ASSESSMENT OF THE EFFECTIVENESS OF SPEED HUMPS AS A TRAFFIC CALMING MEASURE FOR ACCIDENT REDUCTION IN DURBAN

Dissertation for Master of Engineering Degree Specialising in Transport Studies

Prepared by Lemohang Monyatsi (MNYLEM002)

Supervised by Professor Marianne Vanderschuren

01 October 2019

Acknowledgements

This research has been one of the most challenging things I have ever done in my life. My utmost appreciation is for my family for all the support since this journey began. To my Parents, Palo and Palesa Monyatsi, I thank you for your undying support. To my two sisters, Sellwane and Mathapelo Monyatsi, I cannot thank God enough for both of you, my pillars. To my daughter, Retshepisitswe, thank you for making me a better person.

I would like to thank my supervisor, Professor Marianne Vanderschuren, for all the guidance on this project. I would also like to thank EThekwini Municipality for supporting me with funds for this degree. To my friends, my family, spiritual pillars, thank you.

Declaration

I know the meaning of plagiarism and declare that all the work in this document, except for that which is properly acknowledged, is my own. I confirm that my supervisor has seen my report and any concerns revealed by such have been resolved with my supervisor.

Signed by candidate

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ABSTRACT

EThekwini municipality has been allocating millions of rands each year for speed humps as a traffic calming measure, to curb rat-running and ensure pedestrian safety in the city. Since 2012, the city has spent R42.1 million of its capital budget on speed humps. Despite all traffic calming efforts, there hasn't been significant changes in the city's total accidents. Between 2000 and 2015, the city's total crashes has never been below 50 000 per annum. In terms of injuries, the same trend can be observed. Person injuries have been increasing year-on-year since 2012.

To date, there hasn't been a study conducted by EThekwini Municipality to assess the effectiveness of these speed humps implemented across the city. At the moment, despite the city's annual commitment to implement traffic calming, particularly in the form of speed humps, the city does not have an idea as to whether traffic calming measures put in place are successful or not, or whether they are effecting any changes at all. This research, therefore, aims to use information available to assess changes in specific roads, i.e. roads that have been traffic calmed. The study will look at these numbers which are key performance indicators before and after the implementation of speed humps.

This study will assess the impact of reactive (responsive to requests) traffic calming in the form of speed humps using accident data. The assessment will look at changes relating to the number of crashes before and after implementation of speed humps, it will also focus on changes in the severity of accidents involved. The research will study changes in relation to the types of accident involved particularly pedestrians. These key performance indicators (KPIs) will be used to assess changes and answer the question of effectiveness.

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1 INTRODUCTION

1.1 Background

About 1.3 million people worldwide die each year from road traffic crashes. Pedestrians, cyclists and motorcyclists, the most vulnerable users, account for almost 50% of these fatalities (ITF, 2017; WHO, 2018). The 2018 Global Status on Road Safety Report indicated that, although there is some progress made, the number of road traffic deaths in most countries remain shockingly high. The number of fatalities are still very high and improvements that are seen are far from reaching levels that would bring relief to the global community. Road accidents are the 8th leading cause of death for all ages. Road traffic deaths are the number one cause of death for children and young adults between ages of 5-29. Another shocking statistic is that road deaths are 3 times higher in low income countries than in high income countries (WHO, 2018).

The rate of deaths relative the number of accident deaths has started to stabilize} in the past 10 years (See Figure 1). There are currently around 18 deaths per 100,000 people and this figure has been fairly stable for the past 16 years. Although the rate of traffic deaths per population has seen stability, the total number of accidents keeps increasing. The number has increased from 1.15 million in the year 2000 to 1.35 million in 2016. This is far from the aim in the Sustainable Development Goals (SDG). i.e., target of 3.6, which plans to reduce the number road crash deaths by half between 2010 and 2020 (WHO, 2018).

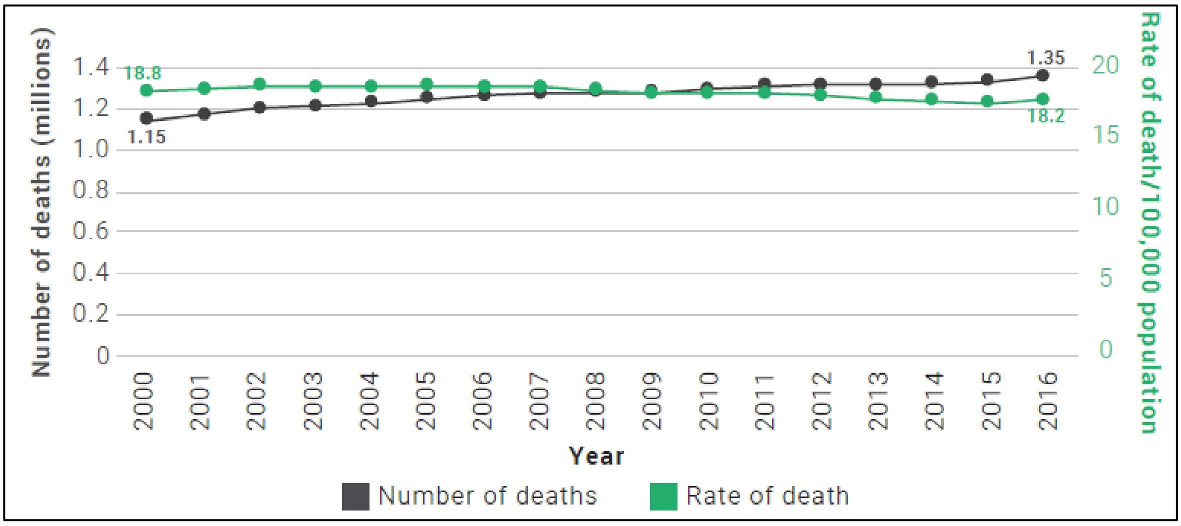


Figure 1: Number and rate of road deaths per 100,000 population: 2000–2016
Source: WHO, 2018

Africa as a continent has the highest road-related death rates. The rate went up from 26.1 to 26.6 per 100 000 people between 2013 and 2016. The recent economic development leading to an increase in car ownership levels met with slow improvement of road infrastructure and road safety programmes have seen more roads deaths in recent years. The African continent has 2% of the world's cars but 20% of road deaths, which shows just how important road safety improvement is in the continent as a whole (World Bank, 2018, WHO, 2018).

In South Africa alone, the number of registered vehicles increased from 11 964 234 in 2016 to 12 205 142 vehicles in 2017, a 2.01% increase in just a year. Although in the same period there was a slight decrease in accidents of 0.1%, a total of 14 050 road fatalities that were recorded, which is a significantly high number of road fatalities compared to most countries as shown on Figure 2 below (RTMC, 2018).

The 2015 Global Status on Road Safety states that Africa has the highest fatality rate per 100 000 vehicles in the world (WHO, 2015). This is costing the continent billions of dollars each year. This is detrimental to the African continent's tourism and economy as a whole. In South Africa, the cost of road crashes was estimated at R162,045 billion or 3,48% of Gross Domestic Product (GDP) for 2017 (RTMC, 2017) with each fatal road traffic crash costing the economy some R5,717,351.00. With such numbers, the cost of road accidents in the country cannot be emphasised enough.

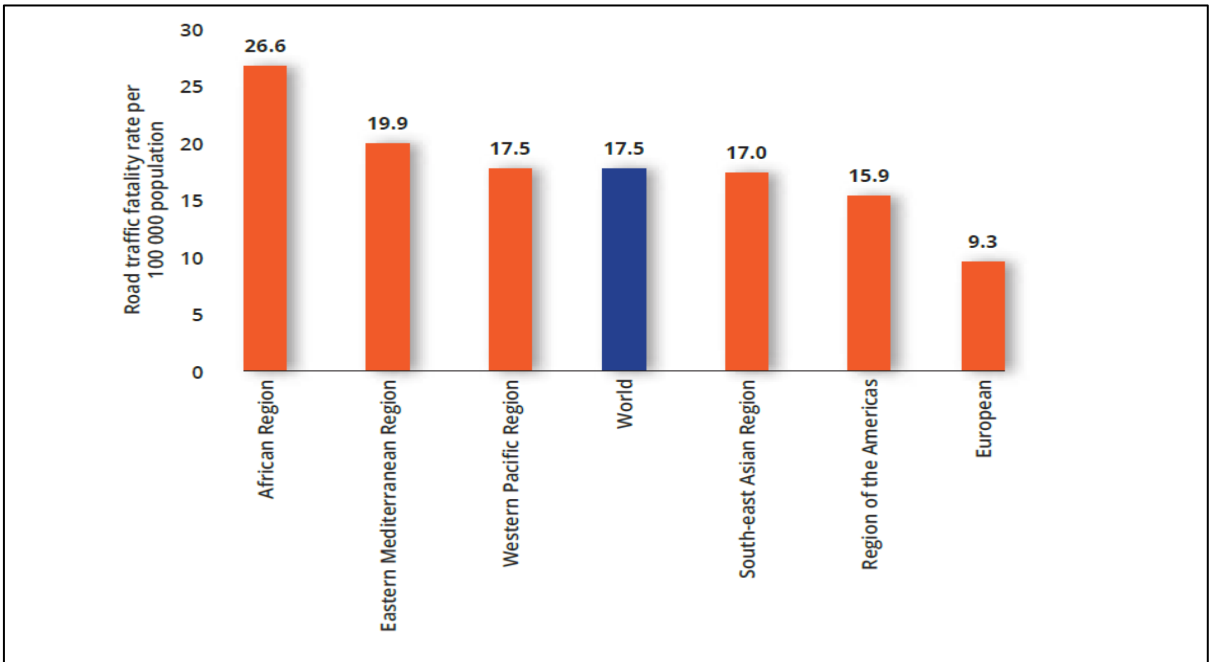


Figure 2: Road fatalities per 100 000 population
Source: WHO, 2015

In 2017, Kwazulu Natal province had 2800 road crash fatalities, this accounted for 20% of South Africa's annual road crash fatalities and cost the economy more than R14 billion (RTMC, 2016). From these road fatalities in the province, the City of Ethekwini accounts for the highest. Since 2000, the city of EThekwini has been having more than 50 000 road crashes per year, with more than 500 deaths each year (ETA, 2016).

1.2 Contributory Factors to Road Accidents

Causes of motor vehicle collisions are often complex, having more than just one contributory factor but largely depend on the characteristics of drivers (McGwin & Brown, 1999). Road accidents in South Africa are classified as caused by human, vehicle and road (geometric and environmental) factors as shown on Figure 3. There are other studies such as United Nations Road Safety Report (UN, 2015) that also look at the deficiency of policy and regulatory framework as a contributory factor to road carnages.

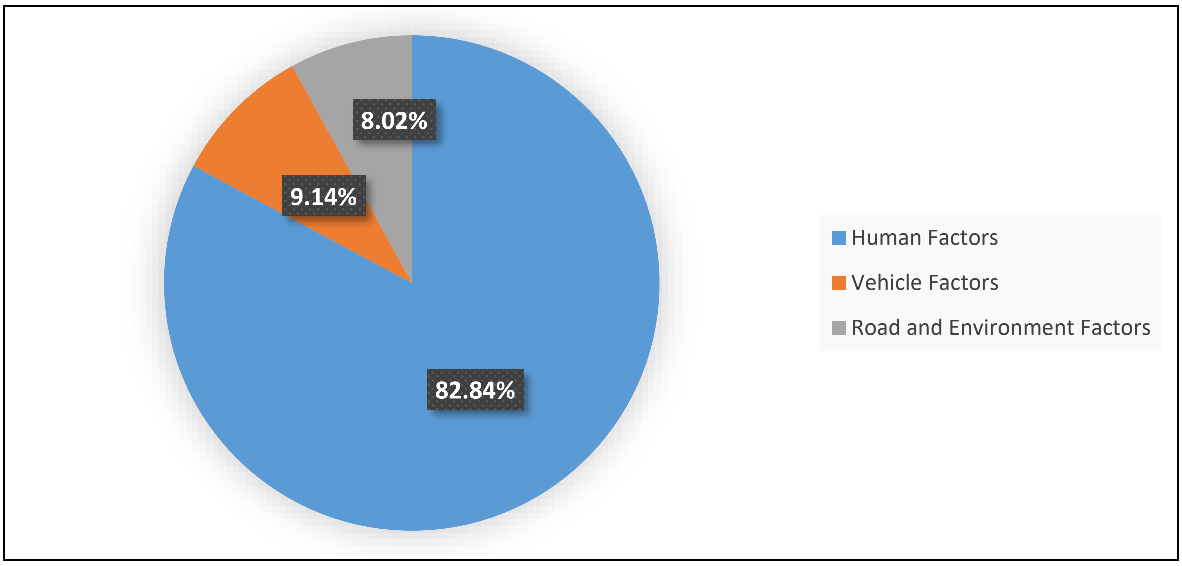


Figure 3 : Contributory Factors to Crashes in South African
Source: UN, 2015; cited by Arrive Alive, 2015

1.2.1 Human Factors

Human factors have, for decades, been and are still leading factors causing road crashes. This is the case in different countries around the world including India (Singh, 2017) and South Africa (Vanderschuren & Jobanputra, 2009). There is a range of human-related factors that hamper with the driver's ability to perceive road conditions, as well as the driver's ability to respond in time to prevailing road conditions. These include the driver's excessive speed, dangerous or risky driving such as using mobile phone devices, inexperience, fatigue, and alcohol and drug abuse. Other studies such as the World Report on Traffic Injury Prevention (WHO, 2004) show also how different groups of people have different exposure to risk, with young male drivers being the most likely to be involved in road accidents.

Other authors, such as Botha (2005) argue that even where the vehicle or road conditions are unfavourable, the driver still does have some sort of responsibility. An example is when there are potholes on the road, the driver has a responsibility to driver carefully upon approach. Where a road accident can occur due to faulty car tyres, the driver's responsibility to inspect tyres prior to driving, mitigates the potential for a road accident.

Other human-related factors include different cognitive abilities. Studies show that, although older people tend to be adherent to speed restrictions and other road laws and regulation, they have limited cognitive abilities and this affects how they react to changes on the road (Rolison & Moutari, 2018).

1.2.2 Road and Environmental Factors

Road designs that introduce transitions in vertical and horizontal alignment without proper signage are very dangerous as drivers do not foresee these changes in order for them to react well in time. Sharp bends are much easier to negotiate when driving speed is relatively low and when drivers react in time. According to the United Nations (2015), 27.99% of road geometry-related crashes occur, due to reported sharp bends, while 20.40% occur as a result of reported poor condition of the road surface. About 15.01% of these road geometry-related crashes happen due to reported poor visibility.

According to PWC's (2013) Report on Transport Infrastructure for South Africa, it is estimated that 78% of South Africa's road network is older than its intended 20-year design life. Over and above this, there is a massive road maintenance backlog in the country and this is projected to get worse (PWC, 2013). This is a serious concern, as road infrastructure status is a factor in road crashes and South Africa continues to lose lives on the road.

1.2.3 Vehicle Factors

Vehicle faults also lead to crashes on the road. According to the UN (2015), 36.03% of all vehicle-related crashes in 2014 were as a result of tyre bursts prior to crash. Faulty brakes contributed 25.04% of vehicle-related factors. Faulty brakes also led to head-rear collision resulting in fatal crashes in some instances. In the same year, 2.07% of all vehicle-related factors were as a result of faulty lights (head-lights, rear-lights, brake-lights).

1.2.4 Responding to road safety challenges

In responding to road safety challenges, countries have adopted "The 4 "E's as a coherent strategy. There are variations to this strategy, with some countries using 3's and some 5 or more, but the general principles are similar (DfT, 2011; NDoT, 2011). The 4 E's are:

- **Enforcement** that is visible to ensure that road users adhere to road rules and transgressions are addressed using applicable laws (WHO, 2015).
- **Education** to support enforcement. Educational programs are effected to change people's behaviour and perceptions by instilling a mind shift or giving a different perspective. These could either be through compulsory means such as inclusion of road safety education at schools or by outreach programmes such as television or radio adverts. Educational programmes are very important as they address human behaviour, which is an important factor in road crashes (WHO, 2008; Mhlanga, 2018).
- **Engineering**, which involves forgiving designs that cater for the needs of the vulnerable. They also include remedial actions in hazardous locations (DfT, 2011).
- **Evaluation,** which includes a reiterative process of research and data collection to ensure that measures put in place serve every unique problem (NDoT, 2011).

In this research, the response to road safety will be in the context of traffic calming with emphasis on speed humps.

1.3 Motivation for Research

EThekwini municipality has been allocating millions of rands each year for the implementation of speed humps, as a traffic calming measure, to curb rat-running and ensure pedestrian safety in the City. Since 2012, the city has spent R42.1 million of its capital budget on speed humps. Despite all traffic calming efforts, there hasn't been a significant change in the City's total road crashes. Between 2000 and 2015, the City's number of total crashes has never been below 50 000 per annum. In terms of injuries, the same trend can be observed. Person injuries have been increasing year-on-year since 2012 (Refer to Tables 1 and 2).

To date, there hasn't been a study conducted by EThekwini Municipality to assess the effectiveness of speed humps implemented across the City. At the moment, despite the City's annual commitment to implement traffic calming, particularly in the form of speed humps, the City does not have any idea as to whether traffic calming measures that have been put in place are successful or not, or whether they are effecting any changes at all. This research, therefore, aims to use the information available to assess whether speeds humps that have been implemented in the city are serving their purpose. The question of speed humps efficacy will be answered using accident statistics as a basis and a 6-year study period will be used. The research will also answer questions related to road safety, particularly on pedestrians.

