of pedestrians stranded in the crosswalk when the light changes. They consist of a regular pedestrian signal with standard shapes and colour,

and an added display showing the number of seconds left to cross the street. The walking speed and crossing distance are used to determine the countdown time. For instance, an eight-lane highway would have a longer countdown period than a four-lane road. Once the countdown period starts, a pedestrian should not start crossing the roadway. The driver's response to a countdown pedestrian signal is the same action for any pedestrian in a crosswalk; the driver must stop and remain stopped for pedestrians in the crosswalk (Redmon, 2011). In a multiple-baseline design at three urban intersections the percentage of pedestrians looking for potential vehicle threats doubled at one site and tripled at another. The number of pedestrian-vehicle accidents decreased more than half (Retting et al, 2003).

### Stop controlled intersections

An all-way stop is not an ideal control measure for a crossing on a Class R2 road where there are large volumes of cars and pedestrians. Such a crossing allows for inequitable crossing opportunities in priority of vehicles leading to insufficient gaps for pedestrians to cross and ultimately causing impatience and risky pedestrian behaviour. COLTO states that all way stops should not be used as a traffic calming measure. All way stops can be applied where pedestrian volumes are low, however land use regulations should be enforced to ensure that the intersection is not used to serve high pedestrian volume attractors.

### Traffic Circle

A traffic circle is a form of circular intersection where vehicles travel around a central island. Vehicles entering the circle must yield to circulating traffic. The channelized approaches and geometry induce reduced travel speeds through the circular roadway.

Traffic circles increase the rate of compliance of vehicles travelling at or below the speed limit at the end of a transition zone by 15% compared to no treatment at all (NCHRP, 2012).

Converting existing intersections to traffic circles can also dramatically improve safety. AASHTO 2010 states that converting two-way stop controlled and signalised intersections to roundabouts reduces total accidents by 71% and 48% respectively and accident injuries and fatalities by 87% and 78% respectively.

Traffic circles are however expensive to construct and are a challenge for elders and disabled pedestrians to cross (NCHRP, 2012).



Figure 36: A pedestrian countdown signal (Katie, 2013).

### Crosswalk markings

Marked crossings are commonly installed at signalised intersections, as well as other high-volume pedestrian crossing locations such as school zones. They should, however, be installed in conjunction with other physical roadway enhancements that reinforce the crossing and /or reduce vehicle speeds.

There are several important issues for practitioners and decision-makers to consider when installing crossings:

- Crossing markings are unlikely to increase pedestrian safety, without related enhancements such as raised crossing islands and traffic signals.
- **Marked crossings are not appropriate where traffic speed is high.**
- Marked crossings on roads with more than two lanes may increase the risk of pedestrian-vehicle crashes.
- Crossing locations should be convenient for pedestrians and accessible for pedestrians in wheelchairs. Pedestrian movements and desire lines (most direct/shortest path between two locations) can be analysed to identify optimum locations for crossings.
- Marked crossings should guide pedestrians to cross at locations where there is street lighting at night.
- Detectable warnings should be installed to advise pedestrians with visual impairments where the kerb ramp ends and the street begins. The warning should also indicate when the traffic light will change.
- There should be adequate visibility between vehicles and pedestrians. For example, night-time pedestrian crossings should be properly illuminated in order to help drivers to see pedestrians.

Different types of marked crossings are available for use at intersections such as the bar pair markings, continental markings and traverse markings etc. A crosswalk marking field visibility study with the objective of investigating the relative daytime and night-time visibility of the listed marking patterns was conducted by the US federal Highway Administration. The study indicates that the continental and bar pairs were preferred over the transvers markings by the participants (Fitzpatrick, Chrysler, Van Houten, Hunter, & Turner, 2011). The study took place at mid-block crosswalks which present a higher crossing risk than signalised intersections. The application of the recommended markings is deemed feasible for High-visibility crosswalks on higher order roads.

#### High-visibility crosswalk treatment

High-visibility crosswalks are used to enhance visibility and minimise inappropriate perceptions between pedestrians and motorists. They are also used to encourage more pedestrians to use crosswalks. On higher order roads the problems that this countermeasure typically addresses include, pedestrians not using the crosswalks, inconspicuous crosswalks, motorists failure to stop at the designated location (Retting et al, 2003).

Because of the low approach angle at which pavement markings are viewed by drivers, the use of high visibility markings can significantly increase the visibility of a crosswalk to oncoming traffic. From proven research, the high visibility continental crosswalk is preferred however it costs more to install and maintain therefore transverse high visibility crosswalks are implemented in the short-term.

Findings on the high visibility crosswalk are mixed. Retting states that Nitzburg and Knoblauch studied high visibility ladder style crosswalk markings at two non-signalised intersections in Clearwater, Florida. The study found that the high visibility crosswalk resulted in significant increases in driver's daytime yielding behaviour – drivers were 30% to 40% more likely to yield after the treatment and the percentage of pedestrians using the crosswalk increased (Chen, Chen, & Ewing, 2012). Studies showed that the implementation of the measure improved pedestrian channelization.

#### HAWK pedestrian crossing treatment

The City of Tucson in Arizona developed the HAWK pedestrian crossing beacon in the late 1990s to assist pedestrians to cross major arterials. Research found 95% of drivers yielding for the HAWK treatment even on major streets with multiple lanes or higher speeds. HAWK is one of the few interventions with promising yielding rates on arterials.

At a HAWK crossing, drivers receive multiple cues emphasizing the potential presence of pedestrians. These cues include the HAWK beacon, high visibility crosswalk markings, a stop bar approximately 15m from the crosswalk, 200mm solid lane lines between through travel lanes, signs which are in some cases illuminated that read "Crosswalk", and school warning signs. When activated the

HAWK provides drivers with red indication informing them to stop, allowing pedestrians to cross the major roadway.

The HAWK is activated by pedestrians. Activation triggers the warning flashing lens on the major street. After a set time the indication changes to a solid yellow light to inform drivers on the major street and a walking person symbol to pedestrians. At the conclusion of a walk phase, the symbol with a countdown display informing them of the time left to cross. During the alternating flashing red lights, drivers can proceed after coming to a full stop and checking have already crossed their lane of travel. Each successive driver is legally required to come to a full stop before proceeding during the alternating flashing red phase.

The alternating flashing red phase allows the delay to traffic to match the actual crossing needs of the pedestrians. Drivers can proceed with a stop-go operation during the flashing red phase. If pedestrians need more time then the drivers remain stopped until they finish crossing. The ability to balance the pedestrian need with the driver delay is a valuable component of the HAWK treatment. Concerns have been raised regarding driver behaviour and understanding of the dark phase and the flashing red phase.

Before and after evaluations of the HAWK indicates a 69% reduction in pedestrian crashes which is statistically significant at the 95% confidence level (Fitzpatrick et al, 2011).

#### Advanced stop and yield lines

Stop lines are solid white lines that extend across all approach lanes to indicate where vehicles must stop in compliance with a stop sign or signal (San Francisco Planning Department, 2008). Advanced stop lines are inexpensive interventions at signal-controlled intersections which involves repositioning of stop lines further back from crosswalks. This results in drivers stopping further back from crosswalks, thus increasing the separation between pedestrians and vehicles and improving visibility (Redmon, 2011).

On multi-lane roads, advance stop and yield lines can be an effective tool for preventing multiple threat vehicle and pedestrian collisions. The City of San Francisco has developed guidelines for implementing this intervention based on location-specific interventions such as vehicles speeds, traffic control, street width, potential for confusion, nearby land uses with vulnerable populations and demand for queuing space. A study by Berger in the United States at 2 intersections indicates that the implementation of the intervention caused vehicles to stop 1.8m and 2m in advance of the pedestrian crossing. Retting et al states that an overall 57% of drivers complied with advance stop lines, the number of drivers who stopped within 1m of the crosswalk increased from 74% to 94% and the drivers who stopped within the crosswalk during the pedestrian phase declined from 25% to 7% (Retting et al, 2003).

Yield lines are another option that can be used to reduce the possibility of multiple collisions at uncontrolled crosswalks on multi-lane roadways. They consist of a

single row of white triangles placed across each approach to indicate the point at which vehicles must yield.

### Signage

Pedestrian zone signs alert drivers to watch for pedestrians. These signs are placed in areas with pedestrian activity such as intersections. Pedestrian zone signs can be made more visible by altering the colours i.e. adding florescent yellow green borders on road signage (Henderson, 2014) similar to what was done on the R61 in Eastern Cape. Turning traffic yield to pedestrians signs remind drivers at intersections making turns that they must yield to pedestrians in crosswalks (Redmon, 2011). This is crucial on high-volume left and right turning vehicle lanes.

### Medians and crossing islands

Raised medians on multilane roads reduce pedestrian crashes and also head-on collisions. They do this by allowing pedestrians to cross one direction of traffic at a time. Crossing islands are level channels in a raised median that link to a pedestrian crosswalk. The benefits of raised medians and crossing islands treatment are:

- Reduce motor vehicle crashes
- Reduce vehicle speeds on the roadway
- Improve traffic flow
- Reduce pedestrian waiting time
- Reduce crossing distance and exposure to vehicles.
- Crossing islands provide universal access through the raised median i.e. wheelchair access.

Many strategies that benefit pedestrian safety have been found to benefit other road users as well (World Health Organisation, 2013). Raised medians and crossing islands are proven safety measures that reduce pedestrian-vehicle accidents on multilane roads (University of North Carolina Highway Safety Research Center).

### Public transport facilities on rural roads

Rural roads serving scattered communities will also form the public transport route in most cases. Public transport facilities in the form of laybys where buses and taxis can stop are therefore essential. The positioning of these laybys will determine their success in preventing public transport vehicles stopping anywhere. Typical considerations include:

- Public transport stops should be located within an acceptable walking distance from generators, attractors and modal transfer facilities such as schools, hospitals, job opportunities.
- Walking distance to stops should be within 400m but not more than 800m (COTO, 2011).
- Public transport stops on Class 2 roads are restricted to laybys downstream of intersections (COTO, 2011). Relocating bus stops from the near side to the far side of intersections can increase the visibility of pedestrians by decreasing the number of pedestrians who enter the roadway in front of a stopped bus. It has

been shown that bus stop relocation significantly decreases the percentage of pedestrians who enter the roadway in front of a stopped bus at signal-controlled intersections (Retting et al, 2003).

- Intersections where a link to other routes can be obtained.
- Adequate sight distance for drivers approaching the facility while passengers are loaded.
- Public transport must be serviced by an adequate network of footways. Sidewalks leading to the waiting area serving passengers are required.
- Sufficient road signs and markings to warn drivers about the facility – with special care for night /poor visibility conditions (ITS Engineers, 2009).
- Dedicated pedestrian crossings should be allowed at each intersection (Henderson, 2014).

A bus stop relocation study by Berger in the United States where one bus stop was relocated from the near-side to the far-side of a traffic signal controlled intersection on an arterial caused a significant reduction of the number of pedestrians entering the roadway in front of a stopped bus (Retting et al, 2003).

### Lighting

Lighting can increase pedestrian's visibility at night, when more than half of all fatal pedestrian crashes occur. Increased intensity of roadway lighting at pedestrian crossings has been associated with significant reductions in night-time pedestrian crashes. Dynamic lighting which is crosswalk lighting that only comes on at night when activated by pedestrians has proven to be effective. The number of night-time crashes decreased by 59% in a study conducted by Pergum in Australia (Retting et al, 2003).

### Special intersection paving

Special intersection paving treatments can force motorists to be more observant. This can be done by breaking the visual monotony of asphalt streets by highlighting intersections as an extension of the pedestrian realm, and announcing key civic or commercial locations. Special intersection paving treatments include integrated colours; textures e.g.: a change in road wearing surface in terms of seal so that motorists would hear and feel a change in the road surface, and scoring patterns. They may be instituted within crosswalk markings or across an entire intersection.

Special intersection paving treatments are more costly to build and maintain than standard treatments. Where capital and maintenance budgets allow, they may be considered on:

- Streets important to the city pattern
- Commercial streets
- At entries to residential areas where residential streets intersect with higher volume streets
- At key civic locations, such as buildings or entries to open spaces
- At mid-block crossings

Paving treatments should:

- Use integrated colour, texture, and pattern. Potential materials include but are not limited to coloured and stamped asphalt, poured concrete pavers
- Provide a surface that does not cause discomfort due to excessive vibration to those using wheelchairs or other assistive mobility devices.
- Use stable, durable, and slip resistant materials
- Include edging treatments to visually contrast with the primary material and with the asphalt roadway.
- Include crosswalk striping (parallel white lines) on the outer edge of the crossing (San Francisco Planning Department, 2008).

#### **4.4.3 Terrain and budget constraints**

Project finance is the biggest constraint in road construction projects. Highways can be built across rivers and through mountains; there is no limit to ingenuity if the capital is available. However terrain difficulties and financial shortfalls are a reality which may necessitate the construction of higher order roads within human settlements. In such cases, consideration for existing settlements and the environment should be emphasised in the planning of roads. Planners must try by all means to do the following:

- Ensure that settlements are segregated as little as possible.
- If the budget allows, where the road cuts through the community, the highway could be built at a higher or lower level (grade separated) than the settlement.

As long as highways and human settlements are within proximity of each other, integrated land use and transport policy must be enforced, particularly in the rural areas.

#### **4.5 PEDESTRIAN AND DRIVER BEHAVIOUR**

Considering the distinct needs of various pedestrians is important. The specific needs of children, the elderly people and those with disabilities should be considered and prioritised when designing pedestrian safety measures.

The following measures can be implemented to improve the safety of elderly pedestrians:

- Increase the time allocated to pedestrians at signalised pedestrian crossings
- Install high visibility crossings and advance stop bars.
- Repair broken kerbs and pedestrian ramps
- Replace missing and or upgrade existing signs
- Install pedestrian refuge islands or preferably raised medians
- Narrow roadways with traffic-calming techniques
- Raise public awareness about the safety needs of elderly pedestrians
- Reduce legal speed limits
- Strengthen enforcement of laws on speed limits and drink-driving (World Health Organisation, 2013).

Pedestrian education is a popular approach, but with the exception of children, there is a lack of evidence regarding the effectiveness of safety education.

## 4.6 IMPLEMENTATION ISSUES IN LOW AND MIDDLE INCOME COUNTRIES

A summary of implementation issues attributed to some of the measures discussed was compiled at a workshop held in Bangkok, Thailand as part of the 2012 GRSP/iRAP Asia Pacific Workshop involving governments and road authorities in the region. The purpose of the workshop was raising awareness on safe system infrastructure treatments and to explore barriers to their implementation in low and middle income countries.

The implementation issues identified were classified into the following groups:

- Cost,
- Compliance issues,
- Design and implementation difficulties,
- Public Acceptance and familiarity with use, and
- Maintenance (Turner & Smith, 2013).

**Table 13: Issues attributed to road safety countermeasures (Turner & Smith, 2013).**

	Roundabouts	Barriers	Pedestrian crossings	Pedestrian footpaths	Traffic calming	Signals	Shoulders
<b>Cost</b>	✓		✓	✓	✓		✓
<b>Compliance</b>	✓		✓	✓		✓	✓
<b>Design/Implementation</b>	✓	✓			✓	✓	✓
<b>Public acceptance</b>	✓		✓		✓		
<b>Maintenance</b>		✓		✓	✓	✓	✓

**Table 13** shows that low to middle income countries expressed cost as an issue for most countermeasures. Compliance failure was significant for roundabouts, pedestrian crossings, traffic signals and shoulders and this mostly likely has an impact on the effectiveness of the countermeasure. Non-compliance is as a result of the following:

- Failure to give way and vehicles operating in the wrong direction on roundabouts,
- Failure of vehicle traffic to give way for pedestrians at crossings,
- Obstruction of vehicles on pedestrian footpaths,
- Failure to stop at signalised intersections, and
- Vehicle misuse of paved shoulders.

The effectiveness of countermeasures is also affected by substandard design, implementation and maintenance. Poor design quality and implementation as well as maintenance backlogs are critical issues in low and middle income countries. Effectiveness also deteriorates to low levels and sometimes to worse than if the treatment were not present if maintenance is inadequate (Turner & Smith, 2013).

Public acceptance may also have an influence on compliance. The issues in **Table 13** indicate that roundabouts, pedestrian crossings and traffic calming typically have the highest public resistance.

These countermeasures are generally successfully implemented in middle to high income countries mainly due to their higher levels of education and exposure which has sensitised road users to road safety but also to the system planning approach that requires ownership from all actors including policy makers, road authorities, designers and contractors. System planning has proven to yield higher standards of countermeasure implementation, compliance and maintenance and should be considered in low and middle income countries where dramatic long term improvements are required.

#### **4.7 SUMMARY OF COUNTERMEASURES**

The countermeasures discussed in this section are summarised in **Table 14**. The summary includes the effectiveness of each countermeasure. The effectiveness is categorised according to the following:

- Proven:  
Evidence from robust studies such as randomised controlled trials, systematic reviews or case-control studies show that these interventions are effective in reducing pedestrian fatalities and injuries, or bringing about desired behaviour change.
- Promising:  
Evidence from robust studies show that some pedestrian safety benefits have resulted from these interventions, but further evaluation from diverse settings is required and caution is thus needed when implementing these interventions.
- Insufficient evidence:  
Evaluation of an intervention has not reached a firm conclusion about its effectiveness.

The measures discussed in this chapter have all undergone trials and many have been proven to be effective. Countermeasures appropriate for the problems identified on the R71 will be selected in the following chapter.

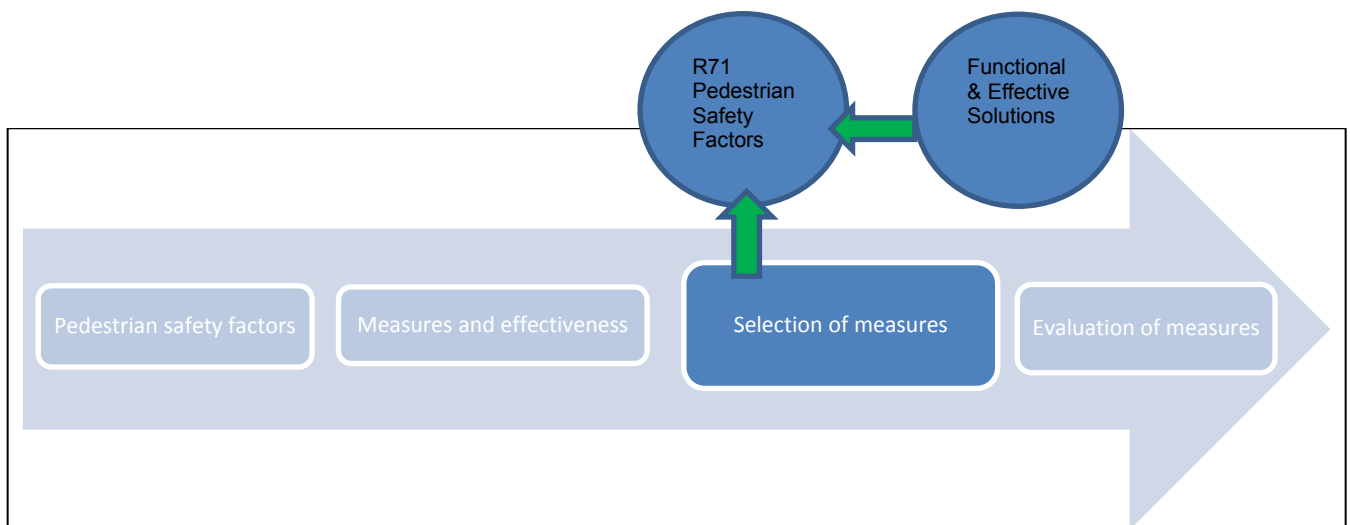
Table 14: Summary of pedestrian safety countermeasures

Safety Factors	Intervention	Effectiveness		
		Proven	Promising	Insufficient Evidence
Road Design	High speed to low speed transition zones for rural highways			
	Traffic calming measures			
	Modified highway cross-section			
	Self-explaining roads			
	Context-specific geometric design			
	Enforcing access management guidelines			
Integrated Land Use and Transport Planning	Provide sidewalks			
	Install overpass/underpass			
	Provide school route improvements			
	Pedestrian channelization			
	High visibility crosswalk treatment			
	Development of supporting access roads			
	Signage			
	Advanced stop and yield lines			
	Medians and crossing islands			
	Public transport facilities			
	Implement lighting/crossing illumination			
	Special Intersection Paving			
	Traffic signals			
	Roundabout			
Pedestrian and Driver Behaviour	Provide education, outreach and training			
	Develop and/or enforce traffic laws on speed, drinking and driving, pedestrian right-of-way, red light disobedience, commercial roadside activity and traffic control			
	Implement "walking school bus" programmes			

## 5. SELECTION OF MEASURES

### 5.1 A SOLUTION FRAMEWORK FOR PEDESTRIAN SAFETY ON HIGHER ORDER RURAL ROADS

Chapter 5 is the third step in the thesis. Functional and effective countermeasures will be selected for the case study.

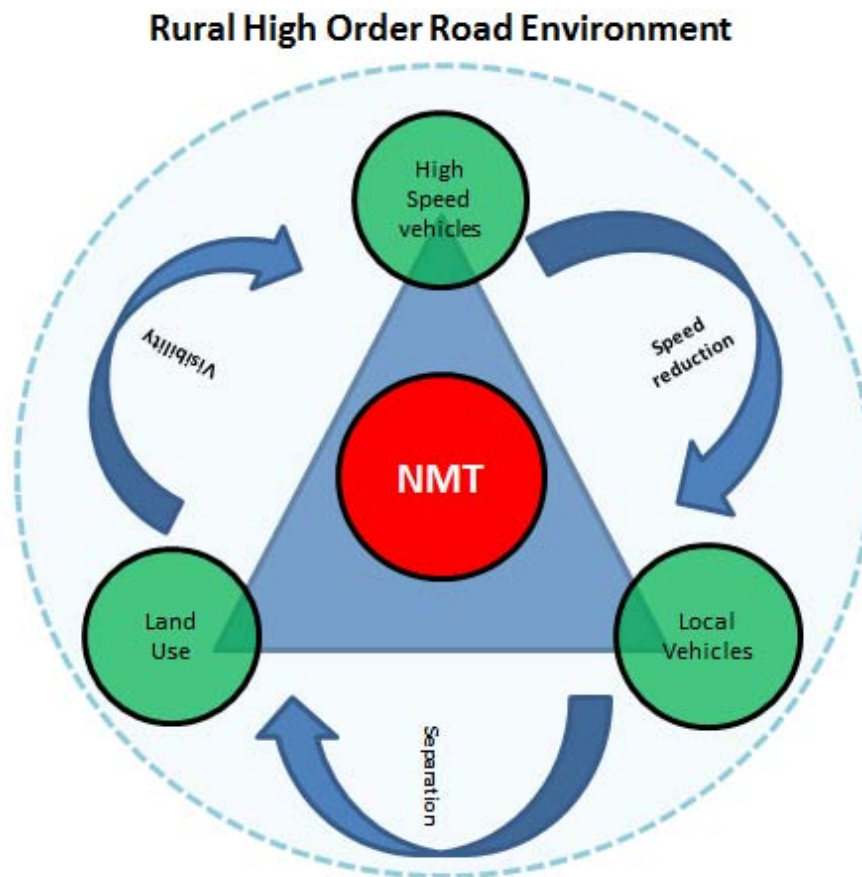


Literature and current practice in industrialised countries stipulates the need for a system-wide approach to road safety which requires acknowledgement of responsibility and action from all actors including policy makers, transport authorities, town planners and road designers. A system framework for the selection and implementation of engineering countermeasures is required to strategically guide and ensure a unified approach that holds all actors accountable.

The three broad categories for pedestrian safety engineering countermeasures defined by Retting et al -described at the beginning of Chapter 5- stand out as important elements of a safety countermeasure selection framework:

- **Separation of pedestrians from vehicles by time and space**  
Separation countermeasures reduce the exposure of pedestrians to potential harm both on the roadside and when they are crossing streets.
- **Measures that increase the visibility of pedestrians**  
In many pedestrian crashes the driver reportedly does not see the pedestrian before the accident; measures are needed to increase the visibility of pedestrians.
- **Reductions in vehicle speeds**  
Higher vehicle speeds are associated with a greater likelihood of crashes involving pedestrians as well as more serious pedestrian injuries (Retting et al, 2003).

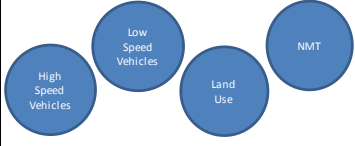
Countermeasure selection will therefore be based on ensuring that firstly pedestrians are successfully separated from high-speed road conditions; secondly on approach to human settlements infrastructure that facilitates the visibility of all road users must be provided and where pedestrian and vehicular crossings are warranted, countermeasures that effectively reduce speed must be implemented. A diagrammatical representation of the rural road environment as an open and complex socio-technical system and the proposed countermeasure categories for a safe system are illustrated in **Figure 37**. Pedestrians and NMT in general are viewed as the main priority in the system particularly due to their vulnerability.



**Figure 37: The rural higher order road and safety countermeasure categories.**

A pedestrian safety solution framework expanded from the safe system countermeasure categories is provided in **Table 15**.

**Table 15 A Solution framework for pedestrian safety on rural high order roads.**

The Road Environment Sub-Systems	Environmental Context	Risk	System Behaviour	Desired Speed (km/h)	Treatment Requirements	
	Rural	Low	No Sub-system Interaction	80-120	Total Separation	Self-explaining and Forgiving Environment
	Village/Semi-Urban Settlement	Medium	Minimal Interaction	60	Total Separation, Visibility and Speed reduction	
	Crossing Location	High	Sub-System Interaction	0-20	Time & Space Separation, Visibility, Speed Reduction	

The Solution Framework for Pedestrian Safety on high order roads illustrates the road environment sub-systems, namely; high speed vehicles fulfilling a mobility need, low speed vehicles, NMT and land use fulfilling an access need. The interaction of sub-systems is determined by environmental contexts which intrinsically have an impact on risk. Therefore successfully controlling system interactions in different environmental contexts is the foundation of the framework.

**Table 15** illustrates that rural high order roads should exist under three clearly defined environmental contexts; rural, village/semi-urban and village/semi-urban crossing locations. Rural sections are defined as the long links between village/semi-urban settlements, where the full mobility function must be maintained. Village/semi-urban sections occur in settlements, where the mobility function is downgraded to suite the access needs of the settlement.

The three contexts differ in terms character, road function, speed, sub-system interaction, risk and therefore safety countermeasures. Crossing locations represent the highest risk given that all the road environment sub-systems will interact at that point. Countermeasures should therefore be applied throughout all environmental contexts of the system to ensure that the road function transforms from a high speed inaccessible mobility road in rural sections to a safe and accessible road at crossing locations.

Prescribing and controlling the desired speed to combat risk is therefore paramount. The desired speeds for rural contexts prescribed in the table will facilitate mobility where total separation of sub-systems is required. The prescribed speeds in the village/semi-urban contexts are extracted from literature on safe crossing speeds for pedestrians and will facilitate safety and accessibility of NMT and low speed local traffic where sub-system interaction is encouraged. The transition from rural to residential sections should be facilitated by speed transition zones.

It is imperative that the road user be aware of the distinction between the different environmental contexts. **Table 15** also shows that system compliance and success will also hinge on selecting and repetitively applying measures that will foster self-explaining road environments. The complexity and imperfection of sub-systems behaviour and the consequences of this on interactions possibly resulting in conflict should be countered as much as possible by a forgiving road environment that allows the system to rectify itself without fatalities.

The countermeasure framework will be used as a guideline for selecting the appropriate countermeasure based on the pedestrian safety factors defined in the status quo analysis of the study area.

## 5.2 FUNCTIONAL AND EFFECTIVE PEDESTRIAN SAFETY MEASURES

A myriad of countermeasures were discussed in the prior chapter. Selection of the right measures for the R71 context -or any other- requires careful consideration based on the aforementioned framework, the pedestrian safety risk factors defined in the status-quo analysis as well as the proven functionality and effectiveness of measures. Functionality and effectiveness refers to the ease of application and operation of an intervention and its ability to solve the specified problem at a reasonable cost. The functionality and effectiveness of interventions can be based on the following criteria:

- **Applicability of the measure to solve that specific problem,**
- **Conformance to local engineering policies and standards,**
  - The chosen solutions should comply with the design guidelines for the study area.
- **Evidence of effectiveness in the study area or similar settings,**
  - Evidence of the effectiveness of an intervention in a study area can be obtained from reputable reports of favourable trials of the intervention.
- **Effective Integration of measures.**
  - In many cases a series of measures need to be applied to counteract the various safety risk factors in a study areas. It is therefore vital that the measures chosen are designed such that they will operate in synergy to mitigate risk instead of adding complexity and confusion to system operations.
- **Ease of use by pedestrians and motorists,**
  - Ease of use of solutions is vital, particularly where pedestrians comprise of vulnerable users such as children and the disabled. Solutions must be self-explanatory if pedestrians and drivers are to use them effectively.
- **Reasonable installation, operational and maintenance costs.**
  - Physical countermeasures and their components must be sourced locally. Reliance on out-of-town distributors and manufactures increases costs and maintenance of solutions. It will be short-sighted to install solutions that will be too difficult to maintain and thus not serve their purpose of saving pedestrian lives.

The World Health Organisation report on pedestrian safety recommends that the following steps should be followed for the selection of adequate interventions:

- Interventions must be tailored to best fit specific site conditions, including traffic speed and volume, number of travel lanes, presence of signs, volume and characteristics of pedestrians, location type, type of land use and other relevant physical and location factors.
- The report states that a combination of measures is more effective than implementing a single strategy.

- Cost and feasibility should not be the only considerations when choosing interventions. Strategies that may be easier and cheaper to implement may have a smaller impact. For example, installation of pedestrian warning signs may increase pedestrian awareness and reduce some risk, but a more effective approach would be substantial infrastructure changes such as the provision of sidewalks and speed management strategies. Engineering-related measures may be more expensive and may raise more resistance than behaviour change strategies, but these types of measures are essential to making improvements (World Health Organisation, 2013).
- It takes a sustained effort over a period of time to improve pedestrian safety. A city or a region may begin with a few measures at the highest risk locations, and over time increase the geographic coverage and number of interventions implemented.
- It should be noted that any warning traffic control device may not work as effectively if it is overused (Fitzpatrick et al, 2011).

It is therefore cost effective and quicker to focus on a combination of measures which have proven effectiveness, are tailor-fit for local conditions and may be strategically staggered or phased-out over the short to medium term to efficiently provide effective results. Measures will be selected based on the aforementioned criteria.

### **5.3 FEASIBLE PEDESTRIAN SAFETY SOLUTIONS FOR THE R71 AND SIMILAR CONTEXTS**

The problems that prevail along the R71 are similar to those of many higher-order rural roads traversing through village settings. The major difference may be area specific characteristics that could amplify or diminish the severity of the problem such as pedestrian and vehicular traffic volumes, land use mix consisting of high or low trip generators, demographic anomalies such as the prevalence of child-headed households, socio-economic conditions such as a high or low employment rate and its associated implications on human and driver behaviour etc. Area characteristics will influence the intensity of applied interventions.

The problems on the R71 were summarised as follows:

#### **Land use Factor:**

- **Non-existent land-use planning**

#### **Road Design Factors:**

- **Inadequate access provision**
- **Non-existent pedestrian infrastructure**
- **Poor design of speed transition zones between rural areas and villages and urban areas.**

High risk areas were identified as:

- **Mankweng**
- **Badimong**
- **Nobody**

- **Dalmada**
- **Moria**
- **Viking**

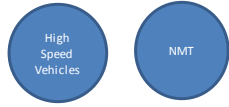
The solution to the R71 pedestrian safety problem lies in following the Solution Framework for Pedestrian Safety on High Order Roads –**Table 15**– and selecting the countermeasures based on the criteria for selecting functional and effective countermeasures described in the previous section. The resulting solution will be system-wide approach that will acclimatise drivers and pedestrians to behave in a responsible manor when using the road.

### 5.3.1 Rural mobility sections

The status-quo analysis indicated that the rural sections of the R71 have limited risk of pedestrian and vehicular accidents since there is minimal pedestrian activity along these sections. The countermeasures recommended for this environment are therefore minor and at best precautionary.

The safety of the drivers and the few pedestrians can be improved by implementing routine maintenance to ensure that the road shoulder is preserved against damage such as edge break etc. A well maintained shoulder can be used for vehicle recovery in the case of run-off the road crashes or a safe stopping location for motorists experiencing trouble. Literature states that adding a sealed shoulder can decrease road accidents by 25-40% (Turner & Smith, 2013). Reflectors should be installed along the yellow line to alert distracted drivers when they leave the road. If future pedestrian movement between the villages is significant physically separated pedestrian pathways must be constructed at a safe distance from the road. The proposed separation is clear view fencing along the pedestrian pathway and guardrails at the edge of the road shoulder in case of run-off road crashes. A summary of the rural section countermeasures are summarised in **Table 16**.

**Table 16: The proposed countermeasures for rural sections.**

The Road Environment Sub-Systems	Environmental Context	Risk	System Behaviour	Desired Speed (km/h)	Treatment Requirements	
	Rural	Low	No Sub-system Interaction	80-100	Maintain road shoulder Implement rumble strips along yellow line to alert drivers when leaving lane In future-if pedestrian volumes increase pathways with physical barriers at safe distance from road must be implemented	Self-explaining and Forgiving Environment

### 5.3.2 Speed transition zones

The current speed management along the R71 was proven ineffective in the status-quo analysis. The 85<sup>th</sup> percentile speed exceeded the posted speed in 5 out of the 8 settlements in the study area. The literature explicitly shows the correlation between speed and pedestrian-vehicular accidents and thus speed was identified as a factor of pedestrian safety. Collisions at the existing posted speeds will result in fatal accidents; therefore the speed near and in the village sections of the R71 must be reviewed. Effective high-to-low speed transition zones are a proposed solution for the road sections spanning rural and residential areas.

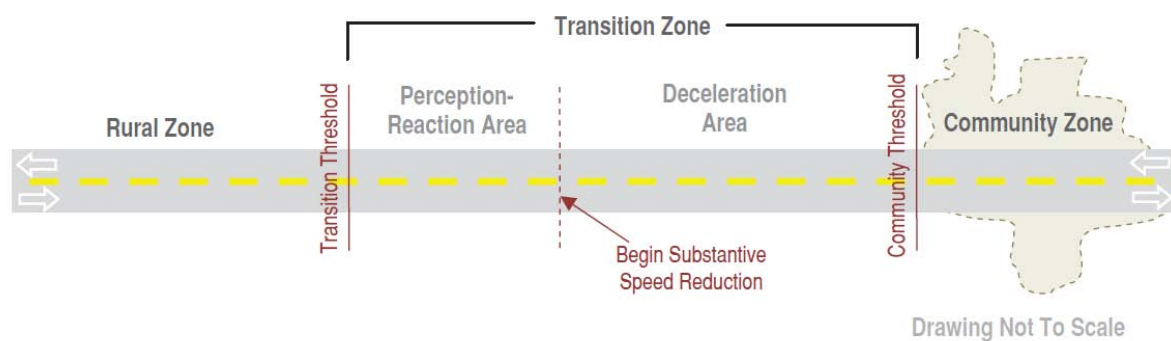
The three zone approach discussed in Chapter 5 was used for the high-level design for speed management along the R71. The three zones are the rural zone, the transition and the community/village zone. The transition zone is made-up of the perception-reaction and deceleration areas illustrated in **Figure 38**. This three-zone approach is consistent with road and traffic design principles and the necessity for engineers to treat the change in speed as an extended length of roadway rather than a specific point. Characteristics of the three zones are listed in **Table 17**. The design process is discussed:

**Table 17: Characteristics of high-to-low speed transition zones (NCHRP, 2012).**

	Rural Zone	Transition zone		Community Zone
		Perception-reaction area	Deceleration area	
Design Speed	≥ 70 km/h	≥ 70 km/h	varies (but decreasing)	≤ 60 km/h
ADT	Lower	Lower	Increasing	Higher
Access density	Lower	Lower	medium	Higher
Ped/bike activity	Lower	Lower	Medium	Higher
Land use	Rural/Low density	Rural/Low density	Increasing density and Intensity	Higher density and Intensity
On-street parking	No	No	Unlikely	Possibly

### 5.3.2.1 Design of speed transition zones

The theoretical location and length of the transition zone are determined by a series of physical, operational and safety characteristics. It may include a section that has similar characteristics to the rural zone as well as the edge of the community. The transition zone should however have elements that differentiate it from the other two zones and inform and assist drivers in making the appropriate speed reduction (NCHRP, 2012).



**Figure 38: The transition zone study area (NCHRP, 2012).**

The theoretical transition zone location is based on the community/village and roadway characteristics, combined with vehicle deceleration distances appropriate for the speed change. The recommended minimum lengths for transitions zones –**Table 18**– have been extracted from the NCHRP guideline. The table is based on the 85<sup>th</sup> percentile speeds in the rural zone and the target speed in the community zone. The perception and deceleration lengths required to achieve the speed transition are also provided. The deceleration distance is based on a comfortable deceleration rate, while the perception-reaction time is set at 2.5 seconds (NCHRP, 2012).

The transition length may have to be longer due to various engineering and/or community factors such as sight distance limitations and grades. Human factor issues such as speed

adaptation may also lead to lengthening the transition zone. Care must be taken to ensure that the speed transition is not over extended due to the fact that drivers will typically travel at a speed that is appropriate for the road way design. If the transition zone is too far from the community, then drivers may not travel at the desired speed (NCHRP, 2012).

**Table 18: The recommended minimum transition zone lengths (NCHRP, 2012).**

		Community Zone Target Speed (km/h)											
		32		40		48		56		64		72	
Rural Zone Speed (km/h)	72	52	117	52	105	52	93	52	78				
		169		157		145		130		0		0	
	80	190	450	190	415	190	380	190	330	190	270		
		640		605		570		520		460		0	
	88	210	510	210	480	210	440	210	400	210	340	210	265
		720		690		650		610		550		475	
	97	230	595	230	565	230	520	230	485	230	425	230	365
		825		795		750		715		655		595	
	105	240	680	240	655	240	600	240	570	240	510	240	465
		920		895		840		810		750		705	

P	D	P= Perception-reaction distance (m)
Total		D= Deceleration distance (m)
Total is the Transition Zone Length (m)		

### 5.3.2.2 R71 Speed transition zones

The objective of applying the transition zone in the study area is to reduce the current 85<sup>th</sup> percentile speed to a desired community/ village zone speed of 60km/h. Seven high-to-low speed transition zones are proposed in the study area. They are illustrated in **Figure 39**. The areas selected are those that are bound to the east and/or west by rural sections of the R71. The proposed community zone speed is deemed adequate for residential sections of the R71 since it provides a balance between access provision and a reasonable level of mobility for vehicles en-route long journeys. The transition lengths -adapted from **Table 18**- are provided in **Table 19**.



**Figure 39: The proposed transition zones on the R71.**

**Table 19: The recommended transition zones and their lengths for areas bound by rural sections in the study area.**

Speed compliance	Areas bound by rural sections	85th Percentile Speed	Posted Speed	Desired Community Zone Speed	Transition Zone length	Minimum Perception-reaction length	Minimum Deceleration length
yes	Dalmada	90	100	60	715	230	485
yes	Mothibaskraal	95	100	60	715	230	485
No	Makanye	95	80	60	715	230	485
No	Viking/Badimong	105	80	60	810	240	570
No	Moria	90	80	60	715	230	485

An overview of the study area indicates that adequate space is available for the transition lengths. An investigation is required to assess the impacts the proposed transition zone in the east of Dalmada will have on the operations of the N1/R71 interchange.