YEAR	NUMBER OF ACCIDENTS				
	Fatal	Serious	Slight	Damage only	Total Accidents
2000	496	2413	7750	42673	53332
2001	537	2624	10311	41037	54509
2002	637	2676	10310	41465	55088
2003	665	2832	9584	42968	56049
2004	724	2845	9475	43690	56734
2005	663	2526	9413	47169	59771
2006	647	3231	10641	50282	64801
2007	609	3694	13934	54115	72352
2008	508	3387	14991	51862	70748
2009	607	3086	11304	52646	67643
2010	596	2679	9499	50491	63265
2011	612	2380	8948	50197	62137
2012	596	2242	8313	51167	62318
2013	497	2342	8738	51437	63014
2014	478	2408	9351	50151	62388
2015	571	2650	9719	52474	65414

Table 1 : Number of accidents in EThekwini
Source: Based on ETA, 2017

YEAR	Person Injuries			
	Deaths	Serious	Slight	Total Injuries
2000	545	3188	11644	15377
2001	609	3719	17404	21732
2002	716	3880	16382	20978
2003	753	3925	14710	19388
2004	795	4072	14432	19299
2005	726	3358	13535	17619
2006	744	4219	15586	20549
2007	687	4826	20245	25758
2008	550	4487	22714	27751
2009	673	4133	15953	20759
2010	651	3672	13869	18192
2011	680	3253	12356	16289
2012	647	3065	11412	15124
2013	588	3197	11879	15664
2014	515	3212	12738	16465
2015	614	3498	13316	17428

Table 2 : Number of person injuries
Source: Based on ETA, 2017

From Table 1 and 2, it can be see that in the past 20 years, the number of accidents in Durban has been very high. With each of these accidents, at least one person is affected and in some instance, two or more people are injured. The number of total accidents grew from just over 50 000 in the year 2000 to about 65 000 accidents in 2015. The number of people injured per year was just over 15 000 to about 17 000 people per year a decade later. In terms of deaths, the number of lives claimed from accidents was 496 people in 2000 and went up to 571 persons in 2015. This consistent increase is worrisome and the impacts are far-reaching as these accidents are costly to the city and the economy in general. The cost of even a slight accident is detrimental to the city as it result in delays and other inconveniences. With serious accidents that result in deaths, the cost is even more to the citizens, the city and the economy of the country.

1.4 Objectives of the Study

This research will look at effectiveness in two ways, the ability of speed humps to reduce travel speeds of vehicles as well the reduction of accidents within the study area. Results will be used to assess if speed humps serve their intended propose in the context of speed and accident reduction. This study will assess the impact of reactive (responsive to requests) traffic calming in the form of speed humps using accident data. The assessment will look at changes relating to the number of crashes before and after implementation of speed humps, it will also focus on changes in the severity of accidents involved. The research will study changes in relation to the types of accident involved particularly pedestrians. The Key Performance Indicators (KPIs) will be used to assess changes and answer the question of effectiveness.

With a three year classified (cars on cars and cars on pedestrians) study before and after the implementation of speed humps, the research will be able to establish trends before and after implementation. This could be used to project future accident estimates. Since the data also contains accident impact and severity information, it will also be possible to study the nature of accidents before and after speed hump implementation. Results of the study can help authorities with decision making relating to continuing speed humps as a traffic calming measure or consider other alternative measures. Authorities can also use results of this research to inform policies related to traffic calming in the city. These results could also inform budget allocation to speed humps.

1.5 Research Questions

This study will collect, analyse and critically evaluate accident data in EThekwini Municipality to that is obtained to answer the following questions:

- What is the impact of speed humps in reducing vehicular speeds?
- What is the impact of speed humps on the total number of accidents, injuries and fatalities?
- Can speed humps reduce the number of pedestrian accidents?
- Can speed humps reduce the number of accidents amongst school-going children?
- What role do speed humps play in communities where there is inadequate NMT facilities such as sidewalks?
- Do speed humps have an impact in reducing public transport (minibus taxis and buses) accidents?

1.6 Methodology

The research aims at assessing the effectiveness of speed humps as a traffic calming measure for accident reduction in Durban. This is done first by providing background and reasons that motivated the study. Problems in the municipality are outlined briefly and then followed by questions that the research seeks to answer. Available literature is then presented and elaborated on. The structure of literature is from a worldwide context down to the South African and EThekwini municipality context. Literature starts off by explaining traffic calming as a road safety concept. Most common types of traffic calming measures are discussed, including types of programs. Advantages and disadvantages of each traffic calming measure and programs are then discussed. Different applicable policies and types of legislations are discussed. Local traffic calming policy is further discussed according to road hierarchy. Discussing road hierarchy and classification will be done to also point out differences in how authorities from abroad implement traffic calming and how EThekwini municipality implements traffic calming. In discussing traffic calming literature, emphasis is placed in speed humps as a case study.

Another important aspect of road safety, which is NMT, will be discussed. The study will deliberate on available international literature on NMT policies, as well as practice. The study will then look at South African policy framework on NMT, as well as implementation across different parts of the country and the City of EThekwini in particular. A critique of prioritisation (or lack thereof) will be discussed. This will be done using policy framework, financial investment, as well as actual implementation on the ground. Lastly on literature, the study motivates on why speed humps are important in reducing road accidents. In research design, the research uses two types of quantitative data to investigate the effectiveness of speed humps. This is primary data, which is obtained through a speed survey done over three days on Tracy Watts Road, as a sample. Secondly, accident data from EThekwini traffic studies is used. This is a three year database before implementation of speed humps (Jan 2011-June 2014) which is compared to three year accident data after speed humps were installed (June 2015-December 2018). This comparison uses Equivalent Accident Numbers (EAN's) and a T-Test is used to test the statistical significance of the results. Results of the speed survey and accident data are then used to conclude on the effectiveness of speed humps in reducing accidents. The overall methodology of the research is shown on Figure 4.

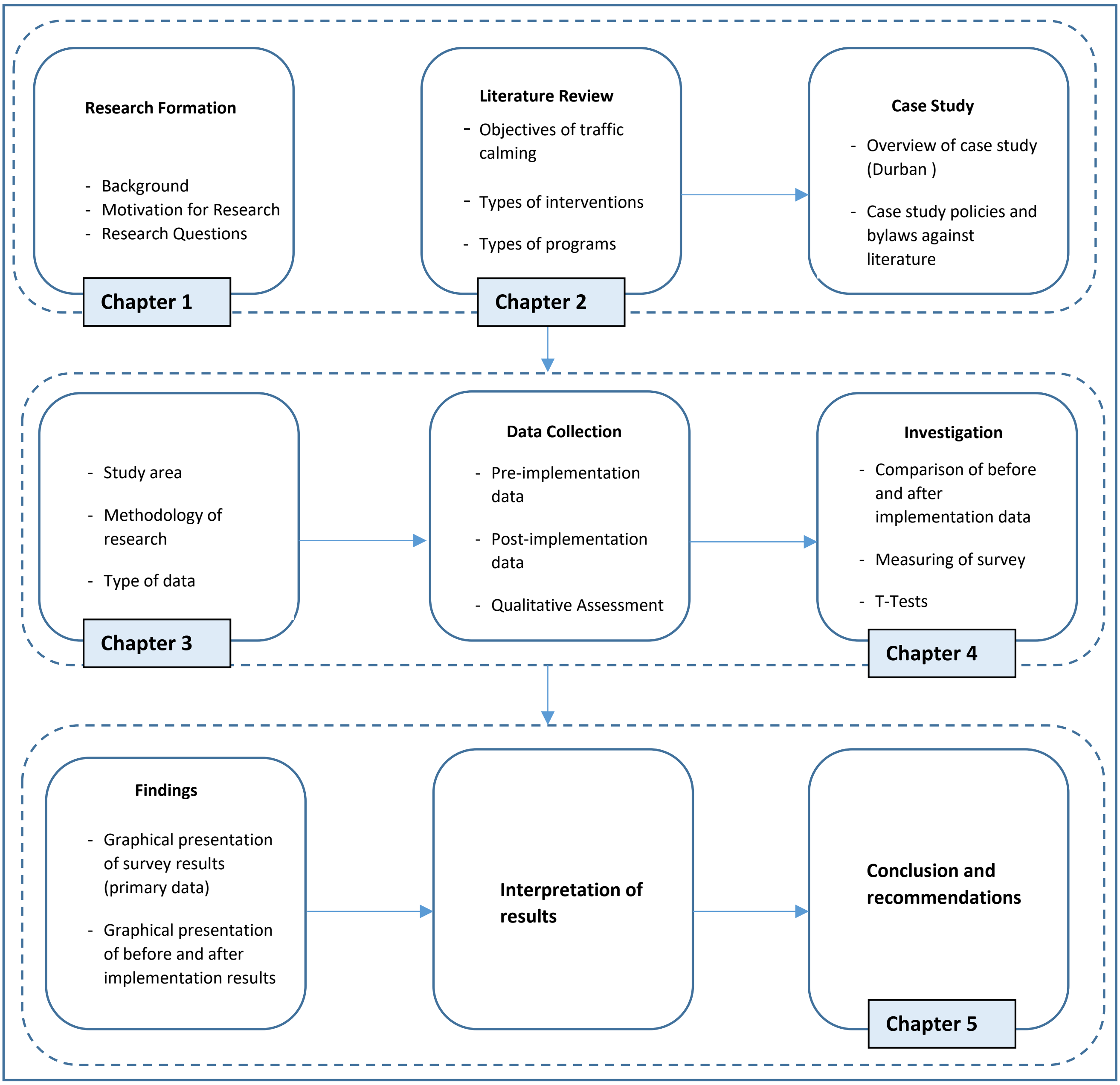


Figure 4 : Research methodology flow diagram

1.7 Scope and Limitations

The study selects roads that were considered for traffic calming. Only roads that were traffic calmed for their entire length were considered. Roads that were partially humped were excluded from the study. In this way, any impacts that predate the study period are excluded. Only 20 roads were taken into account. These roads had no pre-existing humps prior to implementation, and they were traffic calmed throughout their entire length. Roads that were traffic calmed using speed tables and other traffic calming measures other than speed humps were also excluded.

There are some factors that have an impact on travel behaviour in the broader road network that this study does not investigate. An example is spatial configuration and broader land use. The report also does not consider how these factors could impact on traffic calming efficacy. Although changes in travel trends could affect traffic volumes and traffic volumes do have a direct impact on road safety, this research will not take into cognisance any change in travel trends that might have occurred during the period of the study. Changes in travel trends as a result of road network improvements or restraints are also not considered in this study. During observation of vehicular speeds on the road, the research does not consider any possible incidences that could lead to traffic abnormalities on the road under observation. These includes additional trips that could either divert from adjacent roads to the roads under study.

The state of road infrastructure including quality of pavement, visibility of road signs, slope of the road and other factors that could affect driver or pedestrian perception will not be taken into account in the study. The geometry of the road, including the gradient of the road, all other geometric features of the road that could have an impact on driving speeds were not taken into account. The quality of pedestrian facilities is not included in the investigation and analysis of results in the report. The potential impact of cognitive abilities of vehicle drivers that might affect driver behaviour and reaction towards traffic calming will not be taken into account in this study. The study will not consider any vehicle specifications such as performance, make, model and level of roadworthiness. Any potential impact that is related to the performance of vehicles will therefore be ignored. In as afar as implementation period is concerned, EThekwini Municipality only has information about implementation year (July 2014 – 30 June 2015) instead of actual day and month when speed humps were installed.

1.8 Contents of the Report

This report consists of five chapters and they are outlined as follows:

Chapter 1 begins by giving background of the municipality's vision in the context of road safety. It then provides background and status quo of vehicular and pedestrian accidents in the Metropolitan City of Durban. Motivation behind this research is outlined using challenges confronting the municipality's population. From here, the report's methodology is shown graphically. Lastly, the scope and limitations in undertaking this investigation are noted.

Chapter 2 uses available literature to understand traffic calming as a concept. This is done first from an international point of view down to the South Africa perspective. In expanding on literature, the report starts by defining traffic calming and its objectives. From here, it elaborates on existing policy and legislative framework from other developed countries. This is then reduced to South African and the municipality's (case study) perspective. Common types of traffic calming interventions are mentioned along with their advantages and disadvantages as literature suggests. Common traffic calming programs employed by different authorities are elaborated on in order to establish common international practice. Advantages and disadvantages of these programs are also listed. Lastly, different methods of assessing the need for traffic calming in neighbourhoods are discussed. These include traffic calming warrants, guidelines and project priority rating systems. This chapter closes off by discussing literature on speed humps as a traffic calming measure to reduce accidents.

Chapter 3 outlines the study area considered as a case study in the years 2011 to 2018. Important technical information such as road class function is also listed prior to investigation. Data collection methods currently used by EThekwini Municipality are listed and reasons behind their use are elaborated on. An overview of EThekwini Municipality's speed humps warranting and assessment process is then discussed in order to provide rationale for its use.

Chapter 4 uses literature reviewed in Chapter 2, as well as research design preferred in this study from Chapter 3 to investigate the effectiveness of speed humps in reducing accidents. The investigation is carried out in two ways, firstly by using primary data and then secondly by using secondary data. With primary data, a speed survey is conducted on one of the roads under study and results are obtained and discussed in subsequent chapters. Secondary data includes accident counts before implementation of speed humps and after implementation of speed humps. Results from this two-fold investigation are discussed and analysed. T-tests are used to measure statistical significance from the before-and-after study.

The study uses **Chapter 5** to conclude and make recommendations moving forward. This is done by using literature already available against results obtained in the study. These results are used to interrogate current policy and legislative framework governing traffic calming. The research makes necessary recommendations to relevant parties. Recommendations are also made to future researchers to enhance on shortfalls of this study and further improve road safety.

2 LITERATURE REVIEW

2.1 Introduction to Literature Review

Chapter 2 highlights available literature regarding traffic calming around the world including in South Africa. In looking at the existing body of knowledge, the literature review will also look at know efficacies, as well as shortfalls (if any) with regards to traffic calming in general and speed humps in particular.

Existing policies and legislative framework, on which traffic calming is based, will also be covered. The rationale for the installation of traffic calming at EThekwini and the overall approach, whether pro-active or reactive, will be discussed and existing literature on the effectiveness of each traffic calming program will then be revisited. The study will elaborate on tools used to substantiate and justify implementation of speed humps. These include the use of traffic calming warrants and other forms of assessment techniques and strategies.

Historic and current types of traffic calming interventions will also be discussed. In doing so, their properties and applicability will also be discussed with emphasis on speed humps. This will assist in assessing the appropriateness of traffic calming interventions that are employed at EThekwini Municipality. These traffic calming interventions will not be looked at in isolation, but along with NMT requirements and how these requirements are prioritised (or not) in the metropolitan City of EThekwini.

In addition to NMT requirements, road standards and road infrastructure requirements in the City of EThekwini will also assessed. This will be done in the context of the broader national, provincial and local authority policy framework. Any relevant road infrastructure literature will also be used and juxtaposed with that of EThekwini Municipality. In this way, a more proper critique can be achieved.

2.2 International Context

2.2.1 Definition of Traffic Calming

The Institute of Traffic Engineers (ITE) defines traffic calming as “the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behaviour and improve conditions for non-motorised street users” (Faheem, 2011; Lockwood, 1997; cited by Abdel-Wahed & Hashim, 2017).

2.2.2 Objectives of Traffic Calming

The primary objective of traffic calming in general, and speed humps in particular, as a road safety measure is the reduction of speed, volumes or collisions on residential streets. The primary function of residential roads is access and the loss of its functional integrity caused by higher speeds, higher volumes or compromised pedestrian safety is mitigated by traffic calming measures.

Speeds

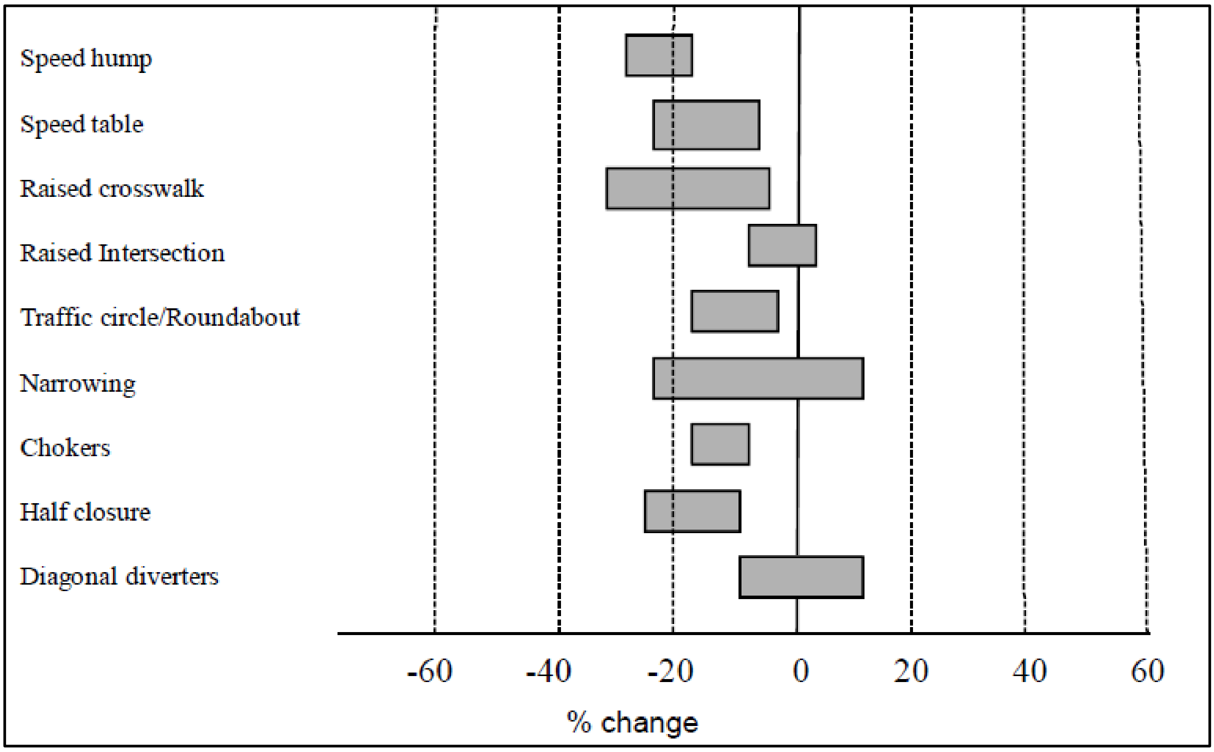


Figure 5 : Impact of traffic calming measures on speeds
Source: Vanderschuren and Jobanputra, 2009

There is literature that affirms the effectiveness of different traffic calming measures in reducing speed impacts on roads (Tester et al., 2004; Yaacob and Hamsa, 2003; Shopes, 2008). Traffic calming measures offer different results but are essentially effective in lowering speeds. As illustrated in Figure 5, the most effective forms of traffic calming are diagonal converters, narrowing and roundabouts. The choice of what form of traffic calming measure to use depends on the intended result, which is either a reduction in speed, volumes or both. Factors such as cost, land availability also influence what traffic calming measure to use (Ewing, 1999; Vanderschuren and Jobanputra, 2009).