### 5.3.2.3 Speed transition zone treatments

The primary objective of the perception-reaction area is to mentally prepare drivers to adjust their driving behaviour and speeds in the deceleration area (NCHRP, 2012). This reaction can be prompted by providing transverse pavement markings. Transverse pavement markings are placed in a pattern of progressively reduced spacing to give drivers the impression that their speed is increasing. This should be complemented with signage located within clear lines of sight to alert drivers of the changes ahead.

The deceleration area may include physical measures to reinforce the needed speed transition. A series of rumble strips are recommended at the start of the deceleration area to enforce deceleration. Road narrowing is an effective low to moderate cost measure which should be applied in succession of the rumble strips to further facilitate deceleration in the area. Road narrowing strategies can be expected to reduce mean speeds by about 3 to 5km/h. Lighting and a welcome sign should be implemented within the deceleration area near the community zone/ village.

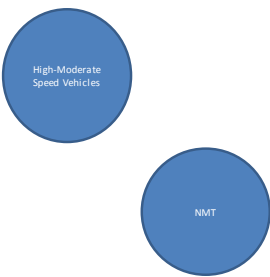
Gateways are recommended throughout the transition zone. This can be done by implementing layered landscaping. Plants are grouped according to height, with smaller plants placed close to the roadway and taller plants placed further away. Layered landscaping together with the lighting will alter the relationship between the width of the road and the height of the nearby vertical elements which influences the driver's perception of the appropriate speed. Where the optical width of the road is less than the height of nearby vertical elements, speeds are lower.

Based on their proven effectiveness, the proposed transition zone treatments are expected to reduce the current 85 percentile speed –which exceeds posted speeds of 80km/h and above in most areas- to 60km/h just before entering the residential sections of the R71 or community zones. Speed limit signs of 60km/hr are required near the community threshold. Gateways improve aesthetics, bestow the community with character and instil an overall sense of pride in the community.

The proposed treatments are not expected to cause driver confusion, however it will still be necessary to inform and educate the community about their function. None of the treatments require high implementation or maintenance costs.

The transition zone should also have a well maintained shoulder with reflectors on the yellow line to provide a greater margin of error for drivers. Towards the community threshold pedestrian pathways must be provided at a safe distance from the road separated by barriers such as fencing masked by vegetation. Guardrails must be installed at the shoulder edge to enforce pedestrian and vehicular separation. The proposed treatments are summarised in **Table 20** below.

**Table 20: Speed transition zone treatments for the R71**

The Road Environment Sub-Systems	Environmental Context	Risk	System Behaviour	Desired Speed (km/h)	Treatment Requirements
	Rural: Transition Zone - Perception-Reaction Area	Low	No Sub-system Interaction	100-80	Transverse Pavement Markings & Warning signs for speed reduction Gateways- layered landscaping creating illusion of road narrowing Maintain road shoulder Install reflectors along yellow line to alert drivers when leaving lane In future-if pedestrian volumes increase pathways with physical barriers at safe distance from road must be implemented
	Rural: Transition Zone - Deceleration Area	Low	No Sub-system Interaction	80-60	Continue layered landscaping Initial intermittent rumble strips at start Succession of rumble strips Road narrowing Lighting Welcome sign Maintain road shoulder Implement rumble strips along yellow line to alert drivers when leaving lane In future-if pedestrian volumes increase pathways with physical barriers at safe distance from road must be implemented
					Self-explaining and Forgiving Environment

Detail design work is required to refine the proposed concept:

- For safety reasons a setback of a few hundred metres may be appropriate between the edge of the community and the transition zone. For a growing community, it may also be necessary to set this threshold far enough away from the current development to allow for near-term growth. It is therefore important to consider future land use changes and to ensure that the urban planning edge is maintained.
- Sight distance limitations may necessitate moving the transition zone thresholds away from the community.
- The design vehicle should be considered when selecting the type of transition zone treatment.
- Community buy-in is important.
- Smaller communities may not be familiar with the various types of transition zone treatments and may need some educating.
- Detailed speed study should be conducted.

### 5.3.3 Village/semi-urban sections

Non-existent land use planning and pedestrian infrastructure as well as inadequate access provision are all community zone issues in the R71 study area. The solutions to these problems will be discussed in this section.

The separation of pedestrians and vehicles is also advocated within the community zone. The R71 is a mobility road and this function can only be served if the interaction with pedestrians is minimised while providing a reasonable level of access. The literature states that pedestrian safety is significantly improved when vehicle and pedestrians are separated. At an impact speed of 60km/h – the proposed community zone speed- the probability of death for a pedestrian is just over 70%. Pedestrians and vehicles should only interact at strategic crossing points such as intersections where vehicles come to a halt to allow pedestrian crossing. The proposed environment is discussed.

### 5.3.3.1 Regulated land use planning

Unregulated land use was identified as a pedestrian safety factor. The illegal movements on the R71 are attributed to the unsafe location of high trip generators and the expanding ribbon development along the road. This outcome substantiates the need for the City of Polokwane to reassess and modify its policies to ensure that the current trend of unregulated land use establishment along the R71 is prohibited. Continued allowance of this type of development will intensify the unsafe road conditions in the study area. Land use within the R71 road reserve should be relocated to more appropriate/safer locations.

### 5.3.3.2 Safe vehicular access provision

Access for pedestrians and vehicles along the R71 should only be allowed at formal intersections. The numerous informal accesses to properties located adjacent to the R71 road reserve indicate the need for parallel internal service roads where space is available. Adjacent land use needs to be integrated with transport solutions to improve access provision. Physically separated (by indigenous bushes such as the layered landscaping for the gateway and a fence) paved access roads are proposed. The access roads must be fully serviced (provision for lighting, traffic calming, pedestrian walkways, public transport facilities, public toilets and hawker facilities, for local economic development) roads that taper from and join the R71 upstream and downstream of intersections. Access to public transport will be more functional and safer for motorists and pedestrians on access roads.

The access road should have a complete streets character to create a safe and attractive environment for pedestrians and other non-motorised transport. Green spaces with street furniture should be developed along the access road reserve to attract pedestrians to the environment. Clear-Vu fence, layered by vegetation is recommended as a barrier between the R71 road reserve and the access road environment. Clear-Vu has proven resilient to cutting, jumping and stealing on many SANRAL projects.

The success of internal access roads is highly dependent on preventing land use from mushrooming within the R71 road reserve, maintaining the fences between the R71 and the access road and preventing public transport from stopping along the R71. If these cannot be achieved, the access roads will not be used. An example of the proposed treatments are illustrated in **Figure 40**.

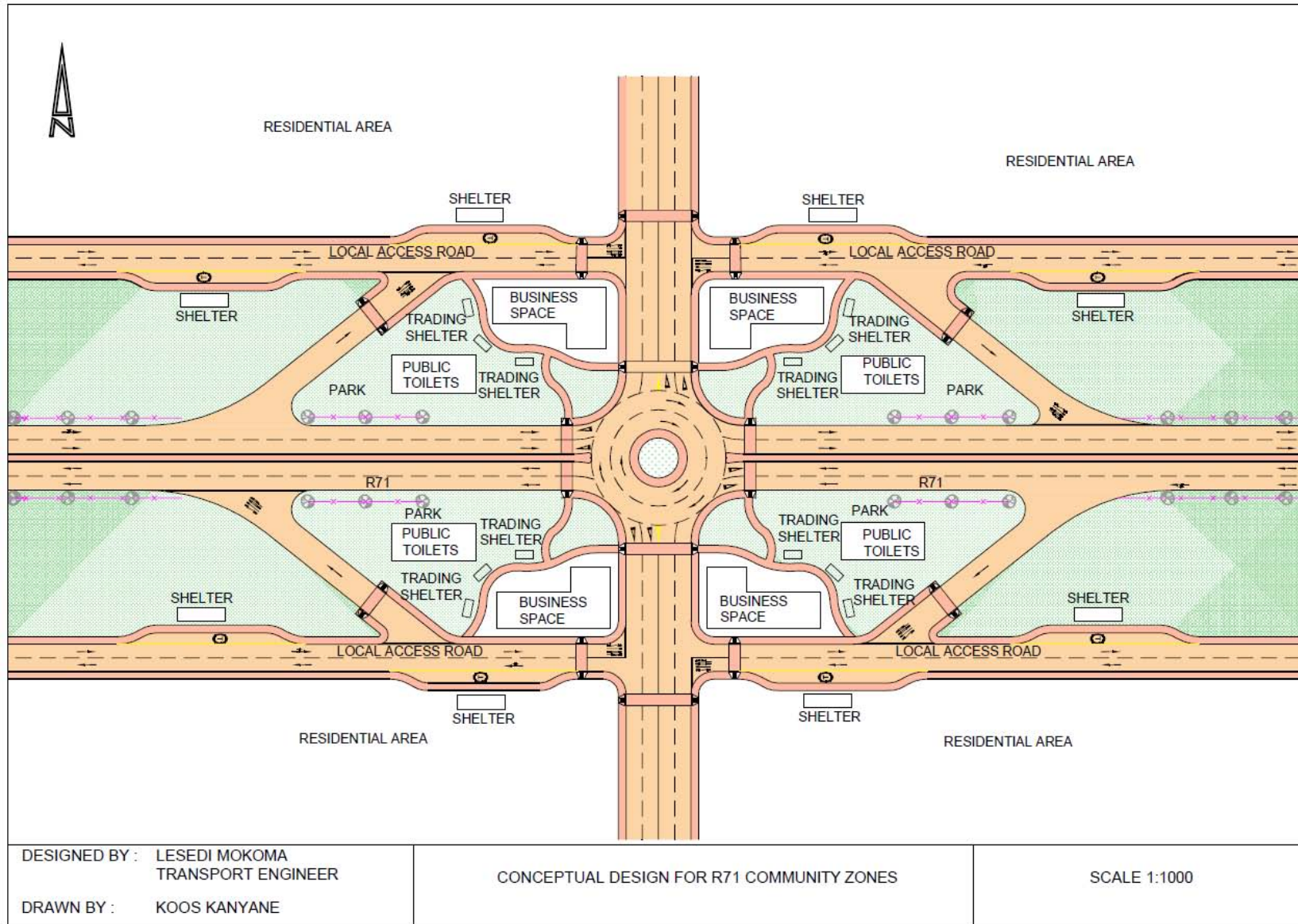


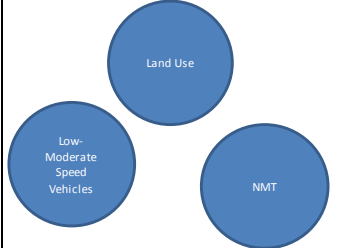
Figure 40: The proposed community zone access road and environment.

The proposed access roads in the community zones may vary due to the available space in each community. The overall community character –discussed above- must still be maintained amidst the space constraints. Access roads and the proposed amenities will decrease the community’s dependence on the R71 as an access road, public transport route and as the best location for economic development. Access roads will accommodate vehicular and pedestrian movements and limit illegal access along the links of the R71. The access road environment integrates land use and transport to promote safety and well-being in the community zone.

A successful access road environment will ensure that the R71 serves only as an access point. This will be discussed in the next section.

Elements of the deceleration zone such as application of road narrowing, lighting and posted 60km/h signage at appropriate intervals on the R71 should be implemented in the community zone. The implementation and maintenance of an adequate road shoulder to increase the margin of error for drivers is also required. The proposed countermeasures are summarised in **Table 21** below.

**Table 21: The proposed community zone countermeasures**

The Road Environment Sub-Systems	Environmental Context	Risk	System Behaviour	Desired Speed (km/h)	Treatment Requirements	
	Community Zone	High	Low and Moderate speed vehicles interact	60	Provide fully serviced internal service road with pedestrian pathways parallel to R71 Relocate illegal land use from the road reserve to new service road and regulate. Implement clear-vu fencing layered with vegetation on the edge of the R71 shoulder Create attractive green spaces along the service road Road narrowing and lighting on the R71 Maintain road shoulder Provide Left-in/left-out (LILO) auxilliary lanes for vehicular access on the R71 Speed Limit signs of 60km/h	Self-explaining and Forgiving Environment

### 5.3.3.3 Strategic crossing facilities

The need for strategic crossing facilities arises from the problem of inadequate access provision for pedestrians along the R71. Safe and convenient crossing facilities should be provided along the road. Crossing facilities should link with the proposed access road environments discussed in the previous section. The solution for strategic pedestrian crossing facilities is broken down as follows:

#### Selecting crossing locations

The literature states that the success of crossing facilities is dependent on their proximity to existing desire lines which inadvertently means close proximity to major land use. Strategic crossing facilities should provide (as practically as possible) the shortest and most direct routes to desired destinations. Direct linkage should exist between habitual areas and other areas of interest, i.e. public transport facilities and shops, etc. Strategic crossing points should avoid significant detours in case the user

may ignore them. This must be balanced with RCAMs access guidelines. These state that pedestrian crossings are feasible on isolated sections of Class 2R roads however at-grade crossing facilities should have a minimum spacing of 5km.

Analysis of the R71 pedestrian movements (status-quo) indicates that pedestrian desire lines crossing over the R71 are available in all human settlements however the lines are denser at the links near intersections. Explanations for this is that many of the high trip generators (businesses, clinics and shops etc) are located at and near the intersections, as well as along the access roads, this consequently attracts public transport; secondly, the intersections are the only formal access points for the linear development that occurs along the access road. Many people therefore walk from deep within the settlement along the access road to the R71. The current reason for the limited use of intersections by pedestrians can be attributed to the yield controlled intersections where vehicles hardly yield for pedestrians and signalised intersections that do not have a pedestrian phase.

The location of the strategic crossing points is recommended at the current intersections in each settlement. These have been adequately spaced according to RCAM specifications. Sight distances at these locations are adequate for pedestrian visibility. Motorists are more likely to anticipate pedestrian crossings at intersections because the majority of them are located in built-up areas. Use of these crossing points will depend on the appeal of the type of crossing treatments provided at the intersections

#### Access restrictions

Fencing-off community zones and concentrating pedestrian traffic at the selected crossings points/ intersections will decrease the number of illegal pedestrian crossing points in the study area. The fewer the crossing opportunities the lower the risk of pedestrian incidents – this must be balanced with adequate access to relevant areas- . Motorists will eventually know where pedestrian crossing points are located and alter their driver behaviour. Low pedestrian demand areas along the R71 which have not been fenced should be provided with access prohibition signs.

#### Crossing Facility Type

The literature review provided a number of crossing facilities. The type selected depends on the pedestrian and vehicular volumes in the catchment area. Pedestrian and vehicular volumes in the study area were low therefore the application of facilities such overpasses and underpasses is not warranted and at-grade facilities will be sufficient.

Intersections on the R71 are very wide, most of which have four approach lanes and are mostly one-way stops with priority for the R71. The R71 traffic is required to yield to pedestrians at transverse crosswalks provided at the intersections. Traffic signals are provided in Mankweng but only one intersection has a pedestrian phase which was not functioning during the site visit.

Traffic flow theory stipulates that the volume of uninterrupted traffic on a road influences the number of gaps available for pedestrian crossing; it therefore follows that the higher the vehicular traffic volume the lower the number of crossing opportunities for pedestrians and the lower the level of service (LOS) for pedestrian access. Uninterrupted flow refers to a situation where the pedestrian crossing location is within 500m of a traffic signal and there is little scope for additional traffic to enter the stream and therefore fill the gaps created by the upstream traffic control (NZTA). **Table 22** shows the relationship between uninterrupted vehicular traffic volumes, pedestrian crossing time and the average delay experienced by pedestrians. The LOS, a measure related to the pedestrian delay is provided in **Table 23**.

**Table 22: Traffic volume versus pedestrian crossing time on roads with uninterrupted flow (NZTA, p. 8)**

Situation	Traffic Flow (veh/h)	Pedestrian Crossing Time (sec)								
		4	6	8	10	12	14	16	18	20
Single Lane Uninterrupted Traffic Flow	200	1	1	2	4	5	8	11	14	18
	400	1	3	6	10	16	24	35	50	70
	600	2	6	12	23	40	67	108	171	267
	800	4	11	26	55	111	215	409		
	1000	6	22	64	169	429				
	1200	12	58	241						
	1400	32	324							
	1600	415								
Two Lane Uninterrupted Traffic Flow	200	0	1	2	3	5	7	10	13	17
	400	1	3	5	9	14	22	32	45	62
	600	2	5	10	19	32	52	82	125	190
	800	3	8	18	36	68	122	213	366	
	1000	4	13	32	71	149	304			
	1200	6	21	58	148	358				
	1400	9	35	112	337					
	1600	14	62	239						
	1800	21	119							
	2000	36	263							
	2200	67								
	2400	150								
2600	452									
More Than Two Lanes Uninterrupted Traffic Flow	200	1	2	3	4	6	9	12	15	19
	400	2	4	7	11	17	25	36	50	68
	600	3	7	13	23	38	61	95	146	221
	800	4	11	23	45	84	150	263	455	
	1000	7	18	42	93	196	402			
	1200	10	30	81	207					
	1400	14	52	169						
	1600	23	99	399						
	1800	38	213							
	2000	70								
	2200	150								
	2400	413								

A crossing facility with an average pedestrian delay of 20 seconds or more has a level of service of E and F and is deemed inappropriate. At an average walking speed of 1.2m/s, crossing a 2 lane road with a width of 7 metres will require 5.8 seconds crossing time. **Table 21** infers that for two lane uninterrupted traffic streams, volumes greater than 1200 vehicles per hour will result in unacceptable pedestrian delay. The 30<sup>th</sup> highest volume or the design hour in the study area is 1800 vehicles per hour, while the 30<sup>th</sup> highest volumes in the east and west directions are 1108 and 999 vehicles per hour respectively. This means at a walking speed of 1.2m/s, for 2 lane uninterrupted traffic the existing traffic streams in the study area have reasonable gaps for pedestrian crossings.

**Table 23: Pedestrian Level of Service (NZTA, p. 10)**

Average Pedestrian Delay (sec)	Level of Service	Definition	Description	Appropriate Situation
<5	A	Excellent	Pedestrians able to cross almost immediately on arrival	Local Streets Collector Roads
5-10	B	Very Good	Most pedestrians able to cross with little delay 95 <sup>th</sup> percentile delay ≈40 secs	
10-15	C	Satisfactory	Most able to cross with acceptable period 95 <sup>th</sup> percentile delay ≈60 secs	Minor Arterial Major Arterial
15-20	D	Some Concern	Some pedestrians must wait longer than desirable for an acceptable gap 95 <sup>th</sup> percentile delay ≈80 secs	
20-40	E	Major Concern	Most pedestrians must wait longer than desirable for an acceptable gap 95 <sup>th</sup> percentile delay ≈80 secs	Inappropriate All Situations
>40	F	Unsatisfactory	Almost all pedestrians must wait longer than desirable for an acceptable gap 95 <sup>th</sup> percentile delay ≈80 secs	

The proposed intersection control along the R71 is a two lane traffic circle. Provision of a traffic circle will reduce the existing intersection approach lanes from four to two, reducing the current crossing time and improving the safety of pedestrians. Pedestrians must be channelised to the crossing facility using pedestrian pathways and landscaping on the verge onto wide continental or bar-paired crosswalk markings on all approaches of the circle. The crosswalks on each approach should be elevated as part of the treatment, to enable pedestrians to cross the road at the same level as the sidewalk. Raised medians –same level as the crosswalk- should be provided as refuge islands for the pedestrians. The crosswalk markings must be preceded by a series of rumble strips and advanced yield lines to reduce the possibility of collision with pedestrians. The literature states that older pedestrians have difficulties crossing traffic circles. This will be countered by pedestrian channelization to the strategic crossing locations, providing crossings downstream and upstream of the traffic circle, adequate sight distances at the intersection and the minimised crossing widths.