Volumes

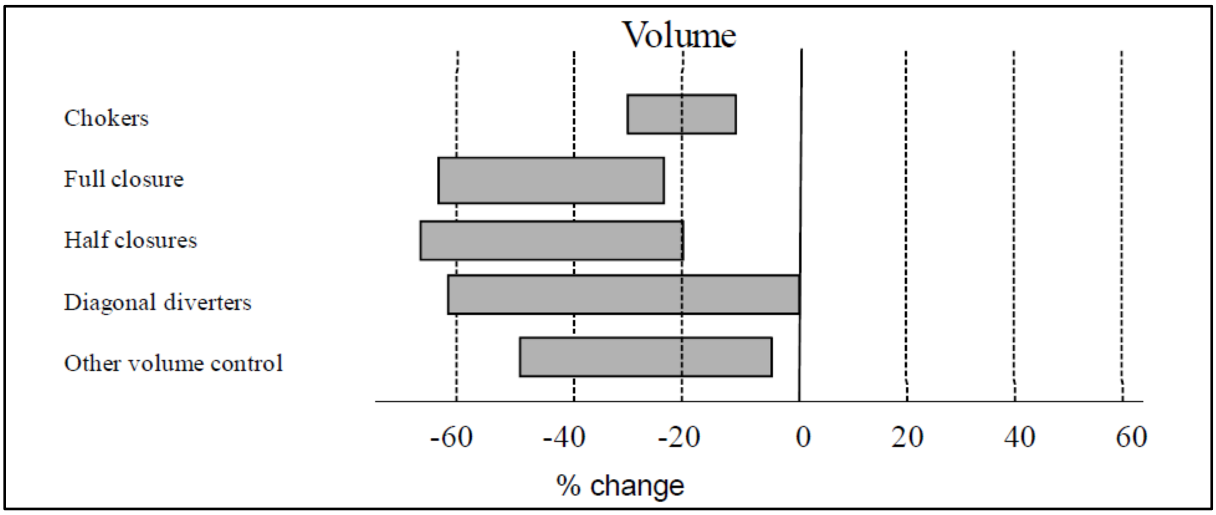


Figure 6: Impact of traffic calming measures on volumes
Source: Vanderschuren and Jobanputra, 2009

Traffic calming can be an important tool to divert traffic from certain residential streets. Traffic calming measures can be used to redistribute traffic as a form of Travel Demand Management (TDM). By reducing extraneous traffic volumes in certain roads, communities get to have pedestrian-friendly roads with less congestion. As shown in Figure 6, other types of volume-curbing measures such as half closure, reduce traffic partially, while some such as diagonal diverters, are more effective as they divert traffic entirely.

Accidents

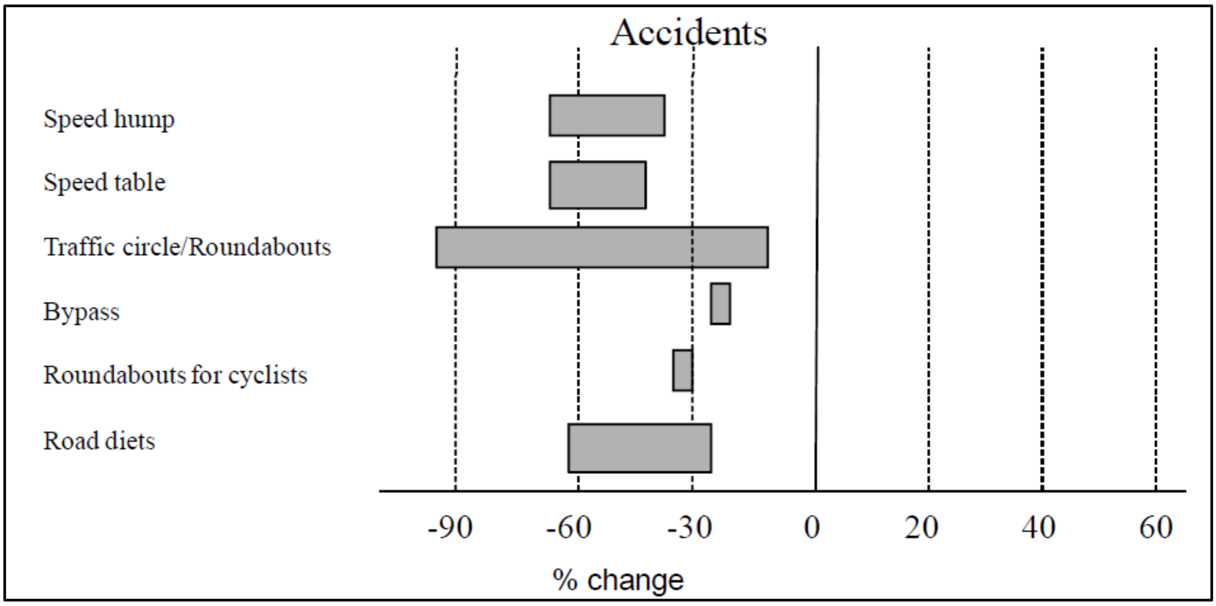


Figure 7: Impact of traffic calming measures on accidents
Source: Vanderschuren and Jobanputra, 2009

As shown in Figure 7, traffic calming is used to curb the number of accidents on the road. This could be by absolute numbers of by rate per population (WHO 2004). Traffic calming is also used to reduce the severity of road accidents as crashes occur at low speeds (Rosen & Sander, 2009; Berthod & Leclerc, 2013). Traffic circles or roundabouts are the most effective traffic calming measure in reducing the number of accidents on the road. Roundabouts are, however, very costly to implement and maintain. They also require more land area for implementation (Vanderschuren & Jobanputra, 2009).

Traffic calming also leads to improvement of the environmental quality of streets as there is less congestion and emissions from vehicles (WHO, 2015). With sophisticated urban design concepts such a transit-oriented developments (TOD's), traffic calming becomes even more important. In such cases, it promotes uses such as improvement of transit access including universal accessibility. It also encourages the use of NMT and assists in reclaiming streets and roadways as multi-use public spaces (Kamyab, et al., 2002). Some research shows that traffic calming effectively reduces noise levels (UK DETR, 1996; cited by Litman, 1999; Pharaoh and Russell, 1989; cited by Litman, 1999), while the opposite is argued by some researchers (Abott, et al., 1995).

2.2.3 Costs of Traffic Calming

Traffic calming comes with benefits but there are also some disadvantages attributed to it. For any traffic calming project, there are costs that are incurred during and after implementation. Costs incurred during implementation are capital expenses of the actual work and materials. Post-implementation costs are maintenance costs. A study by Drenner (2003) also shows that during construction, businesses can be affected negatively. Although traffic calming hardly damages vehicles, there are very few cases where liability claims for damages caused by traffic calming projects are submitted and are successfully (McCourt, 1997; cited by Litman, 1999, Zacharaki and Latinopolou, 2002). Traffic calming directly causes vehicles to slow down upon approach. This impact could be more problematic in cases of emergency vehicles, as it can impact on response time, and pose a risk to the health of patients. In cases of heavy commercial vehicles, these delays could affect businesses. This inconvenience from vehicle delays can be translated into cost and quantified using conventional means (VTPI, 2019). Traffic calming slows down vehicles, consequently leading to delays in travel time. Some vehicles tend to avoid traffic calmed roads and use other available alternatives. This in turn leaves less traffic on calmed roads and transfers the problem of rat-running and even congestion on some roads. By knowing the volumes transferred onto other roads, this cost can then be quantified if there's a cost attached to each additional vehicle. (Litman, 1999). There are also cases where drivers claim to experience temporary stress and frustration due to traffic calming devices implemented on the road. These impacts are temporary and experienced for a short period of time (Litman, 1999).

2.2.4 Long Term Benefit/Cost Analysis of Traffic Calming

Although traffic calming measures come with some disadvantages, these are usually short term and in cases where, they are not relatively short, Implementation of traffic calming comes with a range of benefits to some road users, mostly pedestrians, while it can be costly to users such as vehicle drivers. Costs of traffic calming alluded to on section 2.2.3 are mostly inconveniences but the benefits of traffic calming far outweigh these costs as shown by Litman (1999). Literature affirms the effectiveness of traffic calming in calming down vehicles, slowing speeds and reducing accidents. The reduction of accidents becomes even more important on communities where pedestrians are constantly victims to bad driving behaviour.

2.2.5 Traffic Calming Road Hierarchy

Road network planning involves a hierarchy of roads. This hierarchy is achieved through classification of roads by functions. Through-roads are designed to allow traffic flow while access roads are meant to connect vehicles to destinations. Distributor roads on the other hand, serve a function of connecting through-roads to access roads (SWOV, 2006). Traffic calming is introduced on access roads as a safety measure to either slow down vehicles or reduce traffic volumes. Traffic calming is primarily meant for access roads, as collectors and through-roads serve mobility over access. Although there are cases where traffic calming is implemented on collectors and through-roads, it is not easy to implement on these roads without significantly affecting traffic flow. On high order roads, traffic calming should also be implemented in exceptional cases, where the functional integrity of the roads has been reduced significantly by excessive development and provision of multiple accesses (SWOV, 2006).

2.2.6 Types of Traffic Calming Measures

Traffic calming on roads can be categorised in two ways, based on the intended action. This includes volume control measures, which are put in place to primarily to respond to through traffic by diverting certain movements to other roads. The second is speed control measures, which are primarily used to respond to speeding challenges. They achieve this by changing vertical, horizontal alignment of reducing the roadway (Vanderschuren and Jobanputra, 2009). This research will discuss types of vertical and volume measures and each will be described and discussed in terms of applicability on Table 3.

Table 3 : Traffic Calming Measures

Speed control measures				**Volume measures**
Vertical deflection	Horizontal deflection	Horizontal Narrowing	Others	Divertive/restrictive
✓ Speed cushion ✓ Speed table ✓ Textured pavements ✓ Raised crosswalk ✓ Rumble strips ✓ Speed humps	✓ Traffic circle ✓ Roundabout ✓ Chicanes ✓ Realigned intersection ✓ Tight Radii	✓ Neckdowns ✓ Centre island narrowing ✓ Chokers ✓ 'Road diets' ✓ Bike lanes	✓ Speed Limits ✓ Speed alerts and enforcement ✓ Perceptual design ✓ Warning signs	✓ Full closure ✓ Half closure ✓ Diagonal diverters ✓ Lateral shifts ✓ Median barriers ✓ Neo-traditional design

Source: Adapted from trafficcalming.org and www.vtpi.org

2.2.6.1 Physical Vertical Deflections

Physical vertical deflections are traffic calming measures that introduce a change in the height of the roadway as to force vehicles to slow down upon approaching these instruments. They are mainly used to enforce a reduction in speed and this can also curb traffic volumes (DfT, 2007).

a) Speed Cushion

A speed cushion is a form of a speed deterrent that does not cover the entire length of the roadway. It is cut into sections that leave two (or more) open sections along the length of the roadway. The open sections are left to conveniently allow wide axles of emergency vehicles to be able to drive over the hump without slowing down or stopping. All other smaller vehicles are forced to slow down upon approach (UKDfT, 1994; Berthod and Leclerc, 2013). A 1998 study in the United Kingdom by Layfield and Parry, 1998 ; cited by Johnson and Nedzesky, 2003) showed that speed cushions are not as effective as speed humps, but are still important in reducing speeds and also in reducing driver discomfort especially in heavy and emergency vehicles.

b) Raised Intersection

In areas where there is high pedestrian movement, traffic calming can be extended beyond midsections, it can be implemented at intersections too. To do this, intersections are raised to ensure that vehicles slow down. The layout resembles that of a speed table, with a ramp, and the flat top raised to the level of the sidewalk is used as a pedestrian walking platform. They are effective in reducing speeds and relatively smooth for emergency vehicles. Raised intersections are cost effective as a single installation at an intersection provides traffic calming in two roads. According to Federal Highway Administration (2012), in some cases, raised intersections can improve motorists' yielding to pedestrians from 10% before to 55% after installation. Disadvantages of raised intersections include their possible negative impact on drainage. Raised intersections have a larger surface area compared to speed humps and speed tables, which makes them more expensive to install than both speed humps and speed tables (FHA, 2012).

Figure 8 : Raised intersection at Isaiah Ntshangase road, Moses Mabhida stadium, Durban

c) Speed Table

Speed tables are similar to speed humps, except the former have a flat top and a gradient on each side of the flat top. The flat top is generically about 3 meters wide while the slope is 1.5m wide (ETA, 2012). Speed tables are often constructed using textured materials, which also helps with visibility. The gradual slope of speed tables is effective for reducing speeds. The wide top of speed tables allows large vehicles to slow down comfortably. They can be noisy due to their angular form and shape (DfT, 2007).

Figure 9: Speed table at Old Fort Road, Durban

d) Raised Crosswalk

Raised crosswalks resemble a speed table in shape, except that they have striped pedestrian crosswalk and signage to allow same-level crossing for pedestrians and people with wheelchairs. Raised crosswalks should be installed with appropriate sidewalk transitions on each side of the road. They must be visible enough to allow vehicle drives to slow down on approach and allow pedestrians to cross safely. They are relatively smoother for emergency vehicles. The use of textured materials improves aesthetics. However, raised crosswalks are more expensive than speed humps. They have a shape that increases noise and pollution (Vanderschuren and Jobanputra, 2009; Vanderschuren et al., 2014).

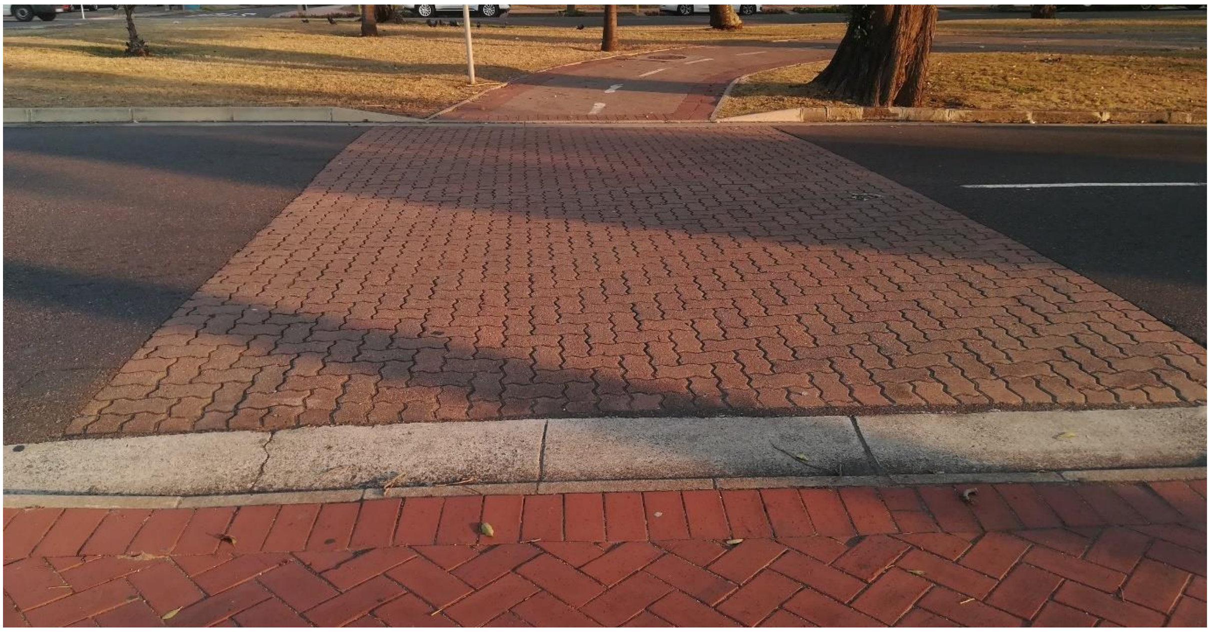


Figure 10: Raised Crosswalk, KE Masinga road, Durban

e) Rumble Strips

Rumble strips are a very effective form of traffic calming used to slow down vehicles without an aggressive vertical transition. They can also be used where high order road intersect with low order roads or where high order roads pass through (for a short length) residential areas. They are effective in notifying drivers of a sudden change in road conditions. These includes roads that suddenly transition into sharp curves, or intersect with railway lines as example (ETA, 2012). They are very noisy and due to this, they are only installed for short a section of the road (Vanderschuren and Jobanputra, 2009).

2.2.6.2 Horizontal Deflection

Horizontal deflections are traffic calming measures that introduce a horizontal shift in the drive direction, thus hindering the vehicle’s ability to drive in a straight line. This effectively forces the driver to slow down and maneuverer around this horizontal obstacle (FHWA, 2016; ITE, 2018).

a) Neighbourhood Traffic Circle

Neighbourhood traffic circles are raised islands that are placed in the middle of an intersection. Traffic circles are normally circular in shape. They create small deflections on approaches, encouraging vehicles to slow down on each of the approaches to manoeuvre the deflection (ITE, 2017). A yield, a stop or a combination of free-flow movement on each of the approaching legs can be used to control traffic circles. To improve visibility, vegetation or landscaping can be placed at the centre median. Traffic circles are very effective as they can show a 30-50% reduction in accidents and severity when compared to signalised intersections (Sampson and Meier, 2005; cited by Aucamp, 2014). However, neighbourhood traffic circles are not safe where roads intersect on a steep gradient as visibility is compromised, and this coupled with a deflective movement can lead to accidents (ETA, 2012).

Figure 11 : Traffic circle at OR Tambo Parade, Durban

b) Roundabout

Roundabouts are similar to traffic circles except that the latter are for high order roads (arterials and main collectors). They have splitter islands and need additional right of way. Roundabouts are a common substitute for signals on intersections. They are not combined with signals (ETA, 2012; City of Joburg, 2002). Roundabouts often offer less delay and also reduce the severity of accidents. Due to their ease to accommodate landscaping, they provide a better aesthetic feature than traffic signals. Due to less delays for vehicles, they are not as pedestrian friendly compared to traffic signals, which can have a dedicated phase for pedestrians. Roundabouts are also relatively cheaper to maintain in comparison to traffic signals. (Vanderschuren and Jobanputra, 2009; Vanderschuren et al., 2014; FHWA, 2017).

Figure 12: Raised Crosswalk, KE Masinga road, Durban

c) Chicane

Chicanes consists of narrowing or kerb extensions that applied from one side of the road to another, effectively creating an S-shape in the roadway. Vehicle drivers are forced to slow down in order to negotiate the change in direction on the road. Chicanes are implemented along a section of the roadway between intersections only (Kacprzak & Solowczuk, 2018). They may negatively impact on parking as they take away space on the roadway. According to UK Department for Transport (DfT, 2007), vehicles are also reported to have crashed with the kerb build outs at some chicanes.

Figure 13 : Chicane at OR Tambo Parade, Durban

d) Realigned Intersection

Realigned intersections are a reconfiguration of T-intersections to have skewed approaches on the main through movements. They are also called modified intersections. They are effective in reducing speeds and improving safety at intersections, particularly through movements that are dangerous due to some motorists not stopping (ITE, 2018). Disadvantages include possible cost of kerb realignment. Realignment of intersection may require some additional right-of-way to cut the corner (Vanderschuren and Jobanputra, 2009).

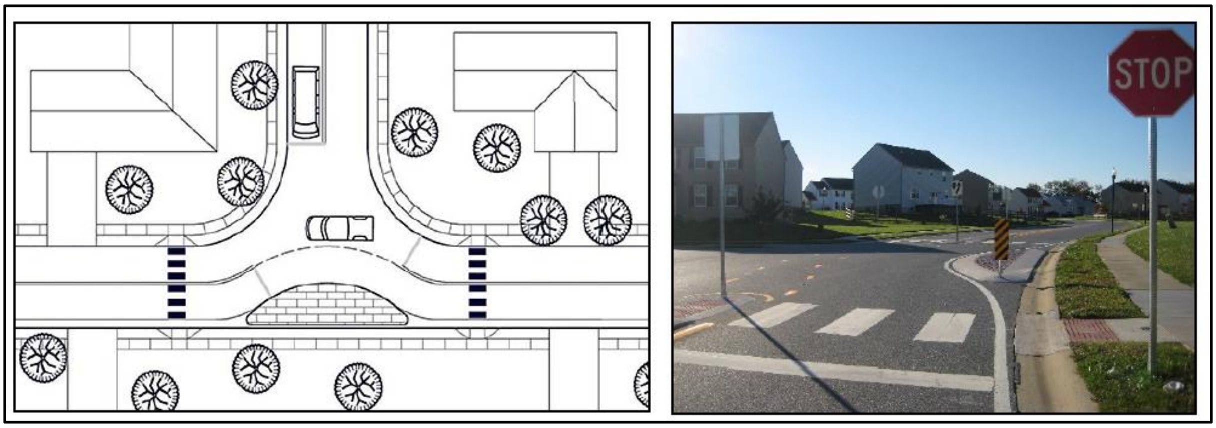


Figure 14: Realigned intersection
Source: Delaware Department of Transport, 2018

e) Tight Radii

The treatment of corner or turning radii is used to force vehicles to slow down upon making turns. This is normally used in highly pedestrianised areas. Tight radius reduce driving speeds at intersections while also reducing crossing distances for pedestrians. A downside to tight radii can be wide swings in turning movements of large vehicles. Realignment of kerb can also be costly (FHWA, 2016).

2.2.6.3 Horizontal narrowing

a) Neckdowns

Neck-downs are road narrowing that is achieved by extending kerbs at intersections to reduce the roadway width from kerb to kerb. This is done to slow down vehicles and improve pedestrian safety on the road (FHWA , 2006; Minnena, 2006). Neckdowns are effective for improving pedestrian circulation and space. They are also effective in reducing speeds. They may slow emergency vehicles. They may also require removal of on-street parking closer to the intersection (Vanderschuren and Jobanputra, 2009).

b) Centre Island Narrowing

Centre islands can be installed in the centreline of a street to narrow the roadway on a particular section of the road. The narrowing of the roadway effectively restricts driving at higher speeds and in this way, traffic calming is achieved. Centre islands that are wide enough can also accommodate display of signboard for displaying information. They can also be used to accommodate vegetation and amenities. In highly pedestrianized areas, centre islands provide refuge for pedestrians crossing the road (FHWA, 2016; ITE, 2018).

c) Chokers

Chokers are curb extensions that narrow the street by widening sidewalk or a strip mid-block. They encourage lower travel speeds since motorists slow down when approaching narrow sections. One-lane choker only allows one vehicle to pass at a traffic calmed-section (pinch), thus resulting in another car having to stop (ITE, 2018). If the pinch point is angled relative to the roadway, it is called an angled choker. They are effective in reducing speeds and volumes. Their impact is limited due to the absence of vertical or horizontal deflection. Chokers may also force NMT users to merge with vehicular traffic. They may require elimination of some on-street parking (Vanderschuren and Jobanputra, 2009).

d) Road Diets

Road diets are narrowing of the roadway and reallocating the space for other uses or travel modes (FHWA, 2006). Road diets can improve the safety of road users, both vehicle drivers and NMT users. They have been proven to increase comfort level for bicyclists due to separation from vehicles. They can also be used to provide barriers and space between travel modes. Road diets can also cost less if they are planned as part of total road reconstruction project, since their application is primarily restriping. Road diets could, however, lead to reduction of parking on the road, depending on their design and extent of application. The reduction of lanes due to implementation of road diets could also decrease road capacity (FHWA, 2019).

e) Bike Lanes

The re-demarcation of road space to accommodate bicycle lanes effectively reduces road space demarcated to cars. Vehicles are forced to slow down due to reduced lane width. Drivers also tend to be cautious of the 'shared' space between themselves and bikers and due to this, tend to reduce their speed. Bike lanes can be designed to add to roadway aesthetics. They also help in creating liveable, and integrated communities (FHWA, 2019). However, bike lanes can be a problem at intersections. They can also increase pedestrian risk in high order roads. They also require some street parking to be shed off (Vanderschuren and Jobanputra, 2009).

Figure 15: Bike lanes on Masabalala Yengwa Avenue, Durban

f) On-street Parking

Implementing on-street parking can be used as a form of passive traffic calming measure. On-street parking can narrow road travel lanes and increases side friction to traffic flow, thus forcing motorists to be cautious and to slow down along a particular section of the road (ITE, 2018). Although this can be effective, it can also have some disadvantages including limiting visibility and sight distance for vehicles on the road. For cyclists, they can also be in the risk of colliding with car doors (ITE, 2018).

2.2.6.4 Volume Reduction Measures

a) Half Closures

Half closures are road barriers that only restrict travel in one movement (ITE, 2018). They are effected over short distances on two-way streets. They are proven to reduce traffic volumes. A disadvantage of half closures is their unintended effect of circuitous routes for residents and emergency vehicles. They may also extend travel times by limiting accessibility on certain nodes. If the barrier is not installed to adequately restrict movement, drivers may be able to circumvent it (Vanderschuren and Jobanputra, 2009).

b) Full Closure

In some instances, there might be a need to close down the entire street for through traffic using a barrier. Full closures can be effected at a link or an intersection (Litman, 1999). They may also be referred to as cul-de-sacs (Minnema, 2006). NMT users, such as cyclists are not affected by full closures as they have gaps in the barriers to allow them go through. Full closures are very effective in creating traffic buffers and eliminating vehicular access into highly pedestrianised areas (ITE, 2018). However, full closures might require legal procedures prior to implementation. The implementation of full closures can also cause circuitous routes for vehicles, effectively increasing travel times (Vanderschuren and Jobanputra, 2009).

c) Lateral Shift

In instances where traffic calming measures cannot be used, such as where there are high traffic volumes of traffic, lateral shifts are often used as means of traffic calming (ITE, 2018). Lateral shifts operate much like chicanes, only with one half used to cause lanes to bend one way, and the back the other way to the original direction of travel. They have been proven to reduce 85^{th} percentile speeds by up to 40% (Harvey, 1992; cited by Minnema, 2006). Lateral shifts are emergency vehicle-friendly and relatively easy to implement. A disadvantage is their high cost in maintenance (Vanderschuren and Jobanputra, 2009).

d) Diagonal Diverters

Diagonal diverters are barriers that are placed diagonally across four-legged intersections, effectively preventing through movements. They are only considered after other measures are deemed not adequately effective. Diagonal diverters can be modified to allow pedestrians and cyclists enjoy full movement on an intersection (ITE, 2018). Their radical impact results in a reduction of intersection capacity (FHWA, 2019. They also result in circuitous travel (Vanderschuren and Jobanputra, 2009).

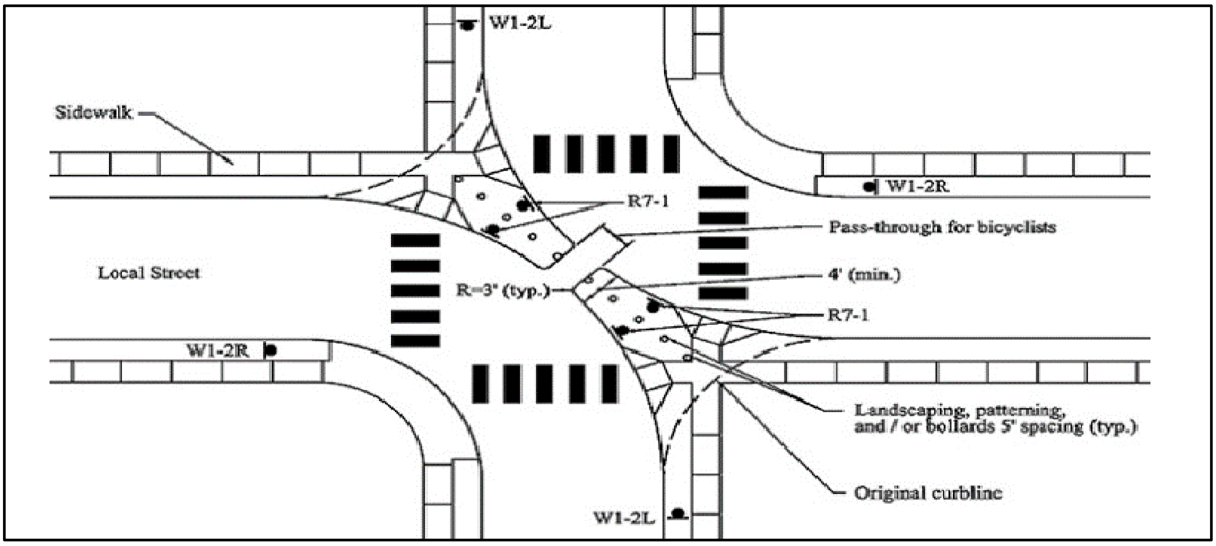


Figure 16: Diagonal Diverters
Source: Delaware Transport Department (www.ITE.org)

e) Centre Island Narrowing

Centre island narrowing is the construction of a physical barrier in the form of a median in the middle of the roadway. This median narrows the roadway width, while also providing refuge for pedestrian (VTPI, 2017). The implementation of centre island narrowing needs signage to prevent vehicles from crashing into the centre island. The downside of centre island narrowing is that, it negatively impacts of parking and driveway access (Vanderschuren and Jobanputra, 2009).

f) Neo-traditional Street Design

Neo-traditional street design is a road design approach comprising of streets with narrower lanes to ensure slower movement of vehicles, shorter blocks to allow accessibility for pedestrians, T-intersections and other features that limit travel speeds as well as traffic volumes (VTPI, 2017). Studies show that Neo-traditional street design improves NMT use (WSDOT, 1994 cited by Litman, 1999) and public transport (Transport Research Board, 1998; cited by Litman, 1999). Neo-traditional street design was also proven to improve road safety (C.N. Kloeden, et al., 1998; cited by Litman, 1999).

2.2.6.5 Others

a) Neighbourhood Entrance Visual Signs (Billboards)

Neighbourhood entrance visual signs are informational visual structures such as “drive slowly” or “kids play area”. They are intended to convey a particular message to road users upon entering a particular neighbourhood. Neighbourhood entrance visual signs are meant to immediately make road users, especially vehicle drivers, aware of road conditions and expected behaviour. These billboards are easy to install and although they are fixed, they can also be uninstalled and moved to a different location if needs be (City of London Ontario, 2017).

b) Targeted Speed Limit Enforcement

Targeted speed limit enforcement measures are one of the most flexible forms of traffic calming. They involve law enforcement authorities and/or speed measuring devices (Vanderschuren and Jobanputra, 2009). Vehicle drivers spot authorities and slow down or drive within the road's speed limit. Transgressors are issued with traffic fines and in some instances, transgressions over certain limits can warrant prosecution. Chapter 3 of the Road Safety Manual for Decision-Makers and Practitioners mentions ways of ensuring that targeted speed enforcement is effective (WHO, 2008). However, this form of traffic calming is effective if implemented over a short time frame. If continued over time, it becomes less effective as drivers could identify enforcement hotpots, slow down only along those sections, and speed on preceding or subsequent sections. Targeted speed limit enforcement also fails to slow down emergency vehicles (City of London Ontario, 2017).

c) Perceptual Design

Perceptual design includes a range of patterns that are painted or projected on the surface of the road to create a mirage of traffic calming features, which encourages drivers to slow down on the road (VTPI, 2017). Research by Montella, (et al., 2010) showed that Perceptual treatments helped drivers to detect the intersection earlier and to slow down.

d) Curb Radius Reduction

Curb radius reduction is the sharpening of a turning radius such that the resultant intersection driving space is reduced and the turning radius is tightened. Drivers are forced to slow down when making a turn. The free additional space is often used to widen the sidewalk and improved pedestrian safety on the road. Curb radius reduction is used in areas where there is high number of pedestrians. Curb radius reduction should not be used in areas where there is a high proportion of heavy vehicles and articulated trucks as they struggle to turn (Vanderschuren and Jobanputra, 2009; Vanderschuren et al., 2014; FHWA, 2017).

e) Textured Pavement

Textured pavement is a form of traffic calming that involves the usage of a different texture other than plain asphalt at certain sections of the road. The textured surface, which could be stamped asphalt or paving blocks, creates vibrations upon contact with vehicle wheels, thus making vehicle drivers "aware" of a sudden change in road conditions (FHWA, 2019). This aesthetically pleasing form of traffic calming is common in areas with high pedestrian movements. Since these are installed on the same level as the roadway surface, they are not as effective in reducing speed. They can also create noise for neighbours (Litman, 1999; Vanderschuren and Jobanputra, 2009). Textured pavements are also implemented on high class roads on crossings as shown on Figure 17.

Figure 17: Textured pavement at Moses Mashida stadium precinct, Durban

f) Curb Extension

Curb extensions are used to reduce the roadway at midblock and intersections. This reduction creates a narrow road perception that forces drivers to slow down upon approach. Another benefit of curb extension is to improve pedestrian safety by extending the surface area of their refuge area. They also create very liveable walking environments, and are aesthetically pleasing when used with landscaping. Curb extensions are a common feature in shared spaces and complete streets. A disadvantage associated with curb extensions includes extra costs for maintenance. They can also create turning problems for emergency vehicles (Vanderschuren and Jobanputra, 2009; Vanderschuren et al, 2014)

Figure 18 : Curb Extension, OR Tambo Parade, Durban

2.2.7 Types Traffic Calming Programs

This research will discuss literature on types of traffic calming programs as they are a precursor to implementation of traffic calming measures. It is important to understand how each type of traffic calming program affects the implementation, as well as results of traffic calming measures. Traffic calming programs are either proactive (installed prior to problems) or reactive by responding to a problem or request from a particular stakeholder. Traffic calming programs may also be implemented by making spot treatments, which is to respond to a particular road (or section) or street. There may also be area wide program implementation, which is when traffic calming is implemented on an area-wide basis. Although proactive area-wide treatment is the most successful, it is also the most expensive and, therefore, the least used program (Ewing, 1999). In South Africa, the largest three metropolitan municipalities (City of Joburg, City of Cape Town and EThekwini) use spot treatments programs. This is also common with other local authorities. In order for local authorities with limited financial resources to pay attention to the most affected areas, projects are prioritized using parameters such as number of accidents, proximity to public areas and speed surveys. This ensures that roads with highest risk are given priority over those with relatively lower risk for road users (Ewing 1999).

Table 4 : Traffic calming program options (Ewing 1999)

	Reactive	**Proactive**
Spot treatment	Somewhat successful;	More successful
Area-wide treatment	Less successful	Most successful

2.2.8 Assessment Framework

Different authorities have developed methods of assessing the need for traffic calming in their neighbourhoods. These range from easier methods that just look at accident statistics to complex and scientific methods that look at physical features of the roads or neighbourhoods, including environmental factors. These methods are usually adopted in the traffic calming policy of respective local authorities. The most common ways of determining the need for traffic calming is through the use of warrants, guidelines and by using priority rating systems (Rahman et al., 2007)

2.2.8.1 Warrants

The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD, 2009) defines warrants as minimum requirements that should be met before a given device is installed. In South Africa, local authorities have adopted the National Department of Transport's Guidelines (NDoT, 1998) for Traffic Calming CR-96/036.1 (1998)] to assess the eligibility of traffic calming on roads. Traffic calming warrants are helpful as they create a standard which rids the system of any bias. In this way political fallouts and dissatisfaction is eliminated. They save time as the criteria is assessor-friendly. Warrants, however, do not allow engineering judgment and discretion, which can be a problem, since each assessment request is different. Warrants also fail to consider how roads within a network interrelate. In other words, roads can still function with a low risk if assesses individually, yet be problematic when assessed collectively in a network and warrants fail to recognise this fact (Ewing, 1999).