The pedestrian use of crossing points depends on the attractiveness of facilities. Factors that affect attractiveness are subjective; however they definitely include safety, convenience and comfort amongst others. Attractive Strategic Pedestrian Crossing Points can be achieved by ensuring that crossing points are safe and aesthetically appealing. Crossing facilities should be connected to wide brightly lit sidewalks that pass through clean and safe environments on the access roads provided in the community zone.

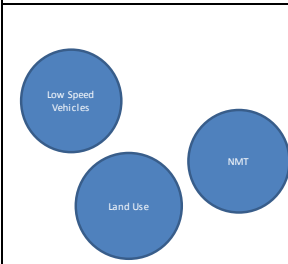
The removal of traffic signals will reduce the dependence of traffic control on electricity and the associated maintenance issues. The literature states that converting the current two-way stop-controlled intersections to traffic circles has the potential of reducing the total number of accidents by 71% and fatal and all injury accidents by 87%. Converting a signalised intersection to a traffic circle has been seen to reduce the total accidents by 48% and fatal and all accidents by 78%. A dual-lane traffic circle

will have more than adequate capacity for the current traffic operations at intersections on the R71. A traffic circle slows all vehicular movements through the intersection and improves pedestrian crossings in all directions.

Traffic circles can be built with a variety of materials, including asphalt, concrete, or pavers. It is recommended that a traffic circle with pavers of contrasting colour (to the pavement) be utilised in order to ensure that the crossing will be visible. Textured pavers will reduce the speed of drivers and encourage them to yield to pedestrians.

Pedestrian warning signs that permanently warn motorists about the possibility of pedestrians crossing downstream will be required. Static permanent warning signs can be placed upstream and in the vicinity of the crossings to effectively warn motorists. Traffic circles are expensive to construct however they are ideal for the rural environment. A summary of the proposed improvements in the community zone is shown in **Table 24**.

**Table 24: The proposed crossing facilities in the community zone**

The Road Environment Sub-Systems	Environmental Context	Risk	System Behaviour	Desired Speed (km/h)	Treatment Requirements
	Community Zone	High	All sub-systems interact	0	Select crossing locations on the R71 based on the proximity to major desirelines Link crossing locations to pedestrian pathways and green spaces along prominent desirelines Implement landscaping along pathways to channelize pedestrians to respective crossing locations. Select the intersection control based on the pedestrian and vehicular volumes. Traffic circle control and wide raised pedestrian crossings Provide pedestrian refuge island on the median Improve safety by implementing rumble strips before crossing facility Implement cloured and textured pavers on the traffic circle for visibility and Provide adequate lighting at the crossing facility provide pedestrian warning signs
					Self-explaining and Forgiving Environment

## 5.4 COMMUNITY PROGRAMMES AND LAW ENFORCEMENT

The proposed interventions must be complimented with the following measures:

### STRATEGIC LAW ENFORCEMENT

Strategic law enforcement is vital for providing safe at-grade pedestrian crossings at intersections. Law enforcement should help ensure NMT and motorists adhere to the law. Possible enforcement includes camera law enforcement, regular speed persecution and visible policing.

### COMMUNITY EDUCATION AND TRAVEL PROGRAMMES

Engaging community members by creating road safety forums, outreach programmes and awareness is important for garnering awareness, public support and compliance. The following interventions are recommended:

- Educating the community about the proposed interventions;
- Creating awareness about drunk walking, the appropriate use of pedestrian infrastructure, motorists behaviour / attitude towards pedestrians;

- Pedestrian visibility campaigns including the possible use of retro-reflective material on school uniforms;
- Organising walking school buses in the community; and
- Advertising - radio campaigns on community radio – visibility.
- Community policing forums can be established in areas where policing resources are strained. Dedicated community traffic patrollers can be trained and appointed to assist the safe crossing of vulnerable road users and to maintain compliance at crossing facilities. First aid training for traffic patrollers will be beneficial for providing low-level but essential assistance to accident victims.

## 5.5 CONCLUSION

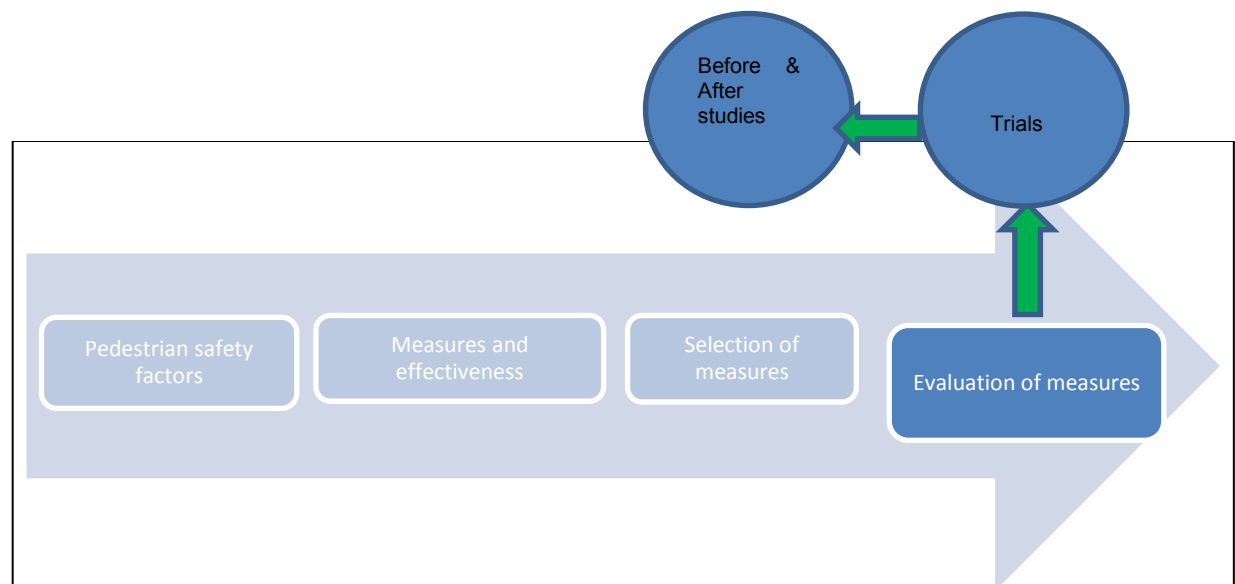
The proposed engineering solutions for the R71 pedestrian safety problem were selected on the basis of effectiveness and functionality. All proposed solutions have been applied in Polokwane to some degree and will not be difficult to implement and operate. The community will however still need to be educated on these principles.

Solutions such as HAWKs and pedestrian countdown signals have proven effectiveness in other countries however, their reliance on electricity and electronic skills for maintenance is not ideal for rural communities in South Africa. An example of this was seen in Mankweng where the pedestrian phase of the traffic signal was not working. This problem caused interruptions to pedestrian movements in the area. The time taken for the signal to be fixed is not known, however, rural municipalities usually don't have the capacity to maintain such devices. The use of electronic systems is further dissuaded by the power supply interruptions that are common in South Africa.

Practical solutions were selected. These are, system-wide speed reduction such as the high to low speed transitions zones; enforcing access management guidelines by limiting access along the R71 and recommending an internal service road; recommending traffic calming and regulated land use policy. Implementation of the solutions requires focused contributions from community leaders, politicians, policy makers, planners, road authorities, municipal departments, law enforcement, educators, business forums and transport designers.

## 6. EVALUATION OF PEDESTRIAN SOLUTIONS

In Chapter 6 the various methods used to evaluate pedestrian safety measures will be discussed.



The recommended pedestrian safety solutions have proven effectiveness in other settings; however this does not guarantee effectiveness on the R71. A trial should be conducted to determine the effectiveness of the solutions in the study area. Providing infrastructure such as access roads, traffic circles and green spaces comes at a high cost and it is sensible to apply the solutions in one community and evaluate for effectiveness before implementing throughout the entire study area.

Trials are necessary to assess solutions if limited or no information is provided on the performance of certain interventions in specific settings. The primary purpose of such an evaluation is to determine whether the interventions have caused a positive change in driver and pedestrian behaviour. The evaluation may indicate whether additional improvements are required. The results of the trial can be shared and may add value to designers investigating similar projects.

Two studies are required; a before/after speed study and a before/after safety study. If detailed and accurate speed and crash data was gathered for the status-quo analysis it can be used as the before period for the data analysis.

### 6.1 BEFORE/AFTER SPEED STUDY

The objective of the study is to determine whether speeds through the transition and community zone have been reduced to a level that's consistent with the desired speed. A minimum of three locations are required for collecting speed data. The key is to select

relevant locations with respect to the transition zone boundaries and also at the exact same locations along the roadway after implementation of the treatment.

The primary measures used to assess the effectiveness of speed treatments in reducing speeds are the following:

- The percentage of vehicles in compliance with the posted speed limit at end the of the transition zone.
- The 85<sup>th</sup> percentile speed and overall speed distribution in comparison to the posted speed limit at the end of the transition zone.
- The percentage of vehicles in compliance with the posted speed limit within the community.
- The 85<sup>th</sup> percentile speed and overall speed distribution in comparison to the posted speed limit within the community.

The temporal effect of the treatment should also be assessed as part of a before/after speed study. Consideration should be given to collecting speed data approximately 3, 6 and 12 months after installation of the treatment to assess the long term effectiveness of the treatment in reducing speeds. It is possible that speeds may be reduced in the short term following installation of a treatment, but as drivers become accustomed to the treatment over time, speeds may increase to the same levels as before installation of the treatment (NCHRP, 2012).

## 6.2 BEFORE/AFTER SAFETY STUDY

The objective of the safety study is to assess whether the treatment improved the number of accidents in the transition and community zones. Ideally 3 to 5 years of accident data is required before and after the implementation of the solution.

Measures of effectiveness for analysis of pedestrian safety intervention trial sites are:

- The over-all frequency of speed-related crashes.
- Where the crashes occurred in relation to the location of the study area.
- The distribution of crash types across the study area.
- The severity distribution of crashes (NCHRP, 2012).

Retting et al, (2013) states that the methodology for a study by Redmon to evaluate the “before-and-after” effects of pedestrian safety countermeasures in numerous areas in the United States made an assessment based on the following measures of effectiveness:

- Percentage of drivers breaking when pedestrians are present.
- Percentage of pedestrians trapped on the crosswalk.
- Percentage of pedestrian-vehicle conflicts.
- Percentage of drivers stopping (Retting et al, 2003).

Inclusion of non-treatment sites is vital when conducting the study. This can be done in two ways. An empirical Bayes methodology using safety performance functions developed using data from non-treatment sites can be used to compare the observed after crash frequency to the expected average after crash frequency estimated using the empirical

Bayes method. Alternatively, the comparison group method can be used. This method allows consideration of general trends in crash frequency or severities whose causes may be unknown, but which are assumed to influence crash frequency and severity at the treatment site and comparison sites equally. Selection of an appropriate comparison group is important (NCHRP, 2012). Changes in annual traffic volumes also have an impact on the frequency of accidents.

Retting et al states that a common weakness in many crash-based before-and-after evaluations of traffic engineering solutions is failure to account for regression to the mean, which can result in overestimation of the effects of an intervention when treatment sites are selected because they have involved high numbers of crashes. The empirical Bayes methodology is preferred because it compensates for the regression to the mean bias (Retting et al, 2003).

### **6.3 STAKEHOLDER CONSULTATIONS**

Stakeholder experience and perspective on the effectiveness of treatments should be obtained by conducting interviews with the community, law enforcement officers, and the road authority etc.

Favourable trial results and positive stakeholder experience will substantiate the roll-out of treatments throughout the entire study area.

## 7. SUMMARY

South Africa's pedestrian accident rate is one of the highest in the world. The percentage of pedestrian accidents to total road accidents is approximately 33% (RTMC, 2011) far greater than the world average of 22% (World Health Organisation, 2013). The problem is more acute in rural areas where 1 in 3 pedestrian accidents results in pedestrian fatalities. The ratio on urban roads is 1 in 10.

The sobering pedestrian safety statistics describing South Africa's rural roads and the limited research in rural road safety prompted the need to research functional and effective traffic engineering solutions that can improve pedestrian safety on rural high order roads located near human settlements. This investigation was conducted using the R71 Polokwane -a road with a history of pedestrian safety problems- as a case study. The thesis approach was as follows:

1. Provide a methodological approach to identifying pedestrian safety risk areas in settlements located near rural high-order roads.
2. Identify traffic engineering countermeasures that have been empirically proven to improve pedestrian/vehicular conflicts or accidents in high risk areas with similar conditions as the R71.
3. Provide a conceptual design of suitable countermeasures for the R71 and other similar contexts.

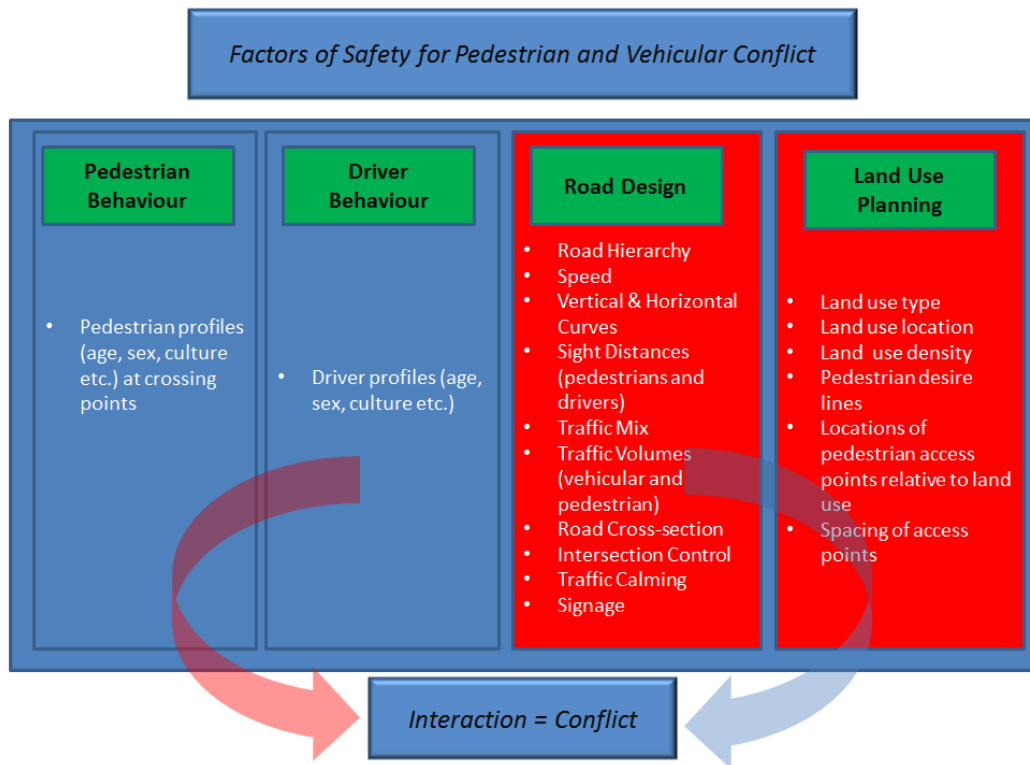
A summary of the process outcomes is provided:

### 7.1 PEDESTRIAN RISK ASSESSMENT

The literature review of underlying causes of pedestrian accidents on rural highways yielded four pedestrian safety risk factors (**Figure 41**). The pedestrian safety risk factors are summarised as follows:

- **Pedestrian behaviour** (Pedestrian/vehicular conflict at crossings, Talking and walking, Reduced reaction time and walking speed for the elderly, Inability of children to gauge vehicle speed and other relevant information, Lack of supervision of children who are too young to make safe judgements, walking under the influence of alcohol etc.).
- **Driver behaviour** (Driver attitudes to pedestrians, unsafe driving practices and driver distractions, e.g. cell phone, advertising, driver fatigue, speeding, driving under the influence of alcohol etc.).
- **Road Design** (inadequate and inappropriate posted speed, sight distances, curve radii, intersection control, pedestrian facilities, lighting etc.).
- **Land use planning** (unregulated building encroachment, limited land use and transportation integration, unregulated and inequitable access management etc.).

A rural high order road environment characterised by any of these factors was assumed to have compromised pedestrian safety or a degree of pedestrian safety risk.



**Figure 41: Pedestrian safety factors on rural highways.**

It was assumed that the higher the prevalence of pedestrian safety risk factors in an area the greater the risk to pedestrian safety. This can be summarised in a pedestrian safety risk function:

$$\text{Pedestrian Safety Risk} = a(\text{pedestrian behaviour}) + b(\text{driver behaviour}) + c(\text{road design}) + d(\text{land use}) + e(\text{accidents} \cdot \text{km travelled}) + f(\mathbf{F})$$

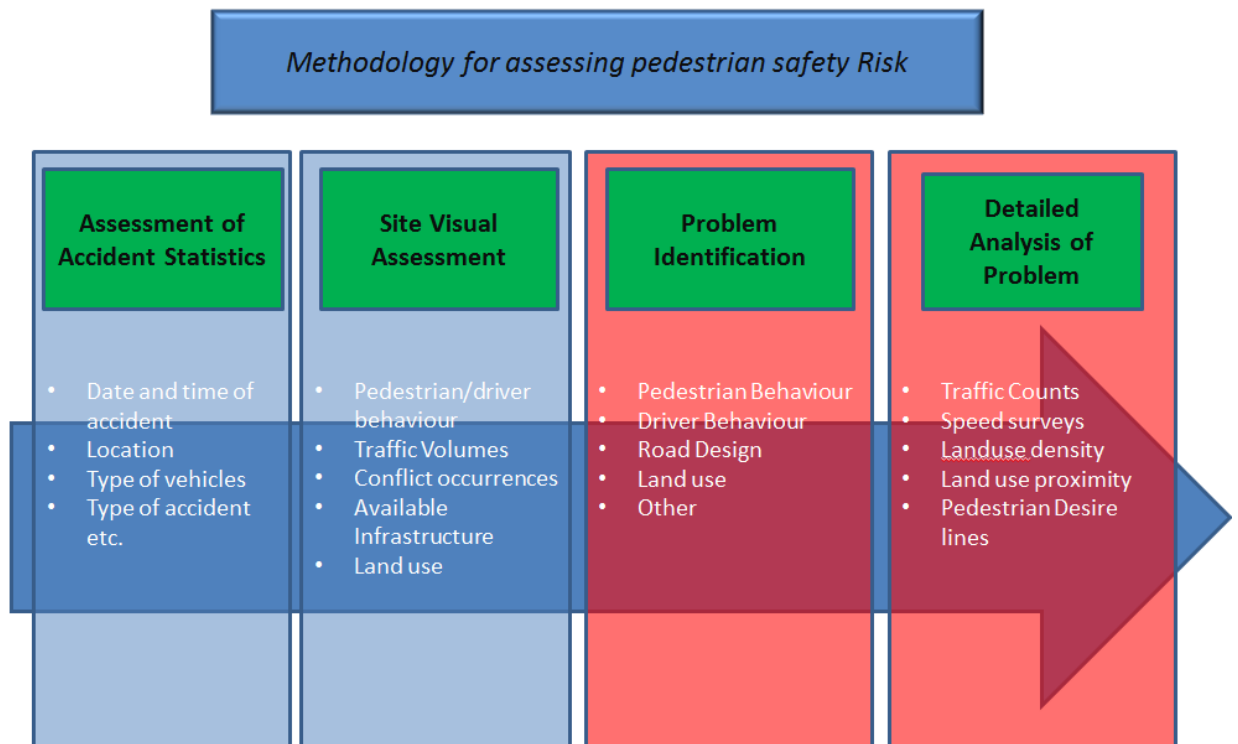
- **a, b, c, d, e** and **f** being weighting factors
- **F** being other factors which have not been included i.e. vehicle condition etc.