2.2.8.2 Guidelines

Guidelines are similar to warrants in that they consider the same factors (speeds, volumes, accidents, pedestrians) when a decision is being made. However, unlike warrants, guidelines do not have a definitive threshold like warrants, they use a more qualitative control matrix. Instead of being definitive, guidelines merely suggest preferred traffic calming measures (Ewing, 1999)

2.2.8.3 Project Priority Rating Systems

This system ranks areas of concern by priority, which is determined by how severe the area is according to the criteria. This is an advantage over warrants since it doesn't only look at the total score but balances (through trade off) out factors in play. It is also an ideal method where funds are limited since it lists roads or areas by their level of risk through total points accumulated (sum of accident, volume and speed). A disadvantage is its intricacy as opposed to a simple score warrant that is easier to explain to residents. Another challenge might be that its scientific nature might make it difficult to customise for smaller municipalities as trade-offs (e.g. on volume/speed) ratios cannot be applied across the board (Ewing, 1999).

2.3 South African context

2.3.1 Policy and Legislative Framework for Traffic Calming in South Africa

In South Africa there is no national regulation that dictates construction and implementation of types of traffic calming measures (vertical defections, horizontal shifts, and roadway narrowing and road closures). The United Kingdom use The Highways (Road Humps) Regulations, 1999 (Statutory Instrument 1999 No. 1025) to set out provisions for road humps in England and Wales (DfT, 2007).

Although there is no law that obligates the government or authorities to implement traffic calming in general or speed humps in particular, it remains an obligation of authorities to ensure safety of the residents for all good reasons. Below are some legal principles around traffic calming that are best to be considered upon planning or implementation:

The South African Constitution

The South African constitution as an over-arching legislation mandates the government to ensure that every citizen has a right to safe movement (SA Government, 1996). This includes freedom to walk safely on public roads provided for the citizens. The installation of speed humps as a traffic calming measure or a measure of reducing accidents can be seen as a way to achieve safety of road users as set out in the highest law of the country, the constitution.

Road Traffic Act (Act 93 of 1996)

The Road Traffic Act (Act 93 of 1996) outlines political principles, including duties of government officials, from Ministers to lower offices, delegated with the task of ensuring that roads operate efficiently. Chapter VI of the Road Traffic Act addresses road safety, which is the cornerstone of traffic calming and Chapter IX addresses Road Traffic Signs and general speed limit. The Act makes it compulsory for road users, particularly vehicles drivers, to observe speed limits (NDoT, 2017).

National Road Traffic Regulations (NRTR)

The National Road Traffic Regulations (NRTR) also goes further to regulate how speed humps should be implemented. Regulation 319 of the NRTR Regulations (2000) prohibits any person from wilfully or unnecessarily preventing, hindering or interrupting free passage of traffic on a public road (NDoT, 2000). In the case of speed humps, the regulation, therefore, compels authorities to construct them such that they do not impede on traffic movement.

Draft Revised White Paper on National Transport Policy (2017)

Formulation of traffic calming policies is done in accordance with Draft Revised White Paper on National Transport Policy imperatives, particularly policy objectives around "improvement of the safety, security, reliability, quality, and speed of transporting goods and people" (NDoT, 2017).

National Land Transportation Act (NLTA) [Act 5 of 2009]

The National Land Transportation Act (NLTA) [Act 5 of 2009] is relevant as a piece of legislation that makes it compulsory for planning authorities to prepare Integrated Transport Plans (ITPs).

2.3.2 Traffic Calming Road Hierarchy

The road classification in South Africa uses six functional classes of the Road Infrastructure Strategic Framework for South Africa (RISFSA), as well as the National Guidelines for Road Access Management in South Africa. The rationale behind these standards is that each individual road cannot serve all road functions of maximum access and maximum mobility. It acknowledges road as a conduit of both access and mobility and the extent is informed by what the road is intended to serve. A road hierarchy is used to achieve this (COTO, 2012).

According to The South African Road Classification and Access Management Manual (COTO, 2012), roads are functionally classified and the critically managed to ensure that they can serve their intended purpose. The South African Road Classification and Access Management Manual provides guidance on how access management must be implemented in a comprehensive and coherent way, and where roads no longer serve their intended function due to factors like population growth and spatial and land uses changes, these roads are then redefined and reclassified as required. Traffic calming in South Africa and elsewhere is guided by road classification. It is by definition intended to serve in low order roads (Class 4 and 5) where operating speeds are above design speeds. In this way, pedestrians in the road are kept safe.

Road networks comprise of a hierarchy of roads, each with a particular class and function. Mobility roads are generally exempted from traffic calming. In instances where there are safety concerns on high order mobility, other engineering solutions that facilitate mobility are used. These includes interchanges, sidewalks and pedestrian platforms that make roads safe for both pedestrians and vehicles. In low order roads such as residential roads, vehicles are meant to drive at low speeds and traffic calming is used to enforce this. These are residential and neighbourhood roads that also serve for low vehicular speeds. Most vehicles can drive upon them safely at 25-30 km/h (Faheed, 2012; cited by Abdel-Wahed & Hashim, 2017). Consideration of road hierarchy is not only a policy for South African roads and countries as well. Traffic calming is only considered on local and collector streets residential roads. It is not considered for high order arterials (NDOT, 1997; City of Joburg, 2002; City of London Ontario, 2017). Table 5 gives a breakdown of a criteria that determines the appropriateness of traffic calming for each road class in EThekwini municipality.

2.3.3 The Role of Traffic Calming in Promoting Non-Motorised Transport (NMT) in South Africa

The importance of NMT in South Africa cannot be overemphasized. According to the National Household Travel Survey (StatsSA, 2014), 21.6% of South African workers use “walking all the way” as their main mode of transport. Against this backdrop, the significance of NMT remains glaring and therefore cannot be an afterthought in transportation planning in South Africa. The National

Department of Transport has been making notable strides in as far as promoting NMT is concerned. This is through legislation, policy and strategy and also prescribing actions in this regard.

Another milestone was the introduction of Final Draft: NMT Facility Guidelines (2014), which is arguably the most promising to date in terms standardising the country's NMT planning and integration of NMT in transport design, as well as giving a balanced and well directed approach in designing the very NMT facilities. This document was introduced as an update to the pedestrian and bicycle facility guidelines (CSIR, 2003). NMT guidelines advocate for a paradigm shift in the design of road space and in how planners and engineers should approach road space allocation (Vanderschuren et al., 2014). It outlines current policy and legislation framework, gives guidelines on NMT planning, as well as an approach on design of NMT facilities and their operations in the South African context. Over and above this, these guidelines are also a tool to refer to for maintenance (post-implementation phase) of NMT facilities, which is key for sustainability of this infrastructure (Vanderschuren et al., 2014). Another notable recent milestone in entrenching a paradigm shift in transport planning and road design is the introduction of the National Technical Requirement 1 (NTR 1) : Pedestrian Crossings by National Department of Transport. This The primary objective of NTR1 is to standardize approach to improving pedestrian safety methods by different authorities. NTR1 adds onto NMT guidelines to strengthen technical content for safe pedestrian facility design in South Africa (National Department of Transport, 2016).

Even with such policy strides, there's still a lot of challenges that confront NMT use in South Africa, particularly in previously disadvantaged communities such as townships. One of the challenges is lack of infrastructure that Mokitimi and Vanderschuren (2016) allude to. In previously disadvantaged communities, NMT is still a challenge. The legacy of apartheid has resulted in spatial planning challenges for historically black townships. One of the challenges is narrow roads with no space for provision of NMT facilities. Due to this, it is sometimes impractical to install sidewalks or other infrastructure for pedestrian safety and refuge. Traffic calming becomes important to ensure safety of NMT users on the road space. In smaller municipalities, implementation of pedestrian facilities such as sidewalks becomes impractical due to cost constraints. Traffic calming is relatively low in costs and could be used as an alternative (Behrens, 2002b).

2.4 EThekwini Municipality Context

2.4.1 Policy and Legislative Framework for Traffic Calming in EThekwini

EThekwini municipality implements traffic calming within the South African legislative framework.

As an implementing authority, the municipality has its own Integrated Development Plan (IDP) which is a five year municipal plan outlining the municipality's vision and plans to achieve it. From this IDP, an Integrated Transport Plan (ITP) is formed and this identifies all road capacity constraints in the city and these are ranked by priority for implementation. A road safety plan is also formulated to ensure that all road safety projects such as traffic calming projects and implementation of sidewalks are in harmony. This is revised on a 5-year basis. To ensure that the municipality's traffic calming projects are implemented in a coherent way, a Traffic Calming Policy (ETA, 2012) was formulated and is currently used.

2.4.2 Traffic Calming Road Hierarchy in EThekwini

EThekwini municipality's roads are classified according to Road Infrastructure Strategic Framework for South Africa (RIFSA) road classification system. Traffic calming is also implemented according to the South African legislative frameworks, includes NLTA and NMT guidelines. However, the municipality has its own bylaws that are mended to suit conditions of the city and its processes. Key bylaws that have an impact on traffic calming will be outlined briefly. It terms of traffic calming, only low order road are considered for implementation. This includes High order collectors (Class 4HV), neighbourhood collectors (Class 4LV) and residential roads (Class 5) are traffic calmed. National and Provincial Highways (Classes 1 and 2) and arterials (Class 3) are exempted from traffic calming. On Class 1, 2 and 3 roads where traffic calming is not supported, other mitigation measure are used. Rumble strips and other signage such as warning lights are used as an alternative to warn drivers of changes in road conditions or a high number of pedestrians using the area. With regards to Class 4 roads, only Low Volume (LV) Class 4 roads are traffic calmed along the entire road length.

High order connectors (Class 4HV) are only traffic calmed in sections of 600m. A warrant is undertaken for every 600m section and traffic calming implemented for every 600m that meets a traffic calming warrant. This means one a road where only one 600m section meets a warrant, only 4 humps will be implemented on that particular road. Low order collectors (Class 4LV) and Class 5 residential streets are traffic calmed along the entire length if a traffic calming warrant is met. EThekwini Municipality's current council policy also exempts signalised intersections from being traffic calmed. The current council policy considers traffic signals a form of traffic calming and a combination of traffic signals and speed humps is not supported by the policy. Industrial and Central Business District (CBD) roads are also not considered for traffic calming by the current council policy of EThekwini Municipality (ETA, 2012).

Table 5 : Appropriateness of traffic calming by road class (adapted from ETA, 2012)

Road Class	Daily Volumes	*Action
1/2 Principal/Major Arterials	40000–140000 vpd 20000-60000 vpd	No Traffic calming. Signage enforcement and other engineering interventions to be considered
3 Minor Arterial	10000-60000 vpd	No Traffic calming. Signage enforcement and other engineering interventions to be considered
4 Collector Street	<10000	Can be traffic calmed subject to warrant being met
4LV Low Order Collector Street	<5000 vpd	Can be traffic calmed subject to warrant being met
5 Residential Street	<1000 vpd	Subject to warrant being met. Speed humps an appropriate measure.

*Additional information on traffic calming principles

2.5 Speed Humps as a traffic calming measure

As a popular form of traffic calming that is this research focuses on, it is important to understand why speed humps are still widely used. It is also important to understand literature on the application of speed humps including the effectiveness as well as shortcomings of speed humps as a traffic calming measure. This understanding will assist the undertaking of this research and conclusions. Speed humps are the most common form of traffic calming and a type of vertical deflections. They are casually called "pavement undulations" or "sleeping policemen". They are typically raised sections characterised by extending transversely across the roadway surface (NDoT, 1997; Parkhill et al., 2017). Speed humps come in different shapes including flat top, round top, speed cushions, trench and ramp humps. The semi-circular shape is the most common.

Speed humps are a very cost effective form of traffic calming, hence, their popularity across different areas in the world. They are spaced carefully as to curb operating speeds effectively. The location of speed humps at very close intervals has negative impacts as it leads to uncomfortable noise to neighbours. This affects peacefulness and calmness in the community in residential areas (JASIŪNIENĖ, et al., 2018). Widely spaced speed humps are also less effective as the allow vehicles to reach higher operating speeds. To arrest this dilemma, it is very important to choose appropriate spacing when placing speed humps to ensure that traffic is calmed but at the same time, tranquillity is maintained in the neighbourhood (Yaacob and Hamsa, 2013).

Figure 19 : Speed Humps, Florida Road, Durban

2.5.1 General Specifications

To achieve their primary objectives, speed humps have to be of a certain standard. The National Department of Transport's Design and Implementation of Speed Humps (1998) served as a guideline to assist local authorities and traffic engineers with a uniform approach to the implementation of speed humps. These guidelines assisted with regards to the dimensioning, spacing, positioning, signage and marking of speed humps. Today, the DoT NMT guidelines (2014) provide the latest general specifications for speed hump design as well and signage for speed humps as shown on Figure 20. Speed humps are typically 3.7m in length and between 80mm and 120mm in height. Different South African local authorities use NMT guidelines as a base for design and amend as per their respective needs. EThekwini Municipality uses a spacing of 150m between speed humps with 120m as the absolute minimum spacing of speed humps.

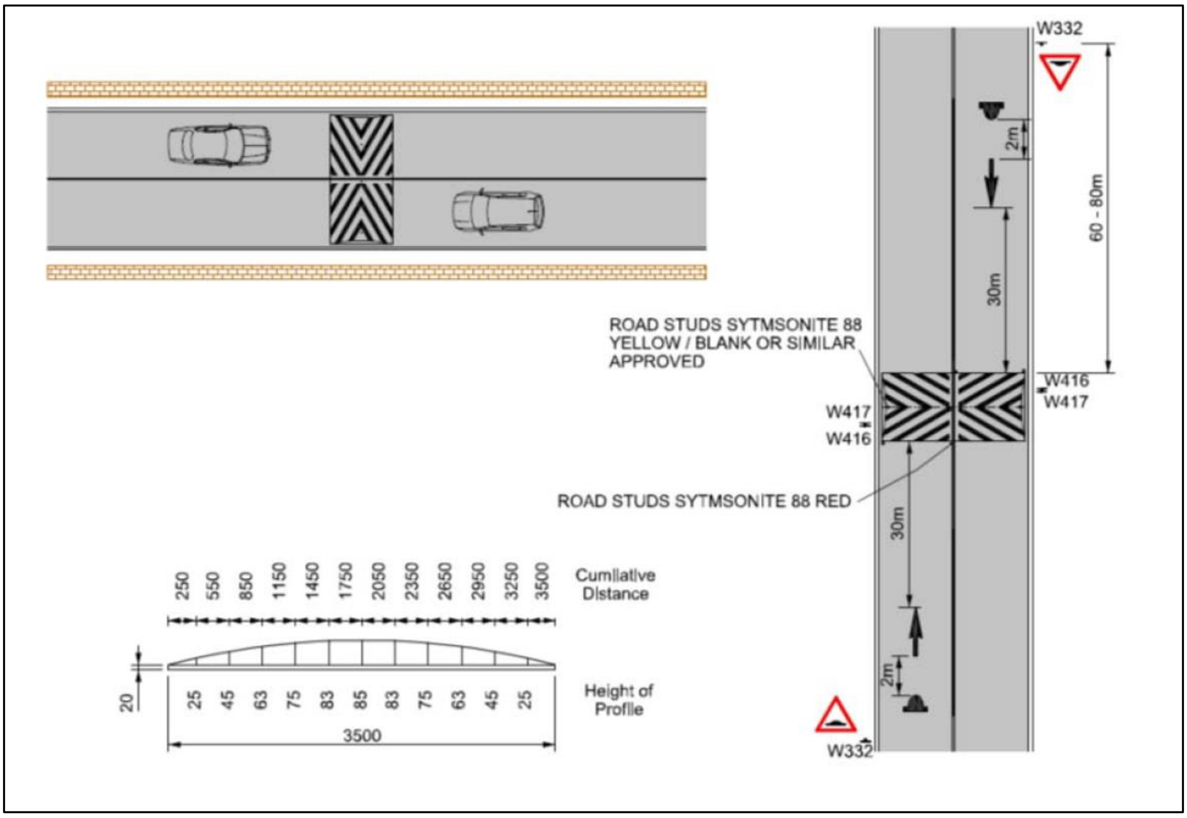


Figure 20 :Cross-section and plan view of a typical round top speed hump
Source: Vanderschuren et al., 2014.

2.5.2 Speed Humps – Effectiveness

There is vast literature on the effectiveness of speed humps as a traffic calming measure. Speed humps have been proven to reduce speed of vehicles (Vanderschuren and Jobanputra, 2009). Dixon and Jacko (1998) conducted a before and after study in The Netherlands to investigate changes in driver behaviour due to implementation of speed humps. This research showed that there was a 40% decrease in travel speeds after speed humps were installed. Another study by Ponnaluri and Groce (2005) showed that speed humps reduce mean speeds, median and 85th percentile speeds. In Belgrade, Serbia (as shown in Figure 21), a study showed that speed humps reduce speed and that the design (height) of the speed hump also affects the extent of this change (Antić et al., 2013).

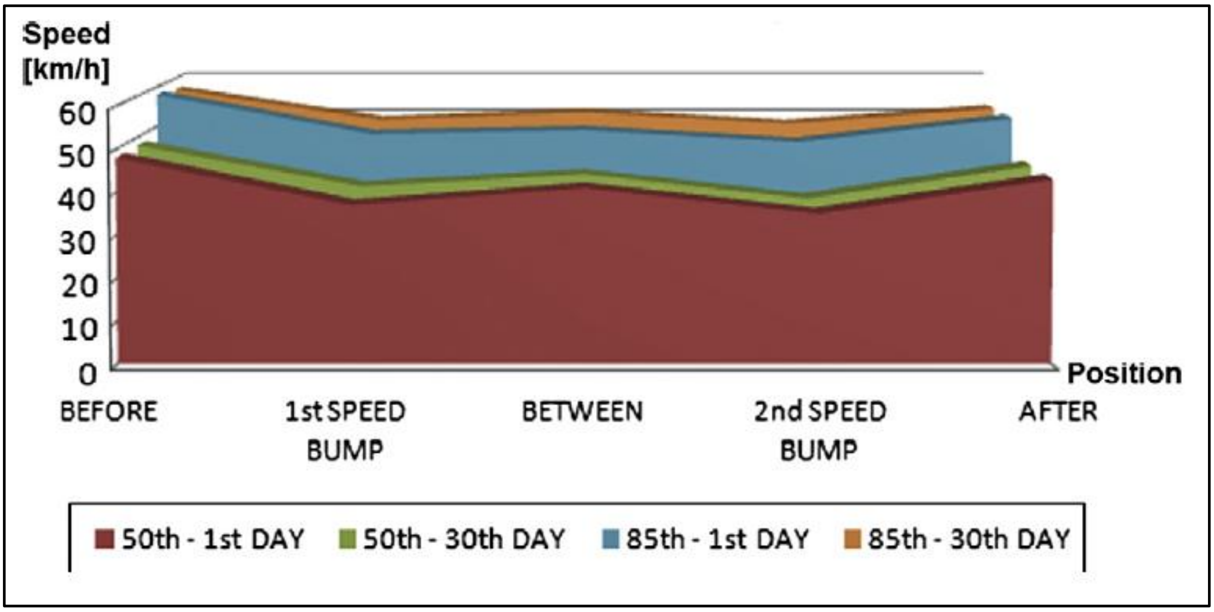


Figure 21 : Speed distribution between speed humps
Source: Antić et al., 2013

A study by Tester (2001) found less probability of fatality amongst crash victims when speed humps are installed. Another case study by Tester (et al., 2004) showed that children living on a road with speed humps were less likely to be victims of car crashes than those living away from a street with speed humps. According to the study, there's 53-60% reduction of probability of injury or death among children hit by a car when a speed hump is present (Tester, et al., 2004). Another study by Yaacob and Hamsa (2013) also affirmed the effectiveness of speed humps in improving road safety. Research by Ewing (1999b) affirmed the effectiveness of speed humps in reduction of 85^{th} percentile speeds. This research proved the effectiveness of speed humps amongst vulnerable and people with limited cognitive abilities. In Masvingo, Zimbabwe, research by Pardon and Average (2013), also showed that speed humps can reduce 85^{th} percentile significantly. In this study carried out, 85^{th} Percentile speeds were reduced from 55-65 km/h down to 30-32km/h after implementation of speed humps.