It was concluded that the function for Pedestrian Safety Risk can only be assessed when a comprehensive data set is provided, this is particularly important when calculating the weights for the different risk factors. The general lack of descriptive qualitative accident and road user behavioural data necessitates for an in-depth data collection exercise.

Knowledge of the underlying causes of pedestrian accidents and a literature review of assessment methodologies was used as a basis for developing a methodology for assessing pedestrian safety risk in a rural context. Prior to an assessment it is vital to thoroughly understand the socio-economic conditions in a study area. Household travel surveys, Integrated Development Plans and other statistics and plans provide a context specific

understanding. The methodology indicates that for existing roads, analysis of accident statistics is typically the starting point for assessing pedestrian safety risk. The outcome of the analysis reveals the context under which accidents are occurring and directs the focus for site visual assessments.

Site visual assessments are necessary for providing planners and designers with a feel for the road environment conditions and to provide hands on experience of near conflicts, travel behaviour, and environmental anomalies. High accident potential spots where no accidents have occurred before can also be established during a site assessment. This knowledge guides the type of surveys to be conducted in the study area. The data collected is required for detailed analysis of the pedestrian risk factors in the area. The methodology is provided in **Figure 42**.



**Figure 42: A methodology for assessing pedestrian safety risk.**

Application of the risk assessment methodology on the R71 yielded the following outcomes:

The safety issues on the R71 are a symptom of the following underlying causes:

- Disintegrated land use and transport planning;
- Lack of pedestrian infrastructure; and
- Poor design of speed transition zones between rural areas and villages and urban areas.

An interesting result of the analysis is that Mankweng had a high prevalence of pedestrian safety risk factors; based on the methodology, this effectively reduced Mankweng to a high pedestrian risk area. Interestingly though, Mankweng had the lowest number of pedestrian accidents in the study area. This is synonymous with research by Zaajac stating that the

urban nature of the settlement contributes to the higher safety. Land use density, advertising, high pedestrian and vehicular volumes may lead to a reduction in speed. The gradual land use type transition between rural areas and Mankweng may also prompt drivers to slow down as they enter Mankweng.

An analysis of the villages indicates that pedestrian accidents are directly proportional to all the risk factors assessed in the status-quo. Moria and Nobody consistently scored as areas with some of the highest risk as well as having the highest number of pedestrian accidents. The overarching problem in rural areas and villages is the non-existent land use planning, inadequate access provision, non-existent pedestrian infrastructure provision and poor design of speed transition zones between rural and village sections.

## 7.2 PEDESTRIAN SAFETY MEASURES AND RECOMMENDATIONS FOR THE R71

Numerous effective countermeasures were outlined in the literature review but some were not suitable for a typical rural setting in South Africa. Measures which would require electricity to function and rare skills to maintain such as pedestrian countdown signals were deemed unsuitable for the R71 and similar rural contexts. A summary of functional and effective countermeasures for addressing each of the four pedestrian safety risk factors is provided in **Table 25**. Countermeasure effectiveness is categorised according to the following:

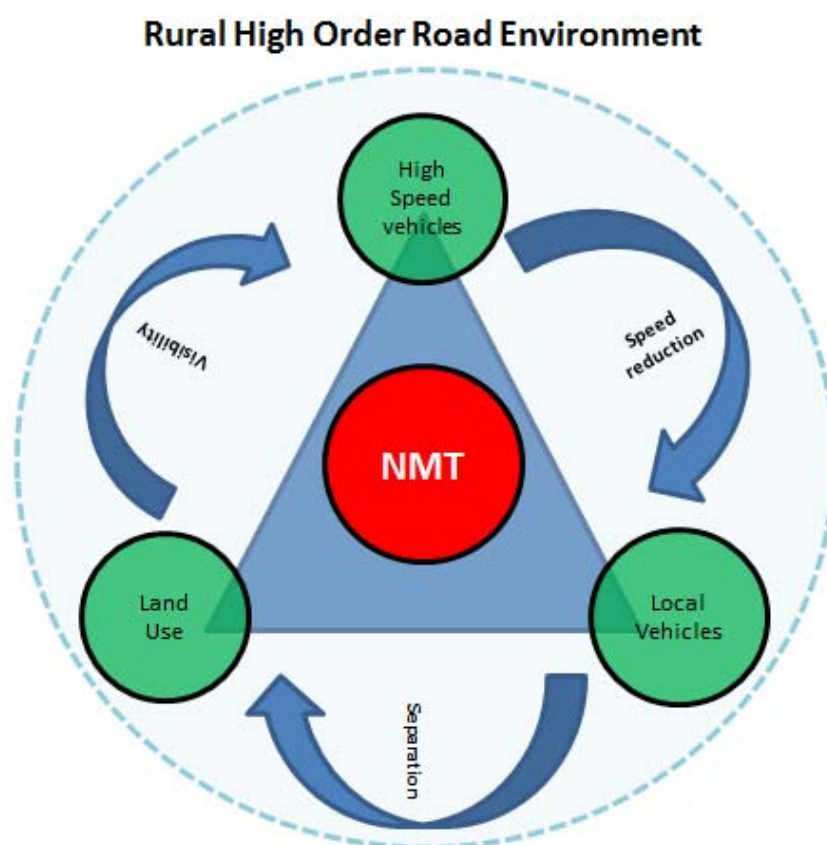
- **Proven:**  
Evidence from robust studies such as randomised controlled trials, systematic reviews or case-control studies show that these interventions are effective in reducing pedestrian fatalities and injuries, or bringing about desired behaviour change.
- **Promising:**  
Evidence from robust studies show that some pedestrian safety benefits have resulted from these interventions, but further evaluation from diverse settings is required and caution is thus needed when implementing these interventions.
- **Insufficient evidence:**  
Evaluation of an intervention has not reached a firm conclusion about its effectiveness.

Table 25: Summary of safety countermeasures for pedestrian safety risk on rural high order roads

Safety Factors	Intervention	Effectiveness		
		Proven	Promising	Insufficient Evidence
Road Design	High speed to low speed transition zones for rural highways			
	Traffic calming measures			
	Modified highway cross-section			
	Self-explaining roads			
	Context-specific geometric design			
	Enforcing access management guidelines			
Integrated Land Use and Transport Planning	Provide sidewalks			
	Install overpass/underpass			
	Provide school route improvements			
	Pedestrian channelization			
	High visibility crosswalk treatment			
	Development of supporting access roads			
	Signage			
	Advanced stop and yield lines			
	Medians and crossing islands			
	Public transport facilities			
	Implement lighting/crossing illumination			
	Special Intersection Paving			
	Traffic signals			
	Roundabout			
Pedestrian and Driver Behaviour	Provide education, outreach and training			
	Develop and/or enforce traffic laws on speed, drinking and driving, pedestrian right-of-way, red light disobedience, commercial roadside activity and traffic control			
	Implement "walking school bus" programmes			

### 7.2.1 A systems framework for countermeasure selection

A framework for selecting pedestrian safety countermeasures using a system-wide approach was designed. This was informed by current best practice in industrialised countries which requires acknowledgement of responsibility and action from all actors including policy makers, transport authorities, town planners and road designers. A system framework for the selection and implementation of engineering countermeasures is required to strategically guide and ensure a unified approach that holds all actors accountable. The first step in designing the framework was to identify all the system elements. A diagrammatical representation of the rural road environment as an open and complex socio-technical system and the proposed countermeasure categories for a safe system are shown in **Figure 43**. Pedestrians and NMT in general are viewed as the main priority in the system particularly due to their vulnerability.

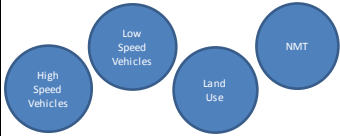


**Figure 43: The road environment system**

The three broad categories for pedestrian safety engineering countermeasures defined by Retting et al are: separation of pedestrians from vehicles by time and space; increased visibility and speed reduction. Countermeasure selection should therefore be based on ensuring that firstly pedestrians are successfully separated from high-speed road conditions; secondly on approach to human settlements infrastructure that facilitates the visibility of all road users must be provided and where pedestrian and vehicular crossings are warranted,

countermeasures that effectively reduce speed must be implemented. The solution framework for pedestrian safety on rural high order roads is presented in **Table 26** below.

**Table 26: The solution framework for pedestrian safety on rural high order roads**

The Road Environment Sub-Systems	Environmental Context	Risk	System Behaviour	Desired Speed (km/h)	Treatment Requirements	
	Rural	Low	No Sub-system Interaction	80-120	Total Separation	Self-explaining and Forgiving Environment
	Village/Semi-Urban Settlement	Medium	Minimal Interaction	60	Total Separation, Visibility and Speed reduction	
	Crossing Location	High	Sub-System Interaction	0-20	Time & Space Separation, Visibility, Speed Reduction	

The Solution Framework for Pedestrian Safety on high order roads illustrates the road environment sub-systems, namely; high speed vehicles fulfilling a mobility need, low speed vehicles, NMT and land use fulfilling a local access need. The interaction of sub-systems is determined by environmental contexts which intrinsically have an impact on risk. Therefore successfully controlling systems interactions in different environmental contexts is the foundation of the framework.

The table shows that rural high order roads should exist under three clearly defined environmental contexts; rural, village/semi-urban and village/semi-urban crossing locations. The three contexts differ in terms of character, road function, speed, sub-system interaction, risk and therefore safety countermeasures. Crossing locations represent the highest risk given that all the road environment sub-systems will interact at that point. Countermeasures should therefore be applied throughout all environmental contexts of the system to ensure that the road function transforms from a high speed inaccessible mobility road in rural sections to a safe and accessible road at crossing locations.

Prescribing and controlling the desired speed to combat risk is therefore paramount. The desired speeds for rural contexts prescribed in the table will facilitate mobility where total separation of sub-systems is required. The prescribed speeds in the village/semi-urban contexts are extracted from literature on safe crossing speeds for pedestrians and will facilitate safety and accessibility of NMT and low speed local traffic where sub-system interaction is encouraged. The transition from rural to residential sections should be facilitated by speed transition zones.

It is imperative that the road user be aware of the distinction between the different environmental contexts. The table also shows that system compliance and success will also hinge on selecting and repetitively applying measures that will foster self-explaining road environments. The complexity and imperfection of sub-systems behaviour and the consequences of this on interactions possibly resulting in conflict should be countered as much as possible by a forgiving road environment that allows the system to rectify itself without fatalities.

### 7.2.2 Recommended pedestrian safety countermeasures for the R71

The recommended solution for the R71 is a system-wide application summarised as follows:

- High-to-low speed transition zones that will cause vehicles to decelerate to a speed of 60km/h and less in residential settlements.
- The provision of attractive parallel service roads with a complete street character in residential settlements is important for access provision and integrating land use and transport. The access roads will serve as public transport routes, areas for local economic development and will comprise of pedestrian walkways and green spaces. Use of these roads must be enforced by installing fencing along the R71.
- The encroaching land use in the study area must be relocated from the R71 road reserve to the proposed service road and stringent measures must be formulated to enforce land use regulations in future.
- Strategic crossing points at the existing intersections on the R71 are proposed. These must be linked to pedestrian pathways provided along major pedestrian desire lines. Crossing facility use must be enforced by implementing landscaping or barriers that channelize pedestrians to crossing locations.
- The vehicle and pedestrian volumes in the study area are appropriate for traffic circle controlled intersections and at-grade raised pedestrian crossing facilities upstream and downstream of intersections.
- Road narrowing, rumble strips, textured paving, lighting and pedestrian warning signs will be implemented upstream of pedestrian crossing facilities.

The proposed solutions are functional and effective for rural roads however they must be trialled before implementation throughout the entire study area. The primary purpose of such an evaluation is to determine whether the interventions have caused a positive change in driver and pedestrian behaviour. The evaluation may indicate whether additional improvements are required. Two studies are required; a before/after speed study and a before/after safety study. If detailed and accurate speed and crash data was gathered for the status-quo analysis it can be used as the before period for the data analysis. Stakeholder experience and perspective on the effectiveness of treatments should be obtained by conducting interviews with the community, law enforcement officers, and the road authority etc. Favourable trial results and positive stakeholder experience will substantiate the roll-out of treatments throughout the entire study area.

The proposed interventions must be complimented with the following measures:

- Educating the community about the proposed interventions;
- Creating awareness about drunk walking, the appropriate use of pedestrian infrastructure, motorists behaviour / attitude towards pedestrians;
- Pedestrian visibility campaigns including the possible use of retro-reflective material on school uniforms;
- Organising walking school buses in the community;
- Advertising - radio campaigns on community radio – visibility; and
- Law enforcement for all road users;

- Community policing forums can be established in areas where policing resources are strained. Dedicated community traffic patrollers can be trained and appointed to assist the safe crossing of vulnerable road users and to maintain compliance at crossing facilities. First aid training for traffic patrollers will be beneficial for providing low-level but essential assistance to accident victims.

These solutions can be applied to contexts with similar characteristics as the R71. The higher the prevalence of pedestrian safety risk factors and accidents in an area the less sub-systems interaction is recommended resulting in grade separated infrastructure at the extreme end. Lower risk areas justify at-grade pedestrian access supported by system-wide speed reduction measures. The type of crossing treatments selected is highly dependent on the road user behaviour as well as the functionality and effectiveness of application in certain contexts.

## 8. CONCLUSIONS AND RECOMMENDATIONS

### 8.1 PEDESTRIAN SAFETY MEASURES AND RECOMMENDATIONS FOR THE R71

The research had two aims which were discussed in the first chapter. They are recapped below:

- Firstly to conduct a literature review that investigates the causes of pedestrian accidents, methods for assessing pedestrian safety risk and functional and effective traffic engineering solutions that can improve pedestrian safety on rural high order roads. The outcomes of the literature review are; a methodology for assessing pedestrian safety risk and a cross table of effective pedestrian safety countermeasures.
- Secondly to conduct an explanatory case study of the R71 pedestrian safety problem guided by the outcomes of the literature review to identify pedestrian safety problems and recommend measures for the problem in a rural South African context. The overarching outcome of the case study is a solution framework for pedestrian safety on rural high-order roads.

The research has attempted to respond to the aims. Limitations to the scope –mini dissertation- and the quality and extent of the data limited the detail of the outcome. The following section provides a list of recommendations to improve future research.

### 8.2 RECOMMENDATIONS FOR EFFECTIVE PEDESTRIAN STUDIES

The research yielded the following recommendations:

- The acquired accident data for the R71 was very limited. The coarse data limited the depth of analysis that could have been conducted on pedestrian safety on the R71. Details such as accident location, accident cause, pedestrian and driver characteristics could have provided in-depth understanding of pedestrian risk factors and appropriate measures could have been recommended. It is therefore reinforced – similar to many reports in the country- that accident data collection processes be dramatically improved. Research institutions should train law enforcement officers and accident investigators on effective ways to collect data. Detailed annual accident statistics for rural high order roads should be available on an accessible platform.
- Detailed historic data will enable proper monitoring of high risk areas as well as open doors to more research on pedestrian safety. Further research such as developing the pedestrian safety index function discussed above may result in the development of a pedestrian safety risk model which may be used to predict the probability of such occurrences under certain conditions.
- The research, although limited, indicated that pedestrian safety on rural mobility roads traversing through residential settlements was highly related to limited access provision, infrastructure and regulated land use planning.

- Everyone is a pedestrian at certain points in their trip. Pedestrian safety should therefore not be an afterthought but an integral part of the project cycle. Authorities must allocate more resources to pedestrian safety investigations and infrastructure provision and maintenance.
- Investment in South African guidelines on pedestrian safety measures on rural higher order roads is recommended. For example, the design standards for high-to-low speed transition zones were adapted from the document produced by the National Cooperative Highway Research program. Design standards derived for South African conditions will have been more appropriate to use.
- ITS applications such the HAWK and pedestrian countdown signals are measures that could be used in the long-term when conditions change in South Africa. It is therefore important to keep abreast of international trends in the pursuit to save lives.

### 8.3 CONCLUSION

The implementation of disintegrated pedestrian safety solutions such as providing engineering countermeasures without consulting communities; not understanding regional road safety needs; conducting sporadic law enforcement patrols etc. is ineffective and inefficient. Labuschagne and Ribbens (2014) suggest that a shift in the paradigm is required in the planning, implementation and operation of NMT-relevant infrastructure. The paradigm shift should start by acknowledging that the road environment is a complex system and requires systems thinking and collaborative solutions.

Pedestrian safety is a problem emanating from systems failure; the result of a breakdown in the interaction between the road user, environment and vehicle. The prevalence of pedestrian risk factors in an area represents a break-down in efficient system functions on all levels of government; the private sector and society in general. A system-wide results focus Rural Pedestrian Safety Strategy must be formulated as part of the Road Safety Strategy to create a clear and focused national plan that will steer the country in a positive direction.

A unified plan endorsed by and assigning responsibility to all actors, whether its policy makers, schools, communities or drivers etc. will result in a cohesive and thus effective safety program. A results focus plan involves the following elements:

- Appraising current road safety performance through high-level strategic review;
- Adopting a far-reaching road safety vision or goal for the longer term;
- Analysing what could be achieved in the shorter term and proposing targets; and
- Agreeing targets across the road safety partnership and ensuring stakeholder accountability for results.

Prescribing to a results focus systems plan will also ensure that institutional deficiencies such as limited funding, substandard design, implementation and maintenance which typically affect the effectiveness of countermeasures will be systematically resolved. A systems plan will engage all actors from the onset; bestowing a sense of ownership for the solution, garnering public acceptance and increasing the likelihood of compliance.

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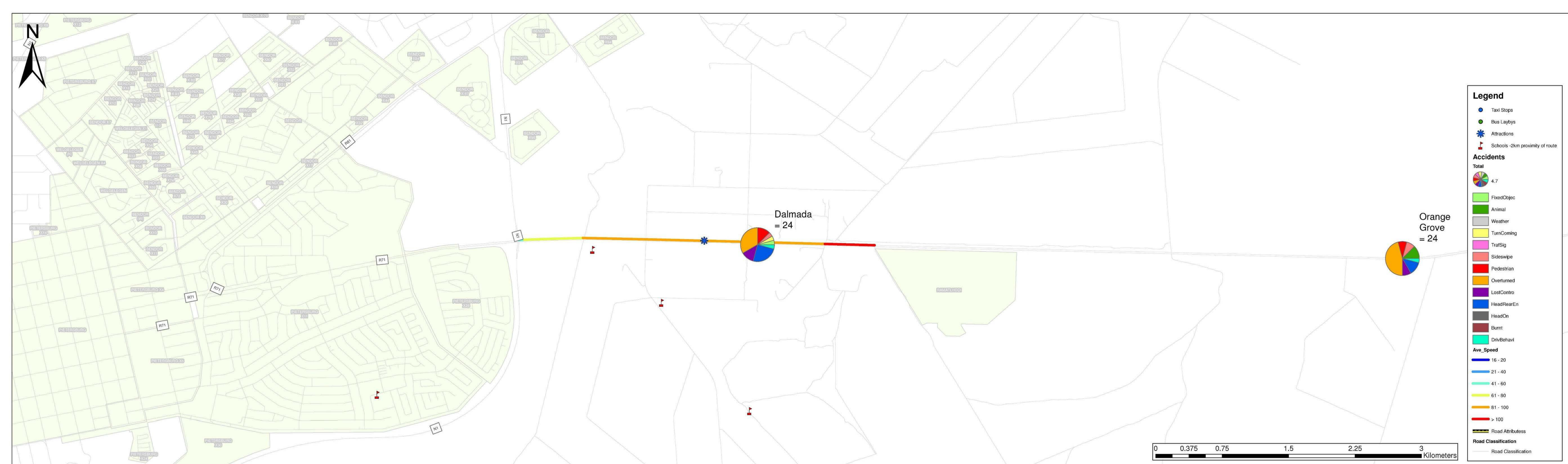
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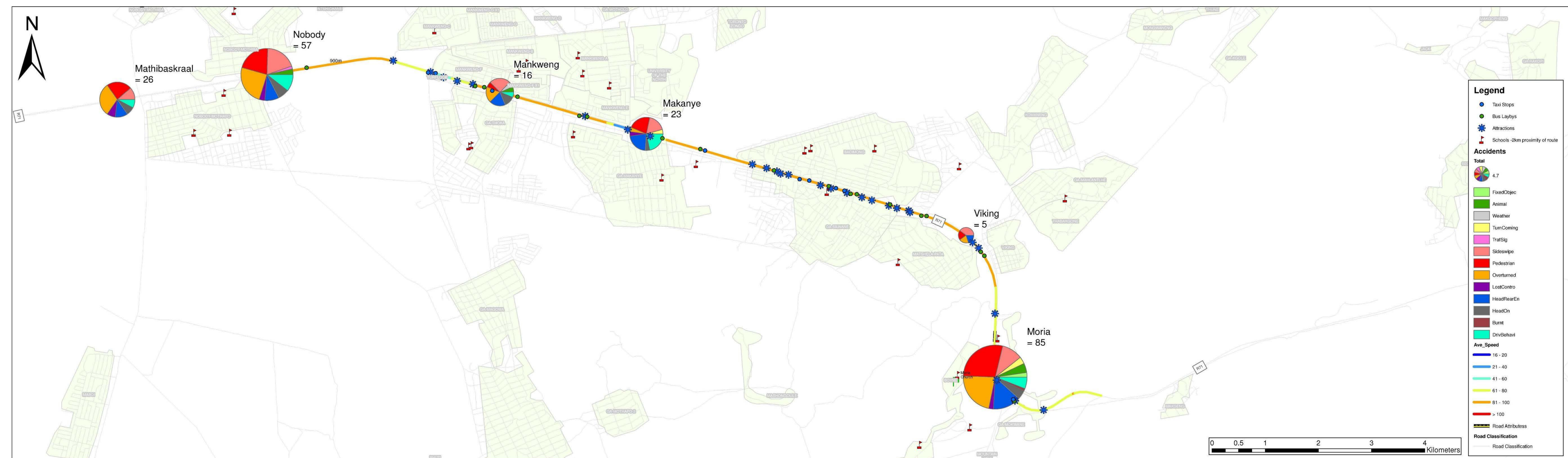
<b>APPENDICES</b>
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**Appendix A- R71 Status Quo**

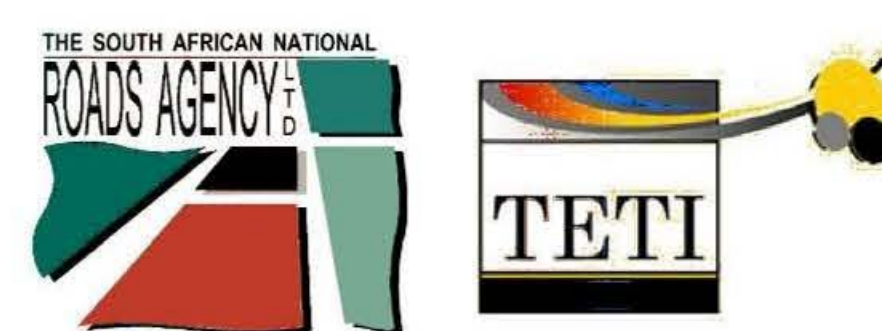
- DRAWING 1: CRASHES BY TYPE
- DRAWING 2: PEDESTRIAN CRASHES
- DRAWING 3: TRAFFIC COUNTS PM
- DRAWING 4: TRAFFIC COUNTS AM
- DRAWING 5: SCHOOLS
- DRAWING 6: ATTRACTION DENSITIES
- DRAWING 7: HOUSEHOLD DENSITY
- DRAWING 8: PUBLIC TRANSPORT FACILITIES
- DRAWING 9: DENSITY OF BUILT-UP AREAS
- DRAWING 10: ACCESS SPACING
- DRAWING 11: PEDESTRIAN COUNTS AM
- DRAWING 12: PEDESTRIAN COUNTS PM
- DRAWING 13: STATUS-QUO
- DRAWING 14: STATUS-QUO
- DRAWING 15: STATUS-QUO



Study Area 1: From km marker 7.4 to 8.6



Study Area 2: From km marker 24.0 to 39.0



**PROJECT:**

R71 Non Motorised Transport Study

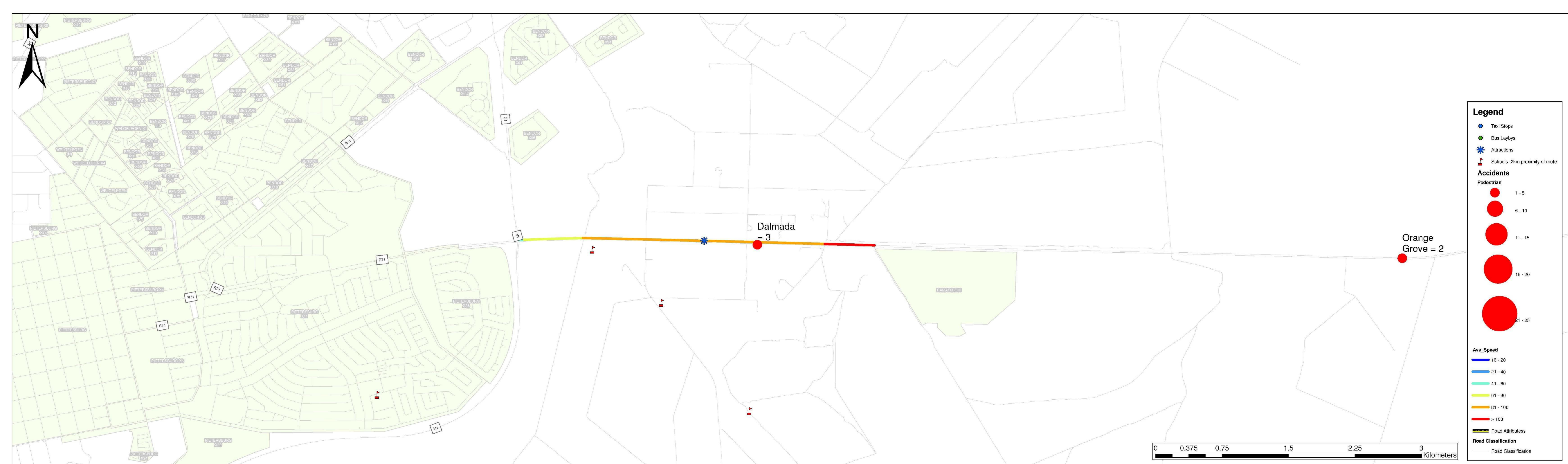
**DRAWING:**

Crashes By Type (2009 to 2011)

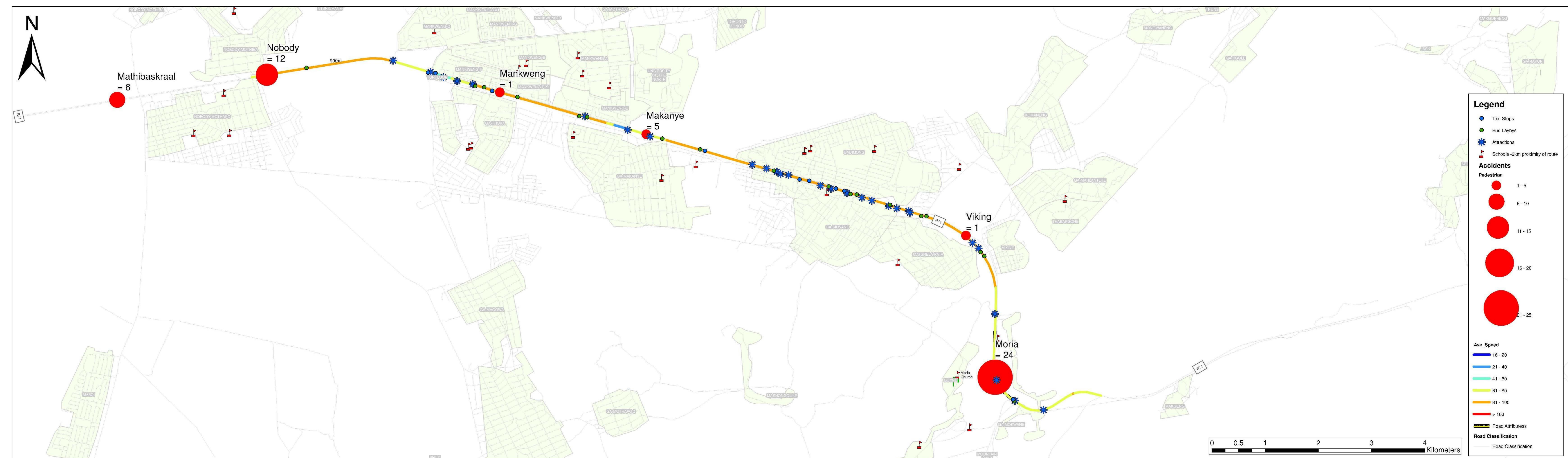
**DRAWING #**

1

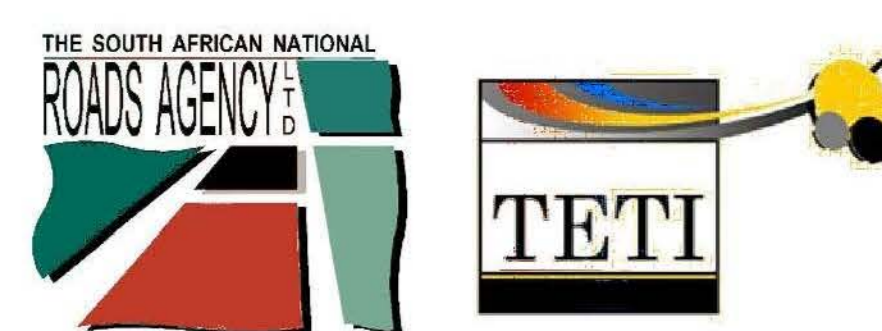
Prepared by	ITS Engineers Pty.Ltd
Created by	Stefan de Bruin (GIS Assistant)
Reviewed by	Jan Coetzee (Pr.Eng)
Date published	2013/04/25
Version	001



Study Area 1: From km marker 7.4 to 8.6



Study Area 2: From km marker 24.0 to 39.0



**PROJECT:**

R71 Non Motorised Transport Study

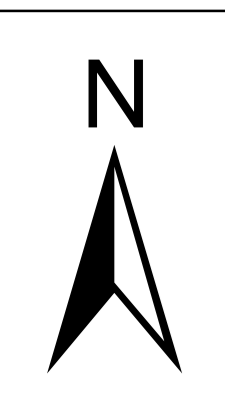
**DRAWING:**

Pedestrian Crashes On Route R71 (2009 to 2011)

**DRAWING #**

2

Prepared by	ITS Engineers Pty.Ltd
Created by	Stefan de Bruin (GIS Assistant)
Reviewed by	Jan Coetzee (Pr.Eng)
Date published	2013/04/25
Version	001



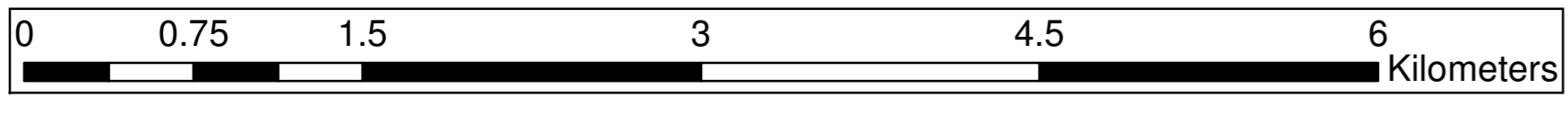
**Legend**

- Traffic\_Counts
- Schools -2km proximity of route
- Ped\_AND\_Other\_Crossings
- Road Attributes
- Km Markers

**Road Classification**

Type

- MAIN
- MAJOR
- SECONDARY
- SUBURBAN
- SUBURBAN-OTHER



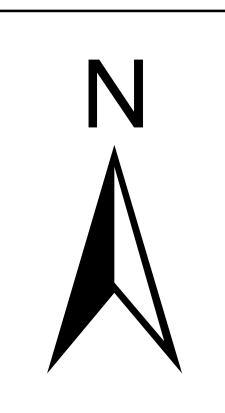
**PROJECT:**

R71 Non Motorised Transport Study

**DRAWING:**

Location Of Traffic Counts (PM Peak)

<b>DRAWING #</b>  4	Prepared by	ITS Engineers Pty.Ltd
	Created by	Stefan de Bruin
	Reviewed by	P. Pretorius
	Date published	2013-07-03
	Version	001



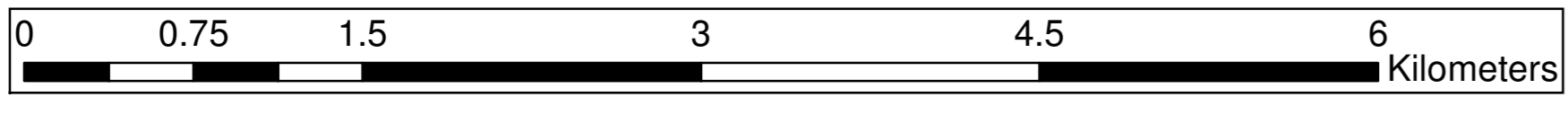
**Legend**

- Traffic\_Counts
- ▲ Schools -2km proximity of route
- ◆ Ped\_AND\_Other\_Crossings
- Road Attributess
- Km Markers

**Road Classification**

Type

- MAIN
- MAJOR
- SECONDARY
- SUBURBAN
- SUBURBAN-OTHER



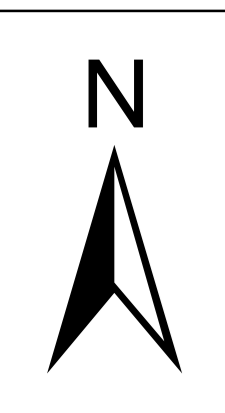
**PROJECT:**

R71 Non Motorised Transport Study

**DRAWING:**

Location Of Traffic Counts (AM Peak)

<b>DRAWING #</b>  <b>3</b>	Prepared by	ITS Engineers Pty.Ltd
	Created by	Stefan de Bruin
	Reviewed by	P. Pretorius
	Date published	2013-07-03
	Version	001



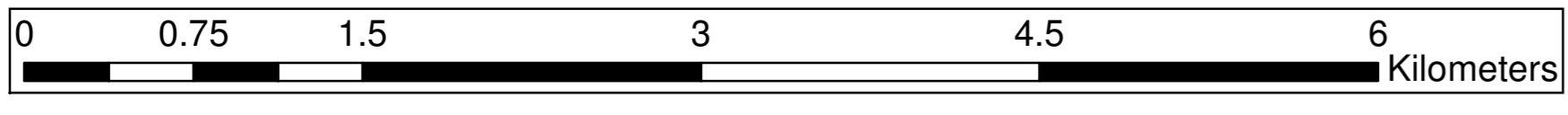
**Legend**

- Traffic\_Counts
- Schools -2km proximity of route
- Ped\_AND\_Other\_Crossings
- Road Attributess
- Km Markers

**Road Classification**

Type

- MAIN
- MAJOR
- SECONDARY
- SUBURBAN
- SUBURBAN-OTHER



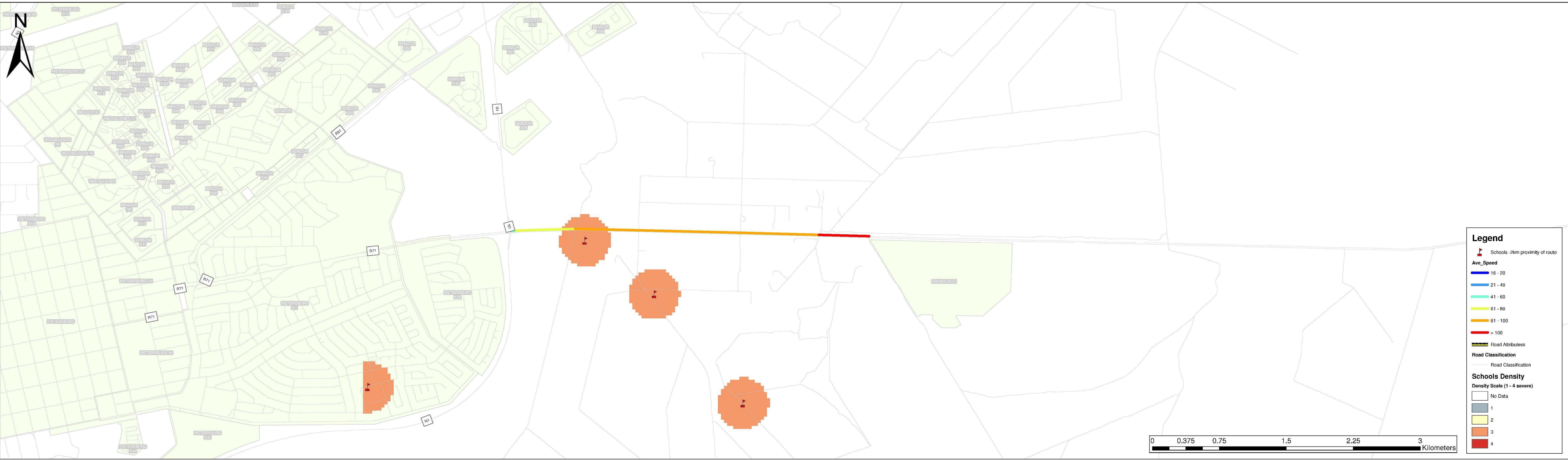
**PROJECT:**

R71 Non Motorised Transport Study

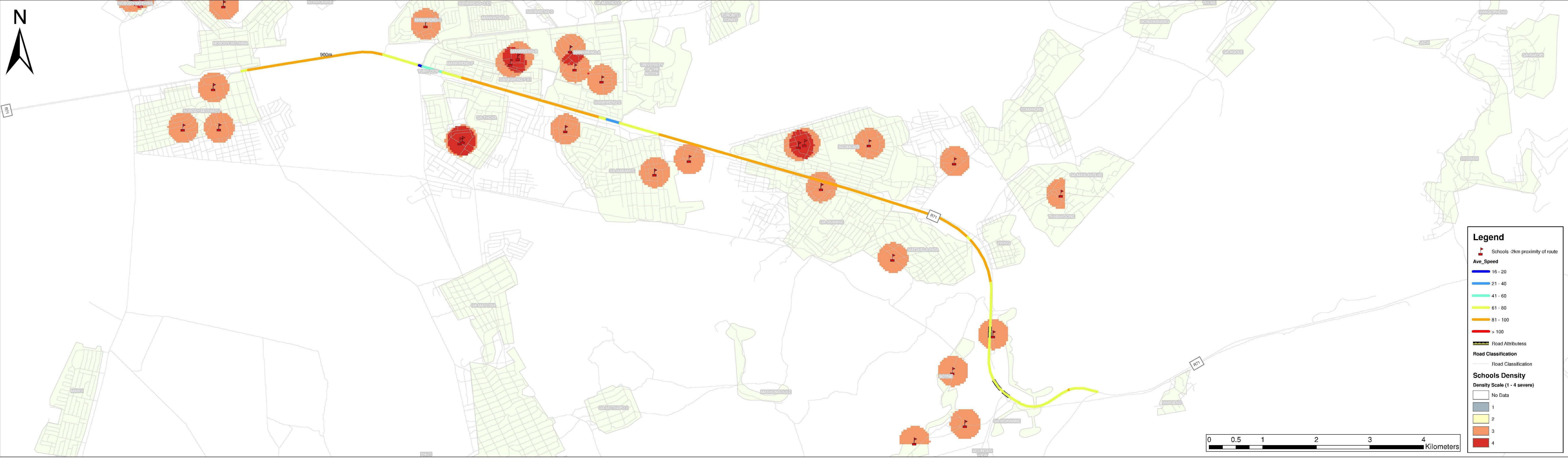
**DRAWING:**

Location Of Traffic Counts (AM Peak)