2.5.3 Overview of Speed Hump Warranting

The Road Traffic Act 1989 (Act 29 of 1989) requires municipalities to record accident incidents that are later captured on the National Accident Register (NAR) for statistical purposes and also to assist in identifying high risk areas. The framework is authorised by the Road Traffic Act 93/1996, Access to Information Act of 2000, Criminal Procedures Act 51 of 1977, Public Financial Management Act of 1999, Prevention and Combating of Corruption Act 12 of 2004, the Road Accident Fund Act 56 of 1996, National Archives Act 43 of 1996, and the Provincial Gazette 5867 enablement 25(1) (g) Act 12 of 1998.

EThekwini municipality currently collects accident reports from all the SAPS and Metro Police Stations in the eThekwini municipality area on a daily basis. This process ensures that every recorded accident is kept in the system. This is an on-going, regularly updated process, each day, road accidents reported to both SAPS and EThekwini metro police within EThekwini Municipality are collected and this information (through metropolitan police) is then consolidated into the municipality's road safety department. This is done each financial year and all roads are then listed by accident rates and prioritized for interventions according to this. Before approval and implementation, a warrant is applied on each road (warrant sheet as per DoT (Guidelines for Traffic Calming CR-96/036.1 (1998)].

Currently, the process of speed hump implementation is two-fold, one being through the city's crash ranking and the second being through warrant requests from residents and other stakeholders. The overall process is shown on Figure 22.

Accident ranking – with the help of SAPS and Metro police, the city collects accident information from its roads on a daily basis. Through this process, the top 25 class 5, use Class 4 (low volumes) and class 4 high volumes roads are the considered and a traffic calming warranting process is undertaken before implementation. Although most accident-ranked roads easily meet the traffic calming warrant, they are still subjected to a verification process.

Warrant requests – this second process is through queries lodged with the municipality's traffic engineering department. Residents are allowed to submit requests for speed humps. The roads in question are then also taken through warranting process and should they meet the requirement, they are then also put on the implementation list. Due to budget constraints, some of the roads meeting traffic calming warrants are carried over to the subsequent financial year.

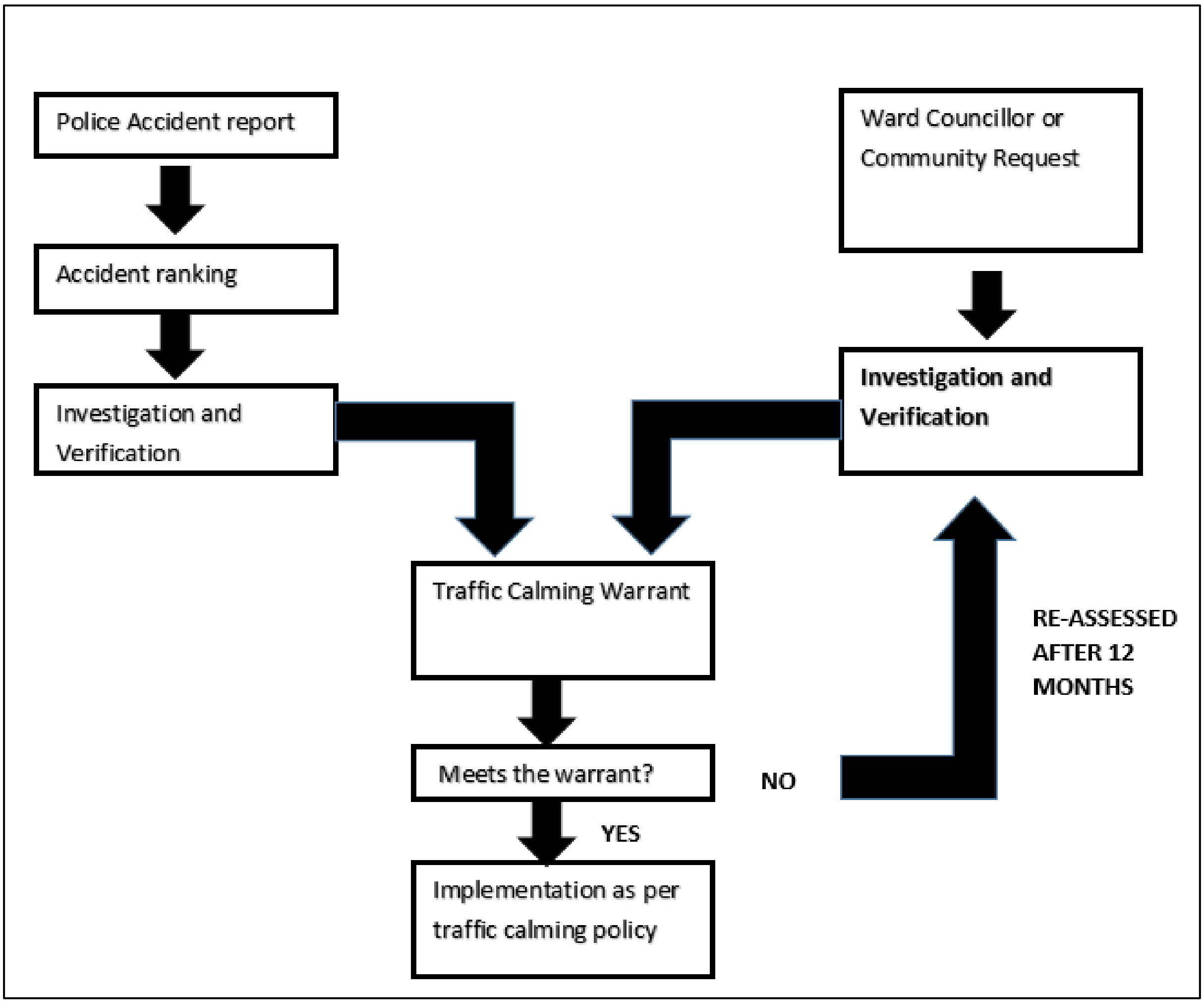


Figure 22 : Traffic calming process for City of EThekwini
Source: Adapted from ETA, 2012

2.5.4 Speed Hump Assessment Process

There's different ways local authorities handle traffic calming requests or assessment queries. In the case of EThekwini municipality this process is shown on Figure 22. This submission can either be done through a request from external stakeholders such as councillors or members of the community. This can also happen through the municipality's internal accident ranking system. With both these submission process, the request is subjected to a site investigation and verification process that also includes vetting of the information. The road is then assessed by using the council traffic calming policy warrant. If this request meets the warrant, the road in question is then included in the municipality's implementation list for construction. If the request does not meet the warrant, the municipality has a feedback loop system to process this. The road will then be recorded and reassessed after 12 months to check if it meets the warrant in the subsequent assessment.

3 RESEARCH DESIGN

3.1 Introduction

In order to investigate the effectiveness of speed humps as a traffic calming measure to reduce accidents, Durban has been used as a case study. Since effectiveness is relative, the research will establish this by comparing results before and after implementation of speed humps. The investigation has been undertaken as discussed in Section 4 of the report. The findings from this investigation will allow the researcher to answer research questions asked on Section 1.4.1. The research will use a two-fold approach to assess the effectiveness of speed humps. A speed survey will be used as primary data as shown on Section 4.1. From the speed survey, the effect of speed humps on reducing speed will be assessed. A before-and-after study will then be conducted using secondary accident data from EThekwini Municipality. With the results of the before-and-after study, the study will be able to assess if speed humps can reduce the number of accidents. A before-and-after study is first done at an aggregated level, using Equivalent Accident Numbers (EANs) and further disaggregated into other indicators as shown on Section 4.2 of the research. A qualitative assessment of the 20 roads is conducted to check for any visible defects on the roads. This is done to ensure that the study does not make incorrect conclusions. Lastly, T-tests are done on each of the before-and-after studies to check for statistical significance of the results.

Table 6 : Capital Budget Traffic Calming for 2014/15 Financial Year

Road Name	**Ward No.**	**No. of humps**	**Road Name**	**Ward No.**	**No. of humps**
P Tshabalala	92	25	Tracy Watts Rd	18	5
Hurst Grove	31	2	Pridley Road	23	5
Sol Mahlangu Road	88	5	Wingate Road	64	7
Berkshire Drive	21	13	Kilburn Avenue	31	2
Silvertree Road	68	7	8th Avenue	27	3
Galloway Road	8	8	Donegal Road	66	3
Sofasonke Road	7	13	Fairlight Road	63	12
Sol Harris Crescent	26	6	High Street	60	6
Amical Cabral Road	90	6	Sizwe Mdlalose	19	6
Phambili Road	85	6	Dumakude Road	17	4
Total Cost Estimate @ R30,000.00 per hump	**R4,320,000.00**				

Each of the roads on Table 6 was assessed for traffic calming, using the municipality's traffic calming warrant (ETA, 2012). All 20 roads met the warrant traffic calming. All roads, with the exception of Donegal Road, are Class 5 residential roads with less than 1000 vehicles per day. Donegal road is a Class 4 low order collector street with less than 5000 vehicles/day.

The design and flow of the study is informed by questions the research will respond to. The methods of research are particularly designed to answer research questions, and then, be able to conclude on the effectiveness of speed humps around each question.

- What is the impact of speed humps in reducing vehicular speeds? – To answer this question, the research will use a speed survey to assess speed differentials between two humps. Variations in speeds will be measured.
- What is the impact of speed humps on the total number of accidents, injuries and fatalities? – In order to establish the impact of speed humps on accidents, a before-and-after study will be done. Accident before implementation of speed humps will be compared with accidents after speed humps are installed. The research will use Equivalent Accident Number (EAN) as this factor is based on the cost of each accident type.
- Can speed humps reduce the number of pedestrian accidents? - The research will disaggregate total EAN information into a sub-category of pedestrian accidents. The number of pedestrian accidents before implementation of speed humps will be compared with pedestrian accidents after speed humps were installed. Changes will then determine if speed humps are effective in improving pedestrian safety.
- Can speed humps reduce the number of accidents amongst school-going children? – The research will use crash data available on people aged 18 years and below. This data will be used as part of a before-and-after study to assess if speed humps had an impact in improving road safety amongst pedestrians aged 18 years and below.
- What role do speed humps play in communities where there is inadequate NMT facilities such as sidewalks? – From the municipality's classified pedestrian data, the study will use accidents that involved pedestrians walking on the roadway. The number of pedestrians involved in crashes before speed humps were installed, will be compared with the number of affected pedestrians after speed humps were implemented.

3.2 Study Area

EThekwini Municipality is South Africa's third largest metropolitan municipality. In the 2016 census, the city had 3,677,575 inhabitants (StatSA, 2016) and 110 wards, as per South African Municipal Demarcation Board (2019). According to EThekwini municipality's updated Integrated Transport Plan (ETA, 2015), 26% of EThekwini residents walks or cycle to the destinations. The ITP (in line with the city's vision 2050, has identified prioritisation transport planning for vulnerable NMT users, for low to high income commuters, for long distance travellers and for road users with special needs (ETA, 2015). Figure 23 shows the municipal boundaries of EThekwini municipality and Figure 24 illustrates each road in relation to the broader municipal boundary. A spatial EAN map of the Durban City is shown on Appendix B

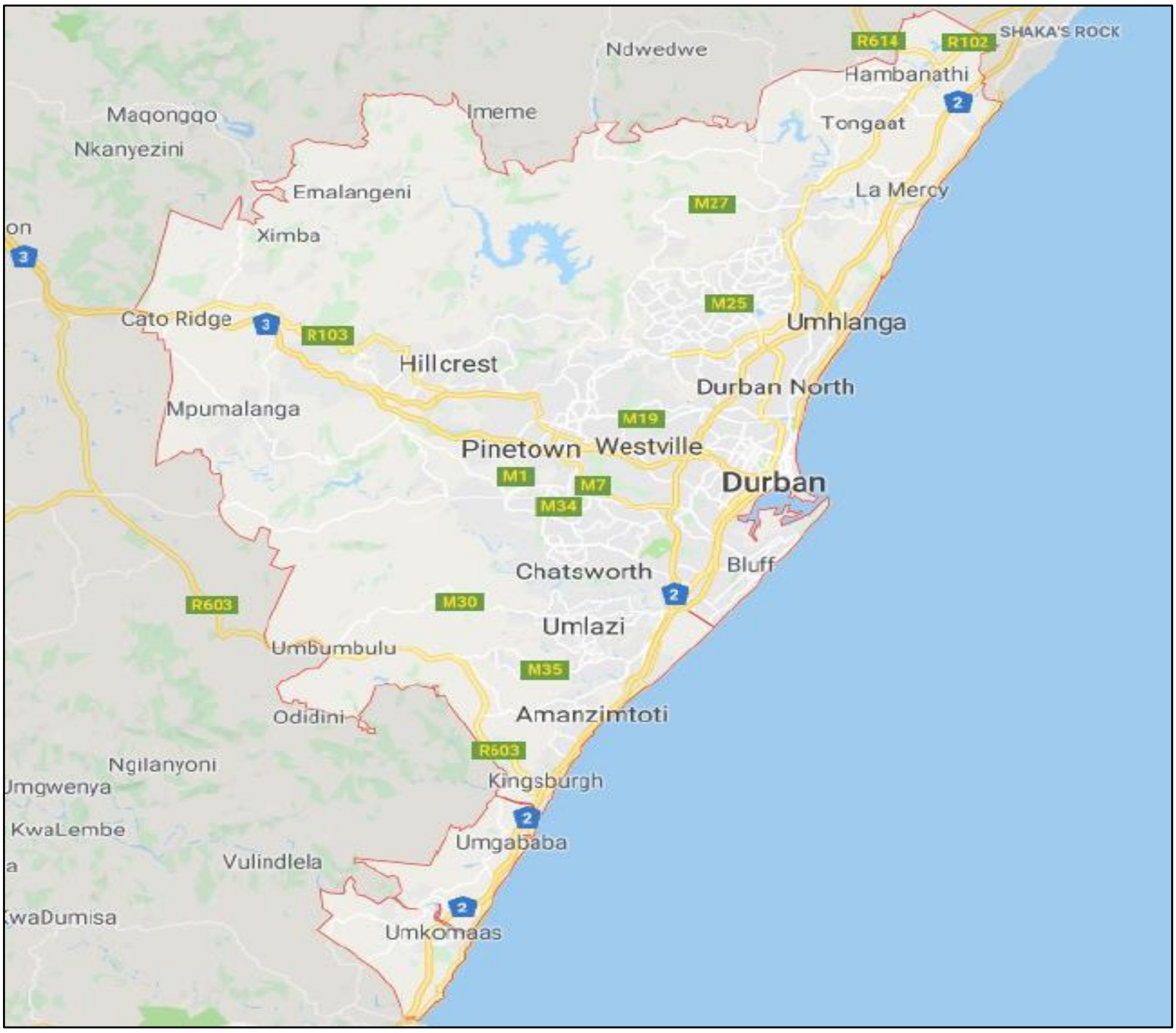


Figure 23 : Spatial representation of EThekwini municipality boundary
Source: Google, 2019

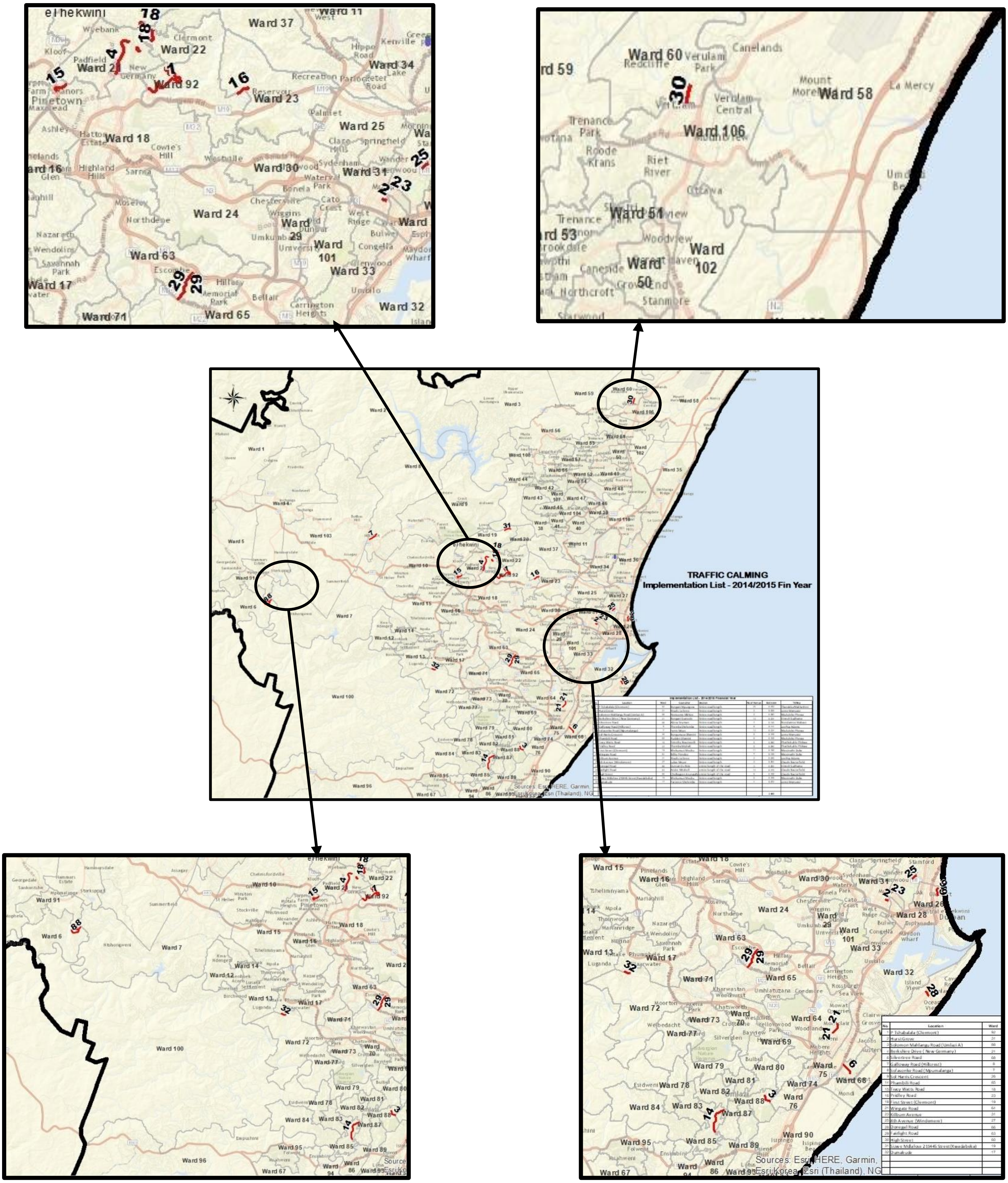


Figure 24 : Illustration of traffic calming by ward in EThekwini (Adapted from ESRI GIS, 2019)

3.3 Data Collection

To investigate the research topic, two data collection methods were used in the study area under assessment. Both data collection methods were quantitative in that they used numerical data or data that can be converted into usable statistics to then answer research questions. The first dataset was recorded by the researcher on-site. This data was ethically cleared and anonymity was preserved in the process. In the second data collection method, information collected by metro police and kept by EThekwini Municipality was interrogated.