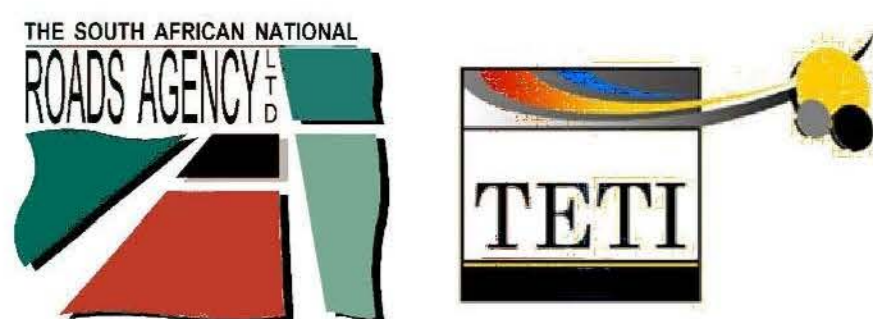
<b>DRAWING #</b>  <b>3</b>	Prepared by	ITS Engineers Pty.Ltd
	Created by	Stefan de Bruin
	Reviewed by	P. Pretorius
	Date published	2013-07-03
	Version	001



Study Area 1: From km marker 7.4 to 8.6



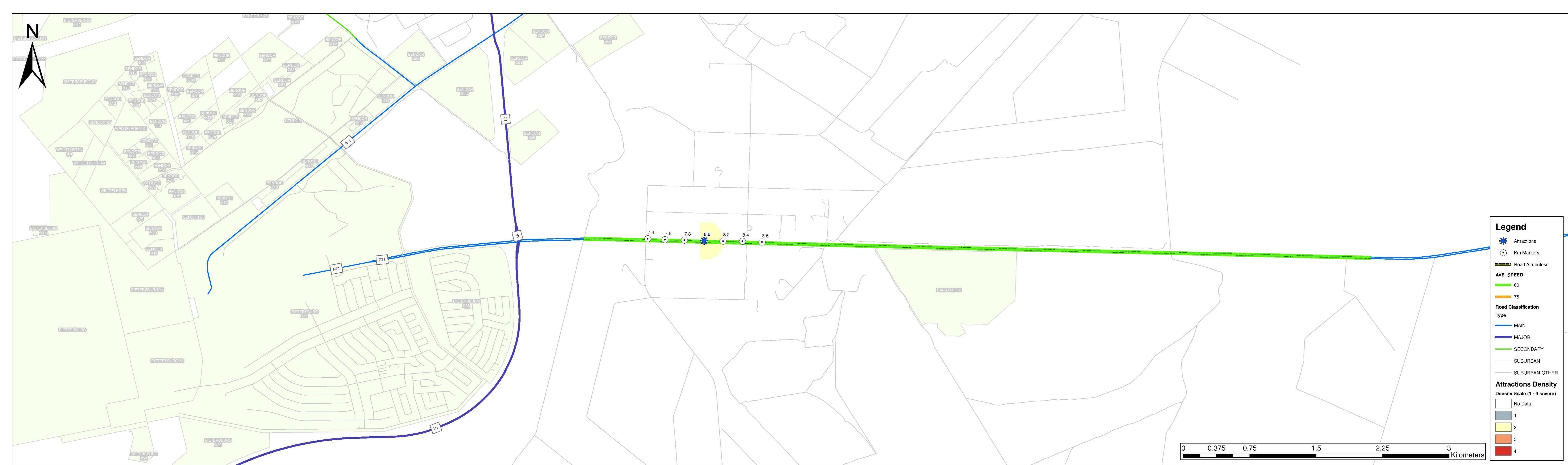
Study Area 2: From km marker 24.0 to 39.0



**PROJECT:**  
R71 Non Motorised Transport Study

**DRAWING:**  
Schools Within 2km From Route R71

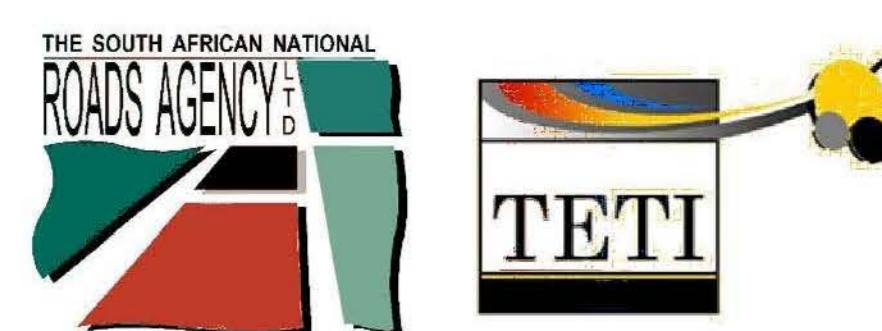
<b>DRAWING #</b>  5	Prepared by	ITS Engineers Pty.Ltd
	Created by	Stefan de Bruin (GIS Assistant)
	Reviewed by	Jan Coetzee (Pr.Eng)
	Date published	2013/04/25
	Version	001



Study Area 1: From km marker 7.4 to 8.6



Study Area 2: From km marker 24.0 to 39.0



**PROJECT:**

R71 Non Motorised Transport Study

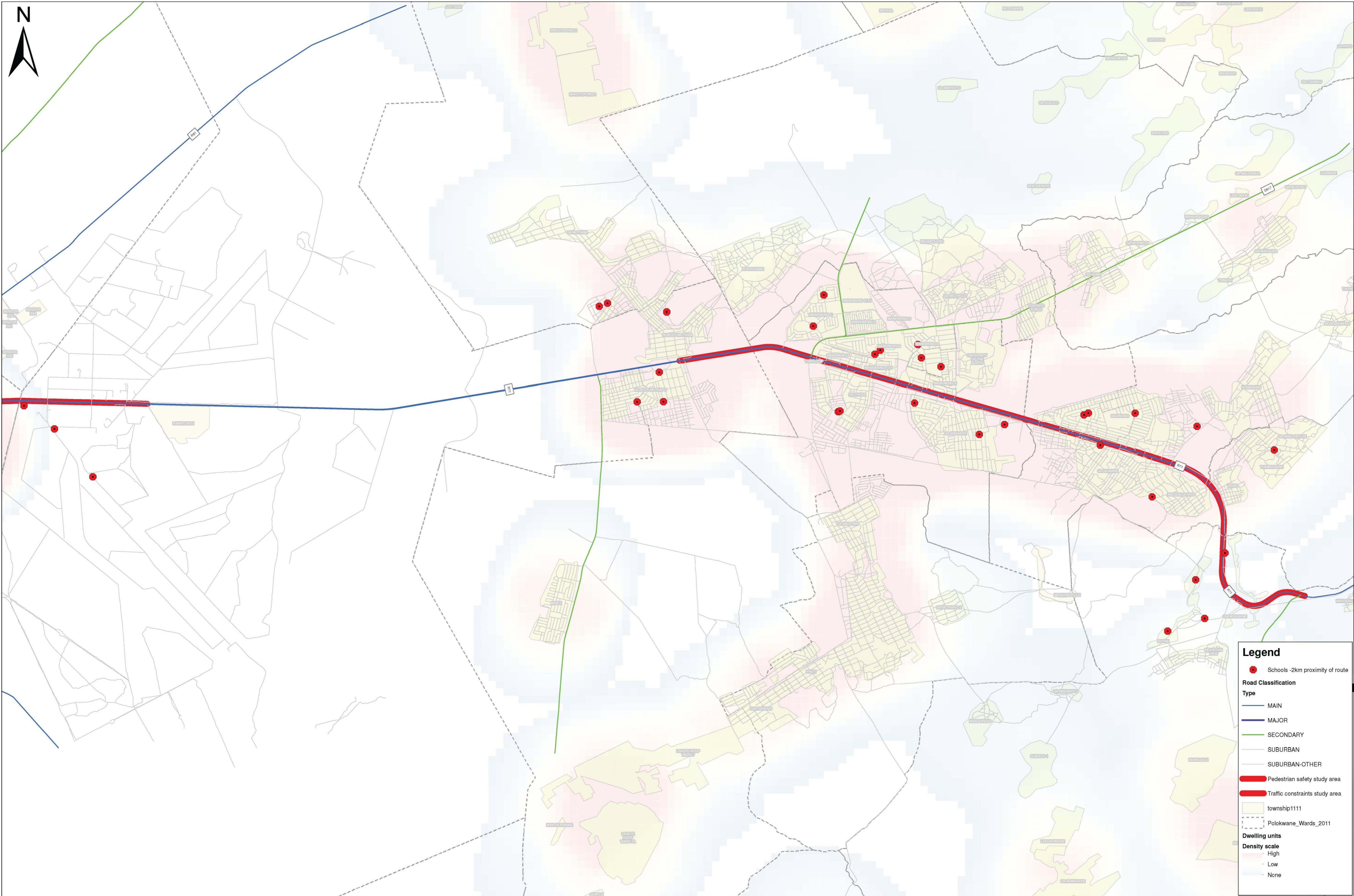
**DRAWING:**

Attractions (Shopping, Social, Clinics etc.) and Attraction Density

**DRAWING #**

6

Prepared by	ITS Engineers Pty.Ltd
Created by	Stefan de Bruin (GIS Assistant)
Reviewed by	Jan Coetzee (Pr.Eng)
Date published	2013/04/03
Version	001



**Legend**

- Schools -2km proximity of route
- Road Classification**
- Type
- MAIN
- MAJOR
- SECONDARY
- SUBURBAN
- SUBURBAN-OTHER
- Pedestrian safety study area
- Traffic constraints study area
- township1111
- Polokwane\_Wards\_2011
- Dwelling units**
- Density scale
- High
- Low
- None



**PROJECT:**

R71 Non Motorised Transport Study

**DRAWING:**

Household density and location of schools in 2km's proximity from route

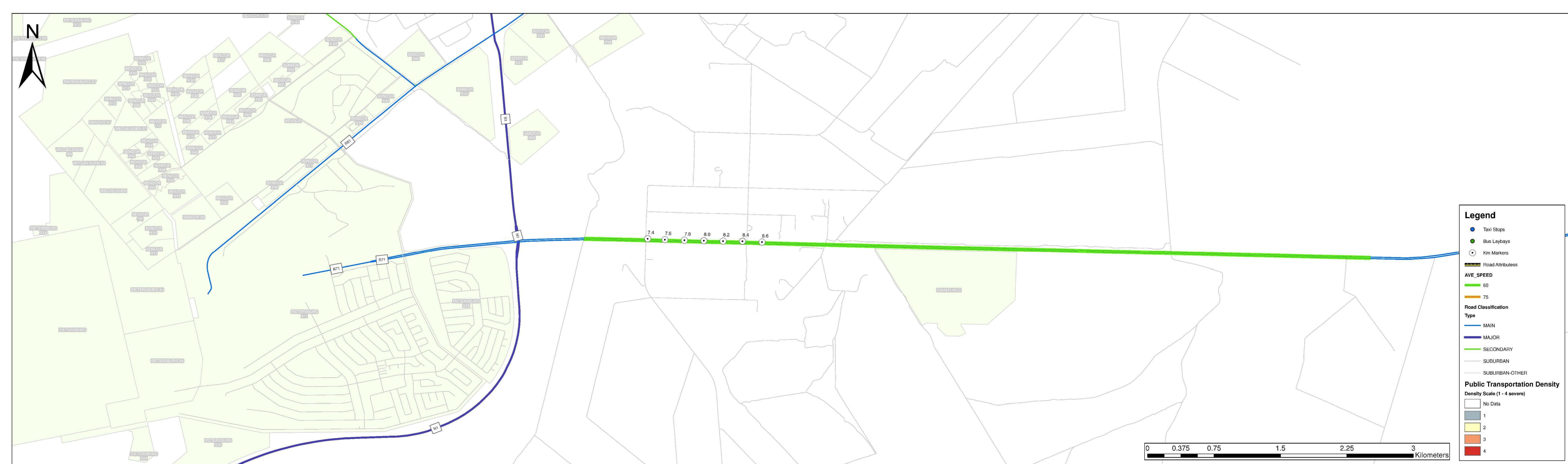
**SCALE: (A0)**

1:30 000

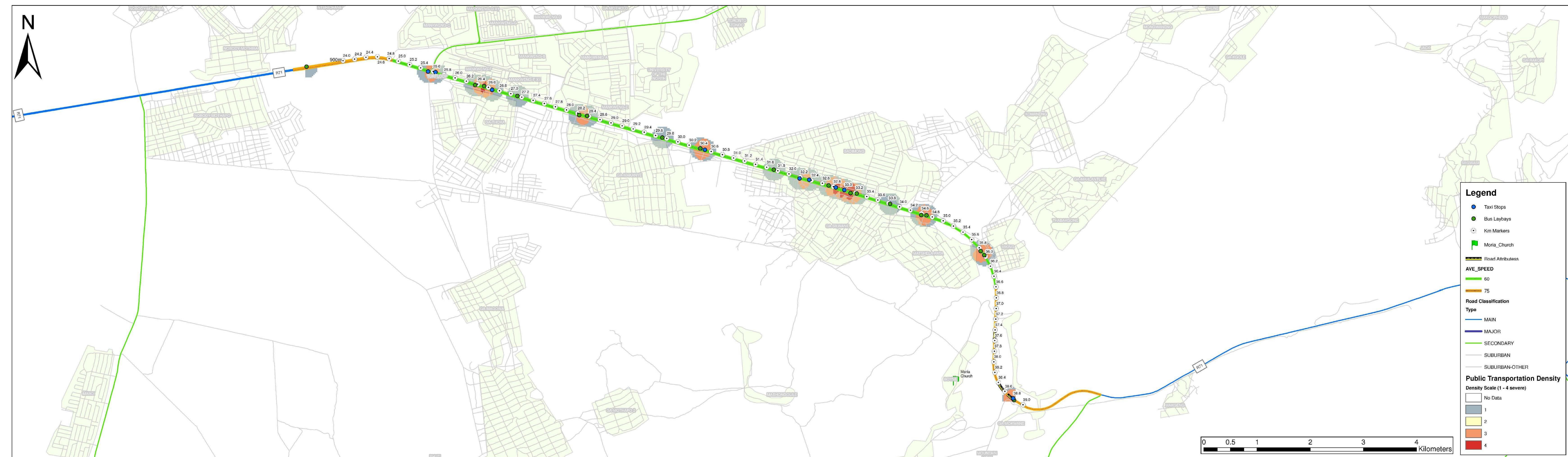
**DRAWING #**

7

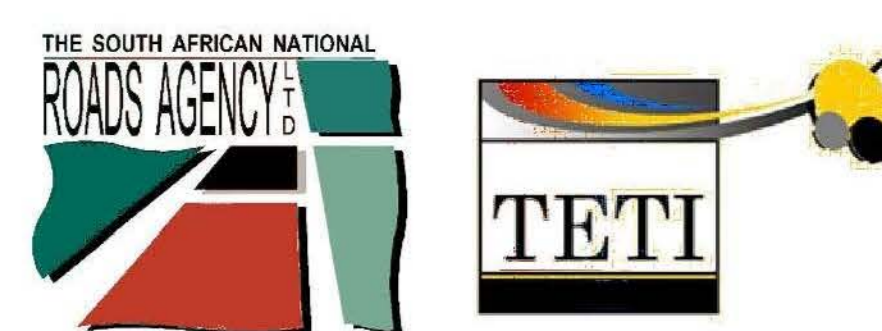
Prepared by	ITS Engineers Pty.Ltd
Created by	Jacqueline Jacobs (GIS Analyst)
Reviewed by	Jan Coetzee (Pr.Eng)
Date published	11/03/2013
Version	001



Study Area 1: From km marker 7.4 to 8.6



Study Area 2: From km marker 24.0 to 39.0

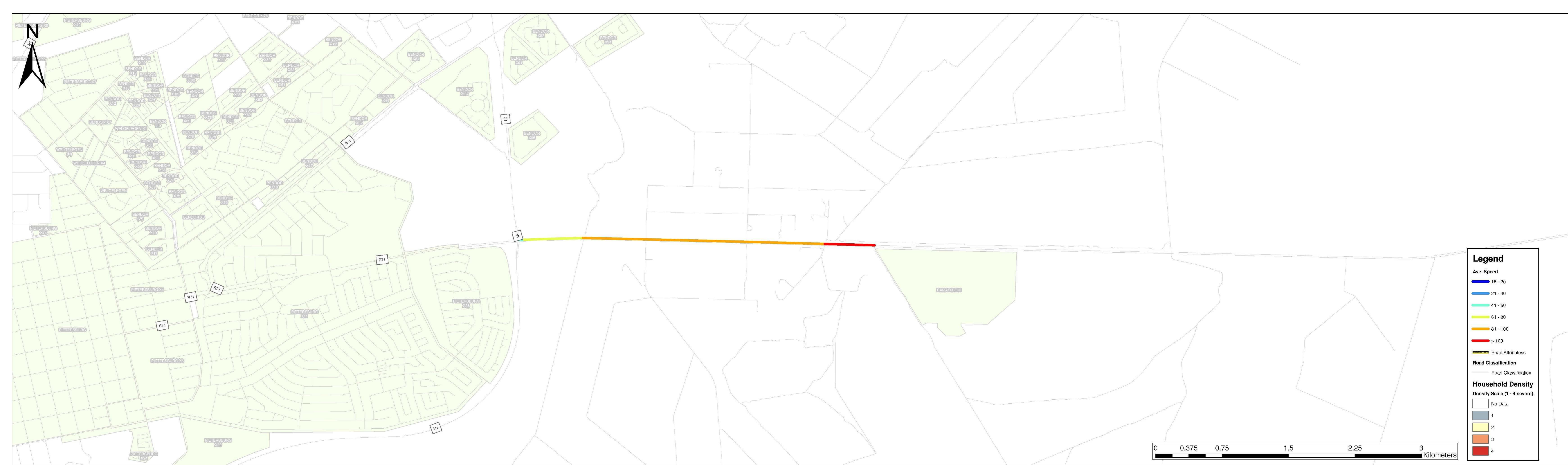


**PROJECT:**  
R71 Non Motorised Transport Study

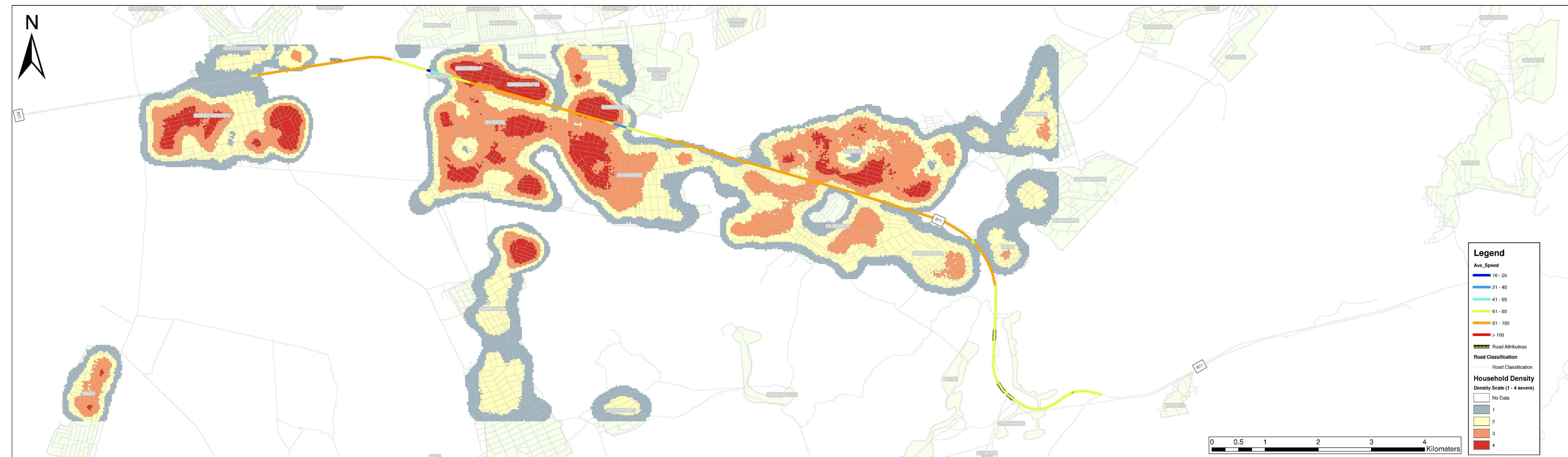
**DRAWING:**  
Public Transport Facilities (Taxi Stops, Bus Laybays) and Density