3.3.1 Primary Data

A study by Ashton and Mackay (1979) show the existence of a clear relationship between vehicular speeds and pedestrian casualties as shown on Figure 25. This study and others prove that the higher the speed of a vehicle, the shorter the time a driver has to stop and avoid a crash. In other words, there is a higher risk of crashing at a higher travel speed. More importantly, the study shows that with a higher speed, the severity of a crash and subsequently the risk of pedestrian death, increases significantly. The study shows that for an example, at an impact speed of 80km/h, there is almost 100% certainty of pedestrian death.

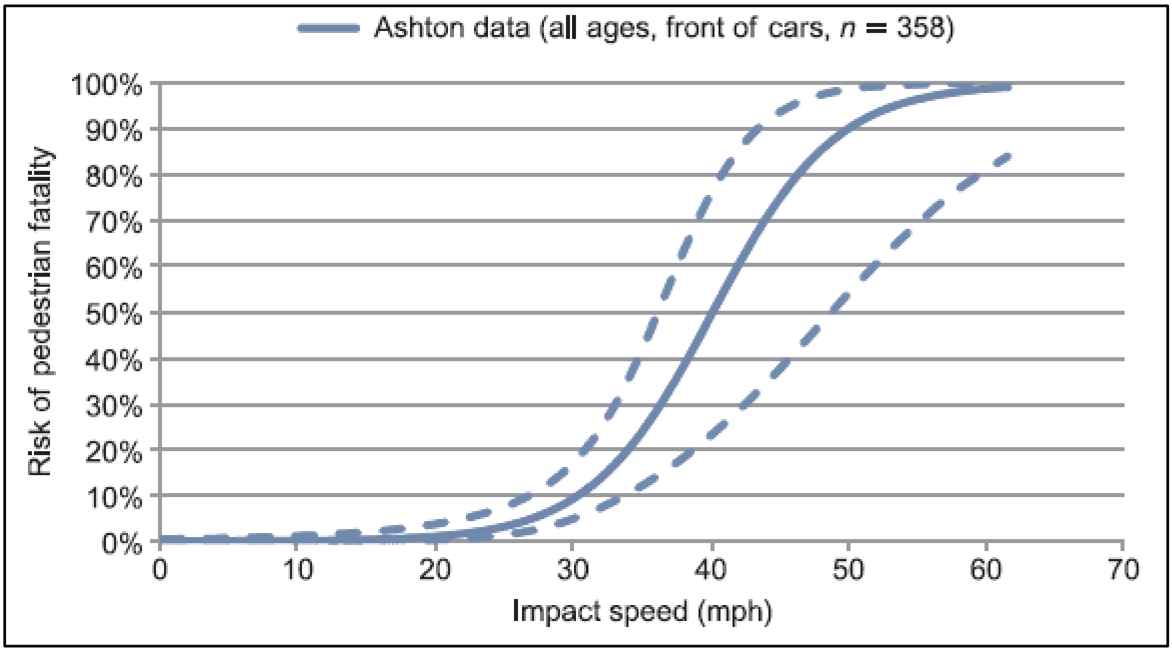


Figure 25 : Likelihood of pedestrian fatality, according to impact speed
Source: Department for Transport, 2010

From this, it can be concluded that reducing speeds can, therefore, reduce the number and severity of accidents. The research will use primary data (speed survey) as shown on Section 3.3.1 to measure vehicular speeds on roads where speed humps have been implemented, at links, as well as sections far enough from speed humps. These intervals (change in distance) along with corresponding speeds will be used with available literature to deduce on the effectiveness of speed humps in speed reduction and, therefore, accident reduction.

3.3.2 Secondary Data

The approach to assessing the effectiveness and impact of the implementation of speed humps is to use secondary data in the form of crash records at the disposal of the municipality. The research will study crash numbers before and after implementation of speed humps. In this case the base period of July 2014 until June 2015 will be used. From this, a three year period before implementation (July 2011- June 2014) will be considered. This will then be juxtaposed to another three year period after the implementation (July 2015- June 2018). The rationale behind the three-year study (as opposed to just a year for an instance) is to improve on reliability of the results. In this way, one-year anomalies that can possibly distort results are eliminated. With a three-year before and three-year post implementation study, more reliable results are obtained and better conclusions can be drawn.

3.3.3 Qualitative Assessment of the roads

The research also included site visits in order to assess conditions of the roads under study. Site visits were conducted between July and August 2019. The assessment of conditions was done to identify any anomalies that could influence road safety conditions and possibly outcomes of the study. The research also used available historical maintenance data in the municipality for each of the roads under study. This was done so that deteriorating pavement conditions or recent road upgrades could be identified. Although detailed land use information was not obtained, the research also did a desktop study on recent notable property developments that were opened during the study period. These notable land use developments are higher trip generators that could affect travel trends and patterns such as shopping malls, schools and office developments. Although this information was limited, it was noted and could be used to identify any possible anomalies.

The research also identified areas where there were no sidewalks or adequate verge. This is because where sidewalks or adequate verge are absent, pedestrians tend to walk on the roadway, which increases pedestrian risk on the road. Signage and road marking were also observed. This was to ensure that all roads have adequate signage and road markings to help both drivers and pedestrians of prevailing road conditions, as well as to mitigate risk of crashes. The research also assessed the surfacing of the road to identify any visible deformations such as cracks. The assessment of the road for deformations was done because deformations are also a cause of distraction to drivers and compromise road safety.

Table 7 : Qualitative Assessment of the roads

Road Name	Surfacing	Sidewalk	Lane markings	Signage	Visibility/Sight distance
P Tshabalala	Good	Present	Visible	Present	Sufficient
Hurst Grove	Good	Present	Visible	Present	Sufficient
Sol Mahlangu Road	Good	Present	Visible	Present	Sufficient
Berkshire Drive	Good	Present	Visible	Present	Sufficient
Silvertree Road	Good	Present	Visible	Present	Sufficient
Galloway Road	Good	Present	Visible	Present	Sufficient
Sofasonke Road	Good	Present	Visible	Present	Sufficient
Sol Harris Crescent	Good	Present	Visible	Present	Sufficient
Amical Cabral Road	Good	Present	Visible	Present	Sufficient
Phambili Road	Good	Present	Visible	Present	Sufficient
Tracy Watts Rd	Good	Present	Visible	Present	Sufficient
Pridley Road	Good	Present	Visible	Present	Sufficient
Wingate Road	Good	Present	Visible	Present	Sufficient
Kilburn Avenue	Good	Present	Visible	Present	Sufficient
8th Avenue	Good	Present	Visible	Present	Sufficient
Donegal Road	Good	Present	Visible	Present	Sufficient
Fairlight Road	Good	Present	Visible	Present	Sufficient
High Street	Good	Present	Visible	Present	Sufficient
Sizwe Mdlalose	Good	Present	Visible	Present	Sufficient
Dumakude Road	Good	Present	Visible	Present	Sufficient

Statistical Analysis

Various researchers have conducted before-and-after studies on the impact of traffic calming measures, particularly speed humps, in reducing speeds and road accidents. A study in Los Angeles (Patao, et al., 2018) focused on the effectiveness of installing speed humps in reducing the number of child and adolescent pedestrian-involved motor vehicle collisions (PMVC). This was specifically for people under the age of 21. Using date collected 2.5 years before installation of speed humps and data recorded 2.5 years after speed humps were installed, the study found a decrease of up to 37.5% in the quantity of pedestrian versus automobile incidents involving children and adolescents, following the installation of a speed hump. Using Fisher's Exact test and Wilcoxon-Mann-Whitney test for categorical and continuous variables respectively, the effect of speed humps in reducing in accidents were found to be statistically significant.

A similar study was conducted in Toronto, Canada. This study investigated the evidence related to the effectiveness of speed humps on reducing pedestrian-motor vehicle collisions (PMVC). Statistical analysis was conducted using statistical software SAS V.9.3 and STATA V.12.1. The installation of speed humps was associated with a 22% reduction of PMVC overall. The study further showed that this was even more effective in children and youth of ages 0-15, where there was an associated 43% reduction of PMVC incidence rates. According to the research, there were similar effect sizes for older adults and severe/fatal PMVC to the total sample of all ages, but these were not statistically significant likely due to the small number of PMVC (Rothman, et al., 2015).

A study in Lithuania assessed the Impact of speed calming measures on road safety. This before-and-after study showed a significant decrease of fatal and injury accidents after vertical traffic calming measures (speed bumps, speed humps, raised crosswalks) were put in place. Fatal and injury accidents were reduced by 60%, the number of people injured decreased by 63% and the number of people killed decreased by 82% (Jateikienė, et al., 2016).

For this research in eThekwini Municipality, Microsoft Excel was used to arrange and compare the extracted before-and-after accident records for each variable measured. For each variable compared, a column determining the difference, whether an increase, decrease or no change, was captured. For the statistical analysis, hypothesis test was used.

Null Hypothesis

H_0: $U_D = U_1 - U_2 = 0$,

UD = mean of the population of difference scores across the two measurements (before and after installation of speed humps)

U1 = mean prior to installation of speed humps

U2 = mean prior to installation of speed humps

For the t-test, the value of Alpha was selected at 0.05. While larger Alpha values are commonly used (i.e. typically 0.5, to ensure 95% level of confidence or 0.1, to ensure a 90% level of confidence), a higher level of confidence was selected to guarantee the confidence of the results considering the small sample sizes in this research (20 samples). The P-value and T-critical values were also determined for each of the areas under study. If the p-value was less than or equal to the selected Alpha value of 0.05 then the relationship was determined to be insignificant. A computer program called Social Statistics was used for statistical analysis. This program was also used for T-Tests, to compare means and test for statistical significance. A summary of analyses of findings and T-test is shown on Section 4.3for each of the measured variables. Full T-Test results extracted from the software are available on Appendix C.

(Available on: https://www.socscistatistics.com/tests/ttestdependent/default2.aspx).

4 INVESTIGATION

4.1 Primary Data – Speed Survey

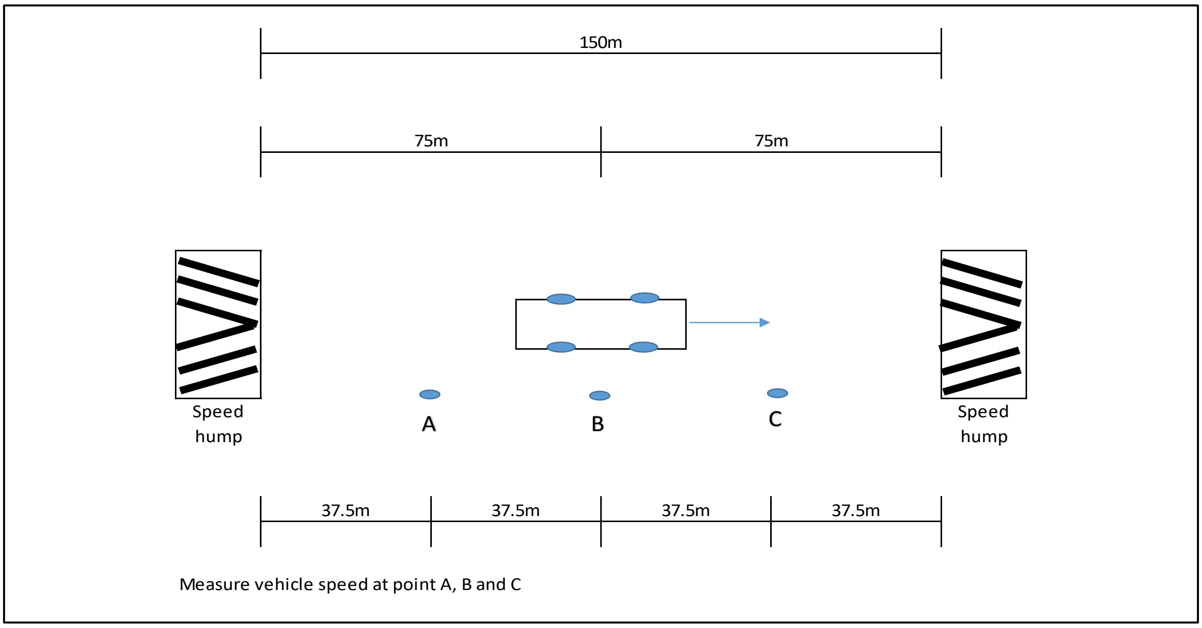
There is literature that affirms correlation and a positive relationship between impact speed and the likelihood of pedestrian fatality. Studies show that if a vehicle crashes into a pedestrian at a lower speed, there is a very low likelihood for associated injury and risk of fatality. At a speed of about 20km/h, there is about 5% probability of fatality from such a crash (Ashton and Mackay, 1979; Rosen and Sanders, 2009; Berthod and Leclerc, 2013). On the other hand, this probability of fatality increases drastically between 40km/h and 60km/h such that if a car travelling at a speed of 60km/h, there is about 90% probability of pedestrian death from this crash. This relationship is shown on Figure 25. Using this theory, if speed humps as a traffic calming measure are effective in reducing vehicular speeds (regardless of their effectiveness in reduction the number of accidents), it can be deduced that any crash occurring where speed humps are installed will occur at a lower speed. In the same breath, if these crashes occur at low speeds, it can then be deduced that speed humps are effective in reducing the severity of crash-related injuries and probability of death of pedestrians during such crashes.

To test the effectiveness of speed humps in reducing travel speeds, a speed survey was undertaken on Tracy Watts Road, one of the roads studied in this research. The road has 4 existing humps as shown on Figure 26. Sight distance on Tracy Watts is adequate on both the Easterly and Westerly direction. The surface of the road was also in a good condition. The road has sidewalks on either side. Three points between two speed humps were selected. One point (**A**) was a 37.5 meters after a vehicle drives off a speed hump. This position was used as an initial position. The second point (**B**) where speed was measured was at 75 meters, halfway between speed humps, where a car presumed to be the furthest away from traffic calming devices. The third point (C) where vehicular speed was measured 37.5 meters away from the second speed humps as shown on Figure 27.

From the speeds measurements, the 85th percentile at each of the points over three days. According to available literature discussed on the impact of speed (Pannaluri and Groce, 2005; Antić et al., 2013) in Section 2.5.2 of this study, the two points that are closer to traffic calming devices would have lower 85th percentile speeds while the point furthest away from speed humps would have the highest 85th percentile speeds.

Figure 26 : Location of Tracy Watts road

To assess the effectiveness of speed humps in reducing speed, a speed survey was undertaken on Tracy Watts Road in Pinetown, Durban. This road is a Class 5 residential road with a speed limit of 40 km/h. This survey was done for a 3-day duration (27-29 August 2019). The road was chosen due to its

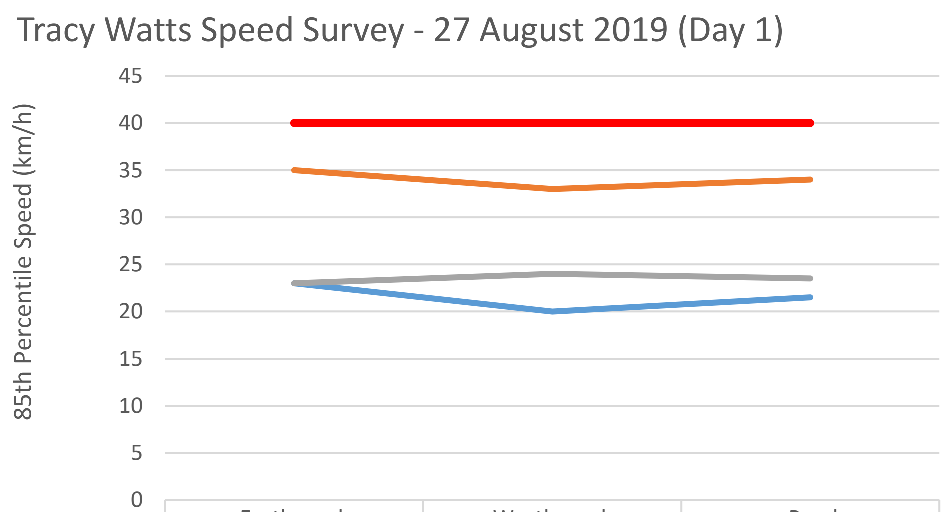


ideal geometrics and use. It is a 5m-wide road, with one lane in each direction. It has speed humps through its entire length with a wide verge on each side. The road is surfaced with bitumen and is relatively flat. The volumes and speeds on the road were measured on both East and Westbound direction. Full survey results are attached on Appendix A.