**DRAWING #**  
8

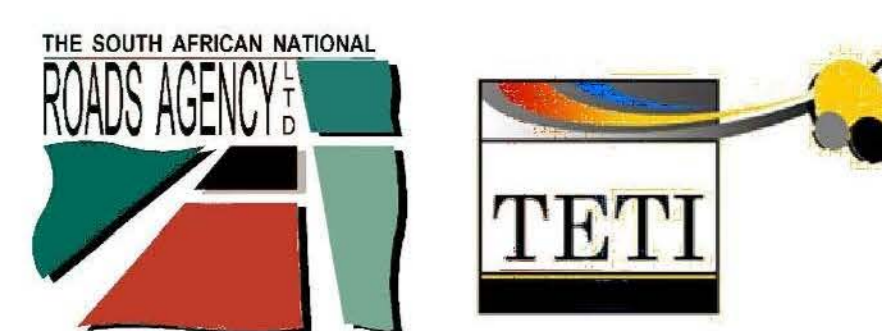
Prepared by	ITS Engineers Pty.Ltd
Created by	Stefan de Bruin (GIS Assistant)
Reviewed by	Jan Coetzee (Pr.Eng)
Date published	2013/04/03
Version	001



Study Area 1: From km marker 7.4 to 8.6



Study Area 2: From km marker 24.0 to 39.0



**PROJECT:**

R71 Non Motorised Transport Study

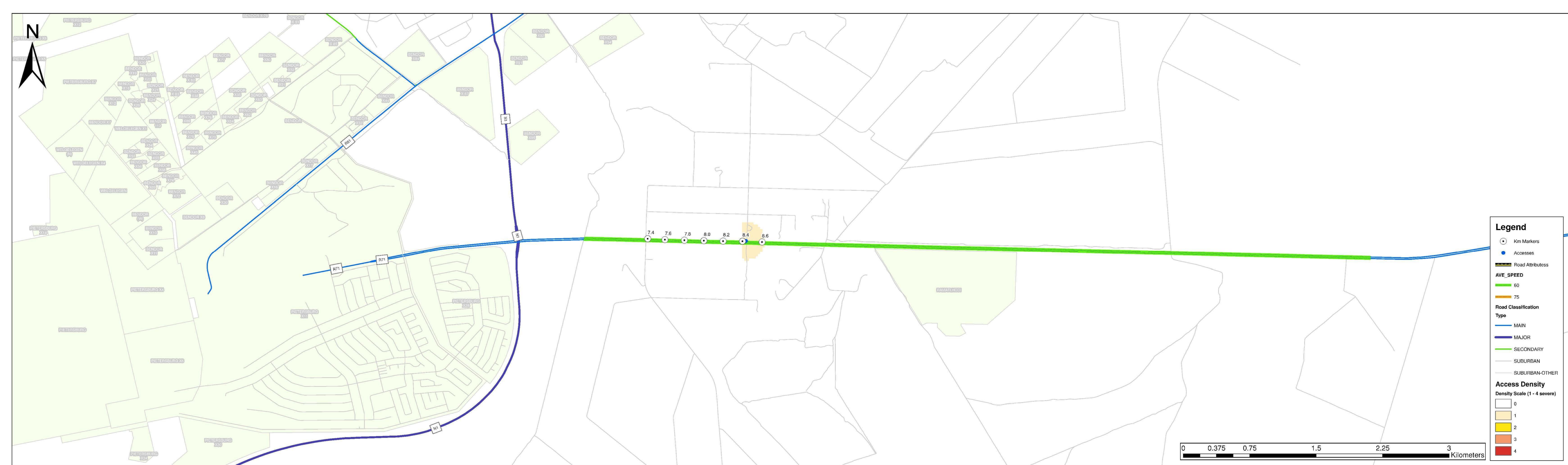
**DRAWING:**

Density Of Built-Up Areas Along Route R71

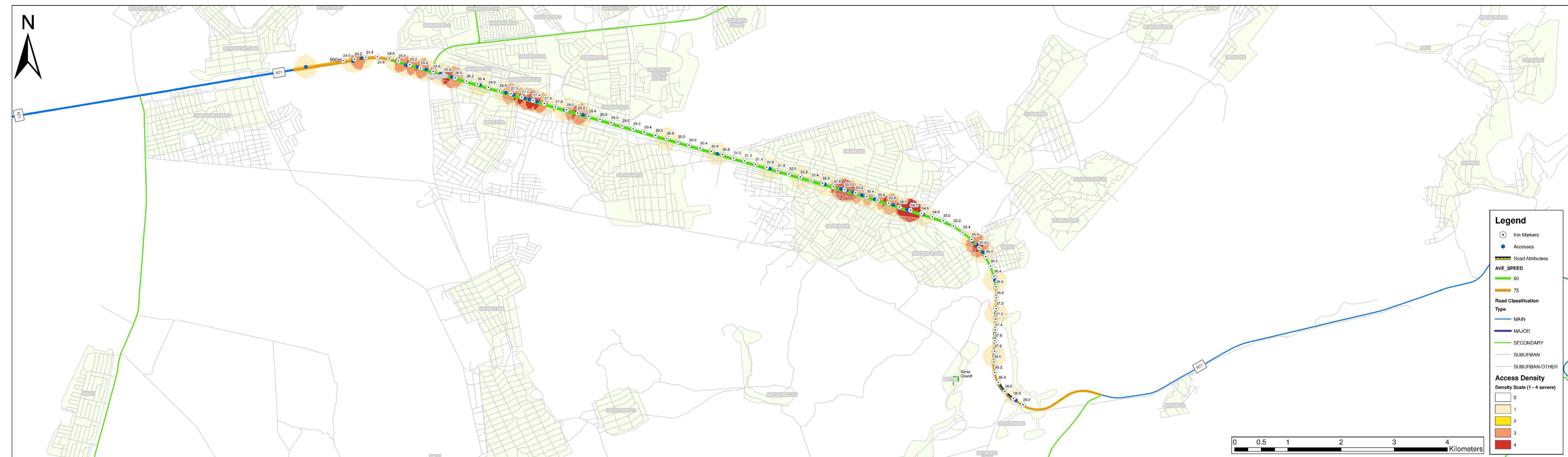
**DRAWING #**

9

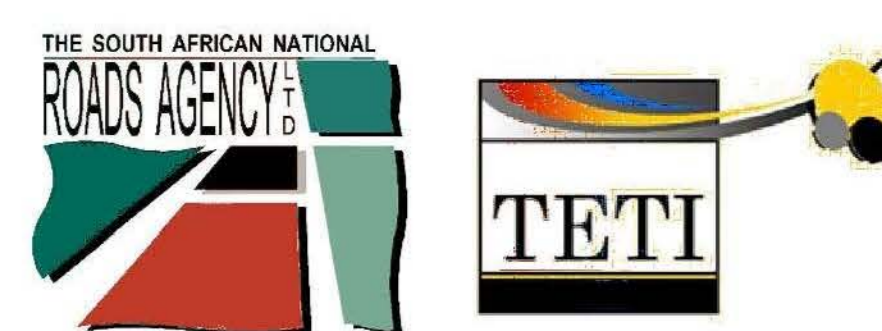
Prepared by	ITS Engineers Pty.Ltd
Created by	Stefan de Bruin (GIS Assistant)
Reviewed by	Jan Coetzee (Pr.Eng)
Date published	2013/04/25
Version	001



Study Area 1: From km marker 7.4 to 8.6



Study Area 2: From km marker 24.0 to 39.0



**PROJECT:**

R71 Non Motorised Transport Study

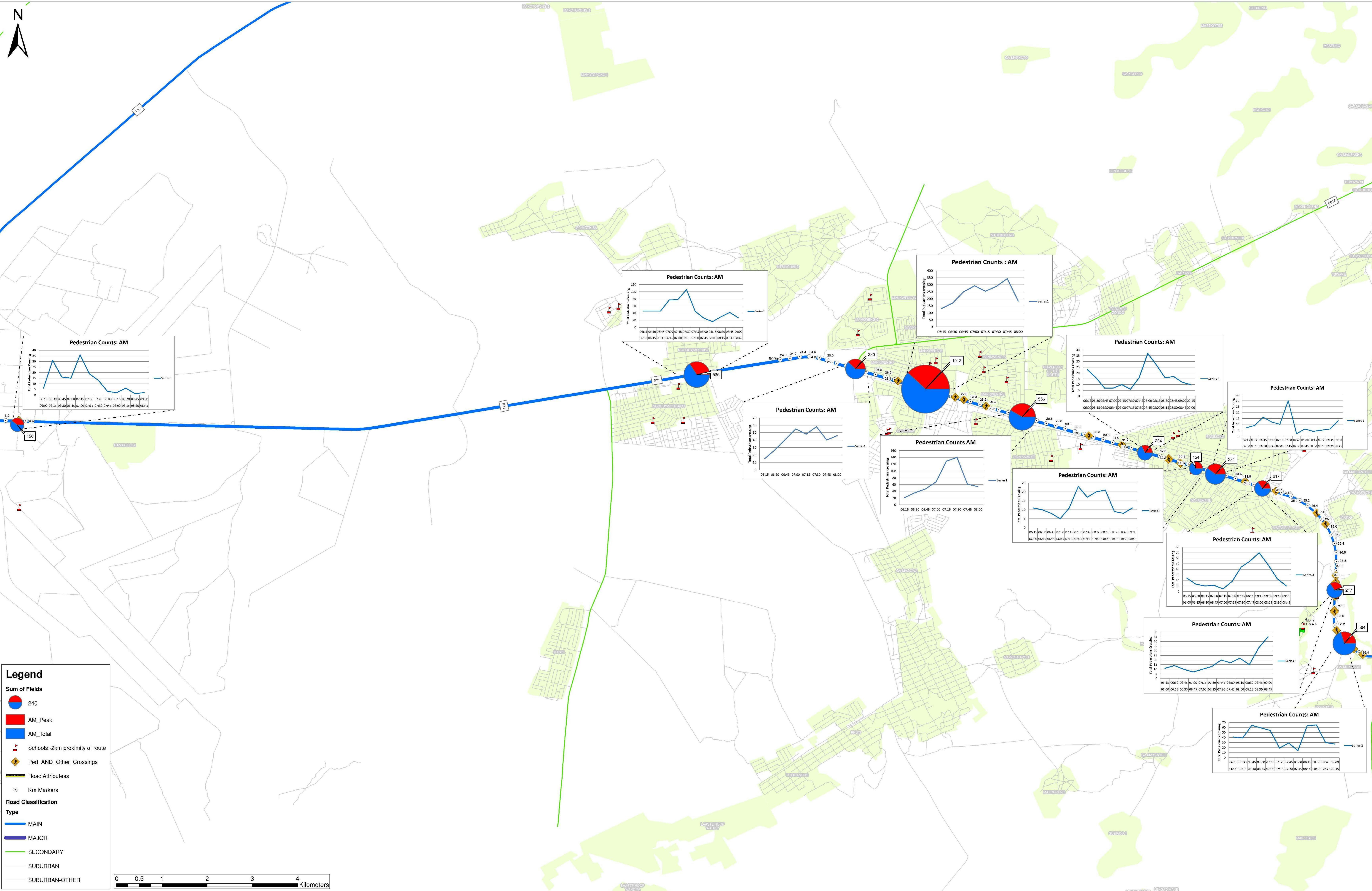
**DRAWING:**

Access Spacing And Density

**DRAWING #**

10

Prepared by	ITS Engineers Pty.Ltd
Created by	Stefan de Bruin (GIS Assistant)
Reviewed by	Jan Coetzee (Pr.Eng)
Date published	2013/04/03
Version	001



**Legend**

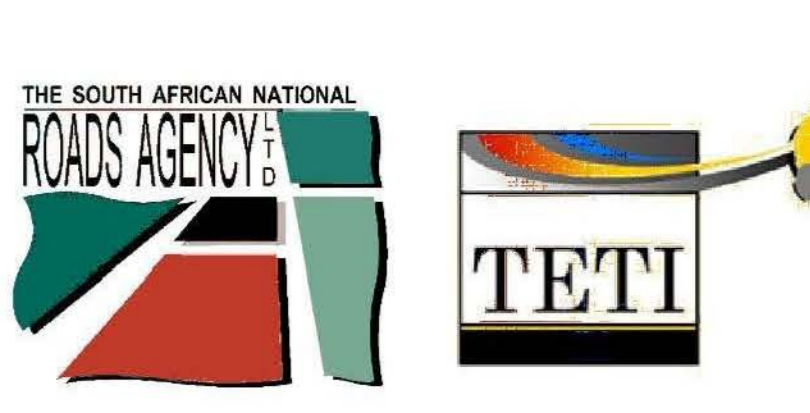
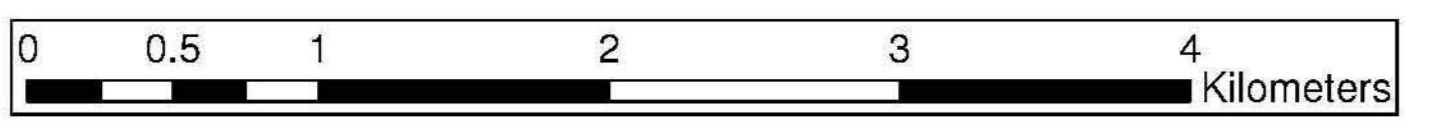
**Sum of Fields**

- 240
- AM\_Peak
- AM\_Total
- Schools -2km proximity of route
- Ped\_AND\_Other\_Crossings
- Road Attributess
- Km Markers

**Road Classification**

**Type**

- MAIN
- MAJOR
- SECONDARY
- SUBURBAN
- SUBURBAN-OTHER



**PROJECT:**

R71 Non Motorised Transport Study

**DRAWING:**

Location Of Pedestrian Counts (AM Peak)

<b>DRAWING #</b>	Prepared by	ITS Engineers Pty.Ltd
	Created by	Stefan de Bruin
	Reviewed by	P. Pretorius
	Date published	2013-07-03
	Version	001



**Legend**

**Sum of Fields**

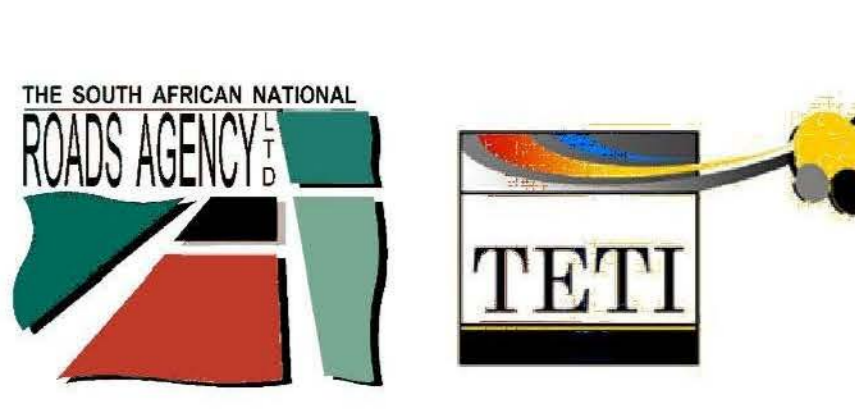
- 180 (Pie chart)
- PM\_Peak (Red)
- PM\_Total (Blue)
- Schools -2km proximity of route (Red building icon)
- Ped\_AND\_Other\_Crossings (Yellow diamond icon)
- Road Attributess (Blue line)
- Km Markers (Black circle icon)

**Road Classification**

**Type**

- MAIN (Thick blue line)
- MAJOR (Thin blue line)
- SECONDARY (Thin green line)
- SUBURBAN (Thin grey line)
- SUBURBAN-OTHER (Thin grey line)

0 0.5 1 2 3 4 Kilometers



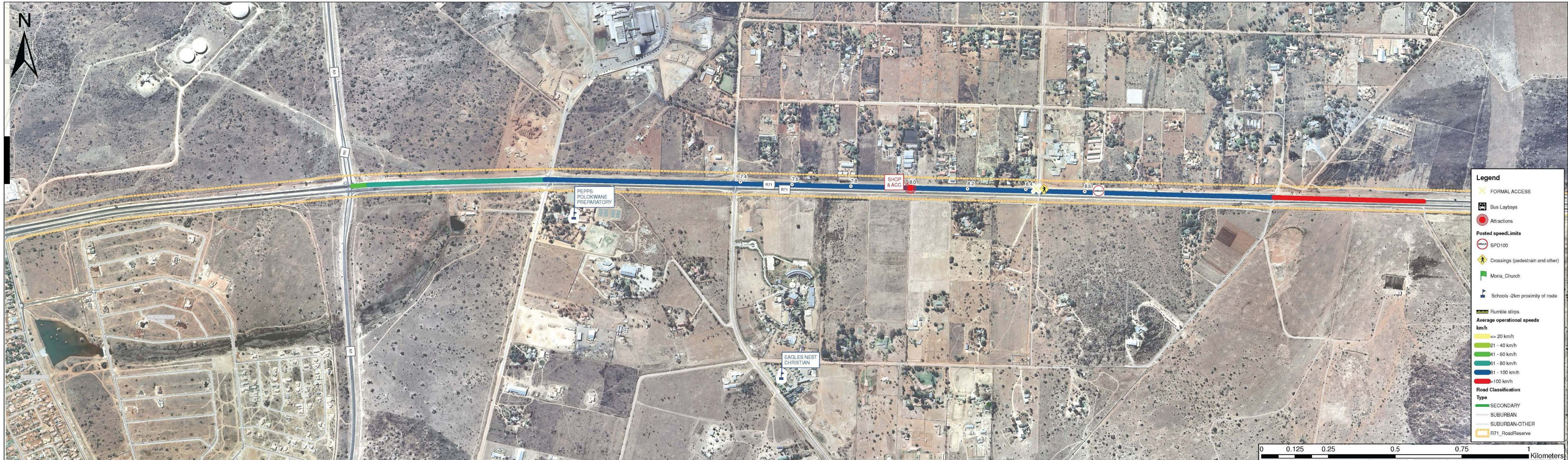
**PROJECT:**

R71 Non Motorised Transport Study

**DRAWING:**

Location Of Pedestrian Counts (PM Peak)

<b>DRAWING #</b>	Prepared by	ITS Engineers Pty.Ltd
	Created by	Stefan de Bruin
	Reviewed by	P. Pretorius
	Date published	2013-07-03
	Version	001



Study Area 1: From km marker 7.4 to 8.6



Study Area 2: From km marker 24.0 to 27.4



Study Area 2: From km marker 27.4 to 32.2



Study Area 2: From km marker 32.2 to 36.0



**PROJECT:**

R71 Non Motorised Transport Study

**DRAWING:**

Route Status Quo  
Crossings, Public transport, speed limits, attractions and accesses

**DRAWING #**

15

Prepared by	ITS Engineers Pty.Ltd
Created by	Jacqueline Jacobs (GIS Analyst)
Reviewed by	-
Date published	2013/04/10
Version	001



Study Area 2: From km marker 36.0 to 37.6



Study Area 2: From km marker 37.6 to 39.0