Figure 27 : On-site speed survey

Impact of Speed Humps on Speed

Day 1



	Eastbound Traffic	Westbound Traffic	Road Average
Point A (37m - From hump 1)	23	20	21.5
Point B (75m-Midpoint)	35	33	34
Point C (112.5m -Towards Hump2)	23	24	23.5
speed limit (40km/h)	40	40	40

Figure 28 : 85th Percentile speeds on Tracy Watts Road for Day 1

From the survey, the 85th percentile was determined on the Eastbound and Westbound traffic respectively. A total average was then determined for the total two-way traffic. According to results of the first day on 27 August 2019, there was a consistent difference between Point B (Midway between the two speed humps) and the two other Points A and C, the points closest to the two speed humps. During Day 1 of the survey, the 85th percentile speed at Point B was an average of 34km/h, higher than the average for both point A and B, which was an average of 21.5km/h and 23.5km/h respectively. This consistent difference was for both Eastbound and Westbound traffic.

From Day 1 results, it can be seen that vehicles slow down when approaching a speed hump. Immediately after driving off, vehicles then start to accelerate and start to slow down again as they approach the subsequent speed hump.

Day 2

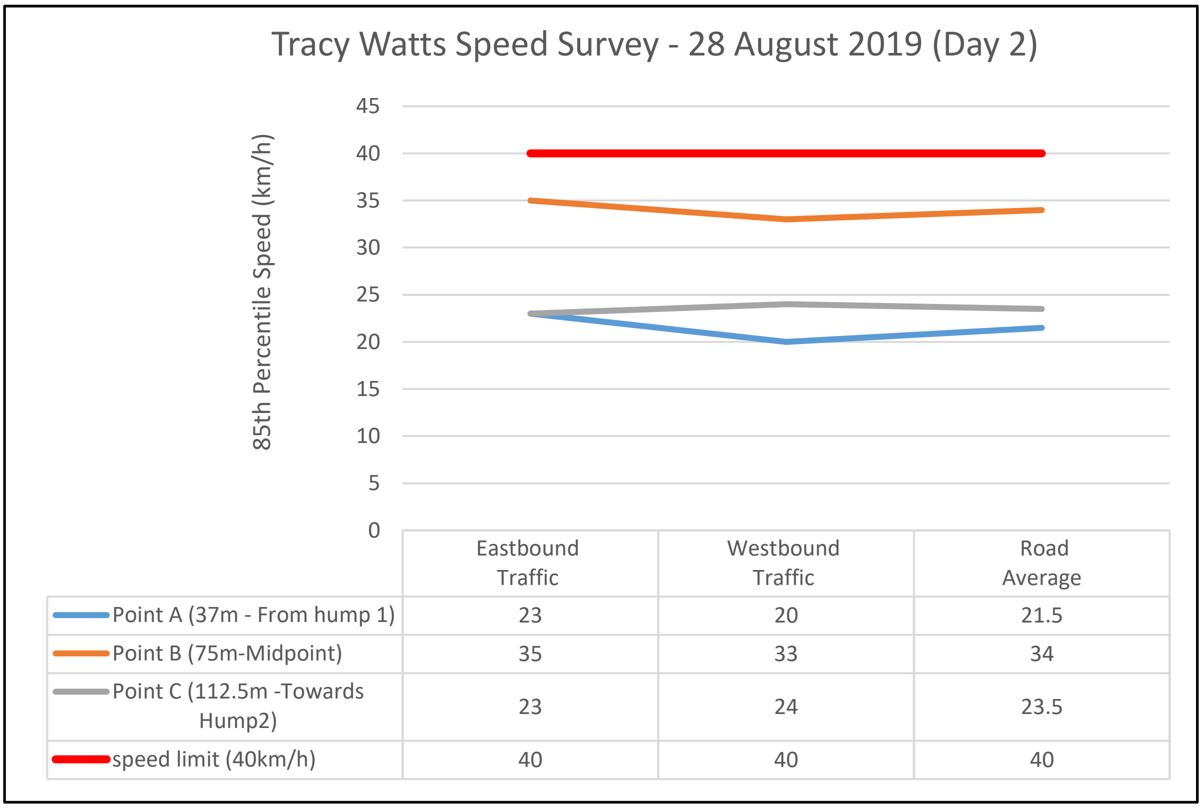
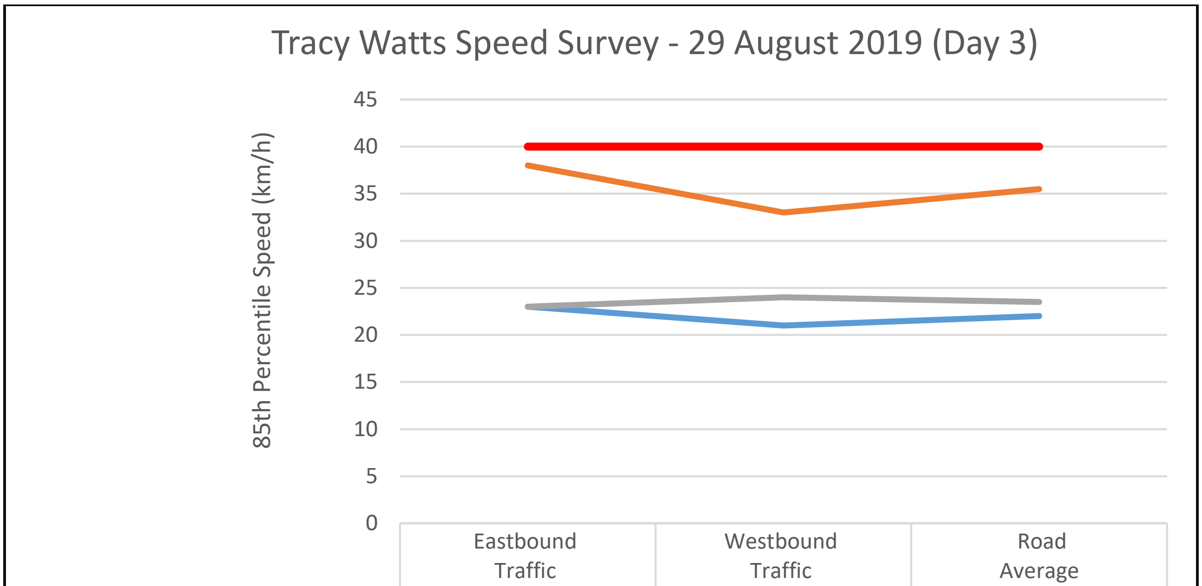


Figure 29 : 85th Percentile speeds on Tracy Watts Road for Day 2

According to results of the second day on 28 August 2019, there was a consistent difference between point B (Midway between the two speed humps) and the two other Points A and C, the points closest to the two speed humps. During day 2 of the survey, the 85th percentile speed at Point B was an average of 34km/h, higher than the average for both point A and B, which was an average of 21.5km/h and 23.5km/h respectively. This consistent difference was for both Eastbound and Westbound traffic.

From Day 2 results, it can be seen that vehicles slow down when approaching a speed hump. Immediately after driving off, vehicles then start to accelerate and start to slow down again as they approach the subsequent speed hump.

Day 3



	Eastbound Traffic	Westbound Traffic	Road Average
Point A (37m - From hump 1)	23	21	22
Point B (75m-Midpoint)	38	33	35.5
Point C (112.5m -Towards Hump2)	23	24	23.5
speed limit (40km/h)	40	40	40

Figure 30 : 85th Percentile speeds on Tracy Watts Road for Day 3

On Day 3 of the survey, the 85th percentile speed at Point B was an average of 35.5km/h, higher than the average for both point A and B, which was an average of 22km/h and 23.5km/h respectively. This consistent difference was for both Eastbound and Westbound traffic. From Day 3 results, it can be seen again that vehicles slow down when approaching a speed hump. Immediately after driving off, vehicles then start to accelerate and start to slow down again as they approach the subsequent speed hump.

Summary of Speed Survey results

From Day 1 to day 3, there is a consistent trend of 85th percentile speeds at Point A, Point B and Point C. Point A, the point closest to speed hump 1, has travel speeds that are almost equal to Point C, the point closest to speed hump 2. However, Point B, the point furthest away from both speed hump 1 and speed hump 2, has higher 85th percentile speeds. This difference in speed was consistent for all 3 days of the survey. Vehicles can be seen starting from low speeds at Point A, then proceed to higher speeds as they move away from speed hump 1, and they slow down upon approach of the second speed hump.

4.2 Secondary Data – Accident Statistics

4.2.1 Change in Total Accidents – EANs

The number of accidents before and after implementation of speed humps was presented using Equivalent Accident Number (EAN) which weighs accidents according to their severity, with fatal accidents scoring the highest.

Table 8 : Comparison of accidents before and after implementation of speed humps

Road Name	EANs Before	EANs After	Change	Road Name	EANs Before	EANs After	Change
P Tshabalala	106	91	-15	Tracy Watts Rd	69	78	9
Hurst Grove	66	53	-13	Pridley Road	59	46	-13
Sol Mahlangu Road	267	229	-38	Wingate Road	28	19	-9
Berkshire Drive	61	38	-23	Kilburn Avenue	10	3	-7
Silvertree Road	75	38	-37	8th Avenue	27	19	-8
Galloway Road	35	35	0	Donegal Road	25	15	-10
Sofasonke Road	72	37	-35	Fairlight Road	85	81	-4
Sol Harris Crescent	115	89	-26	High Street	31	31	0
Amical Cabral Road	42	36	-6	Sizwe Mdlalose	3	1	-2
Phambili Road	167	124	-43	Dumakude Road	3	7	4

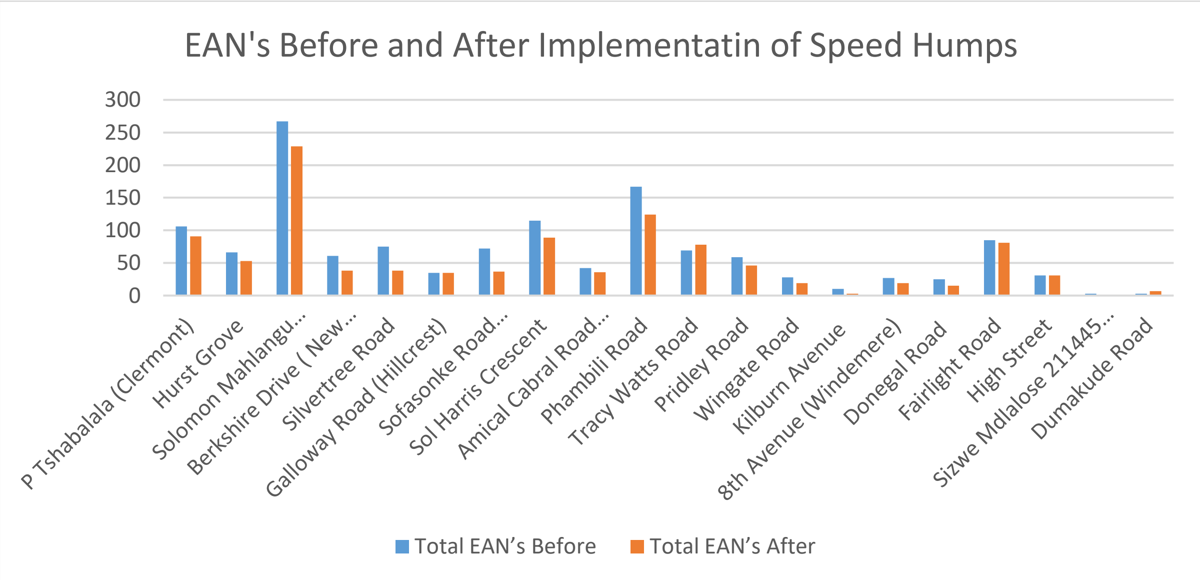


Figure 31 : Graphical representation of accidents before and after implementation of speed humps

There was a total of 1346 EAN's in the three years before implementation of speed humps. The total number of accidents was reduced to 1070 in the three years after the implementation of speed humps on roads selected for study in Durban. This translates to 20.51 % reduction in road accidents. Over and above this decline in total number of accidents, it can also be noted that 18 of the 20 (90%) roads under study had a decline in accidents. This affirms literature that speed humps reduce accidents. Only two roads were outliers, showing an increase in total accident numbers. The degree of change was different with each road. The highest EAN change was on Phambili Road, which had 167 EAN's before implementation of speed humps and 124 EAN's after implementation.

4.2.2 Change in Pedestrian Accidents – Total Pedestrians

Another important objective of this research was to establish the effectiveness of speed humps in promoting pedestrian safety in the City of EThekwini in line with the municipality's strategic vision of *making Durban the most liveable City in Africa by 2030* (EThekwini Municipality, 2015).

Table 9 : Comparison of pedestrian accidents before and after implementation of speed humps

Road Name	**Peds Before**	**Peds After**	**Change**	**Road Name**	**Peds Before**	**Peds After**	**Change**
P Tshabalala	10	6	-4	Tracy Watts Rd	0	0	0
Hurst Grove	0	1	1	Pridley Road	2	0	-2
Sol Mahlangu Road	14	9	-5	Wingate Road	1	1	0
Berkshire Drive	4	2	-2	Kilburn Avenue	0	0	0
Silvertree Road	9	1	-8	8th Avenue	0	2	2
Galloway Road	0	0	0	Donegal Road	0	0	0
Sofasonke Road	0	2	2	Fairlight Road	0	0	0
Sol Harris Crescent	2	1	-1	High Street	0	0	0
Amical Cabral Road	1	1	0	Sizwe Mdlalose	0	1	1
Phambili Road	16	4	-12	Dumakude Road	0	0	0
					Total pedestrians involved before implementation		**59**
					Total pedestrians involved after implementation		**31**

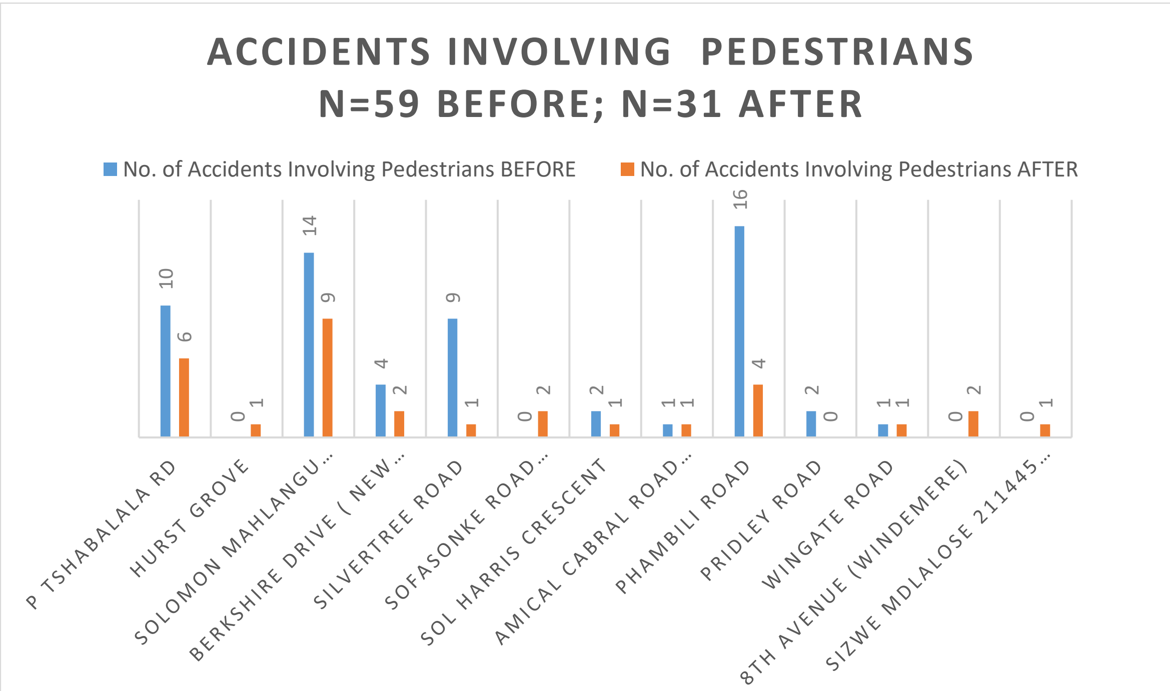


Figure 32 : Change in pedestrian accidents – Total pedestrians

In the three years prior to implementation of traffic calming, there were 59 pedestrians involved in road crashes on roads under study. After implementation of speed humps, the number of pedestrians involved was reduced from 59 to 31, a 47.46% reduction. The highest change occurred on Phambili Road where there were 16 pedestrians that were victims of road crashes before speed humps were implemented. The number of pedestrians involved was reduced to 4 after implementation of speed humps. Another significant decrease was on Solomon Mahlangu road, where there were 14 pedestrian accidents before implementation of speed humps, down to 9 pedestrians after speed humps were installed. Only 4 out of 20 roads (Hurst Grove, Sofasonke Road, 8th Avenue and Sizwe Mdlalose Road) increased in the number of pedestrian incidents after speed humps were installed. Roads that had 0 incidents before and after implementation of speed humps were not shown on Figure 32.

4.2.3 Change in Pedestrian Accidents – Pedestrians 18 years and below

People with limited cognitive abilities such as school kids are vulnerable road users. EThekwini has a lot of accidents amongst this group (Mhlanga, 2018). From the total number of pedestrian accidents, it was important to further dissect them further to establish the impact of speed humps amongst school-going population.

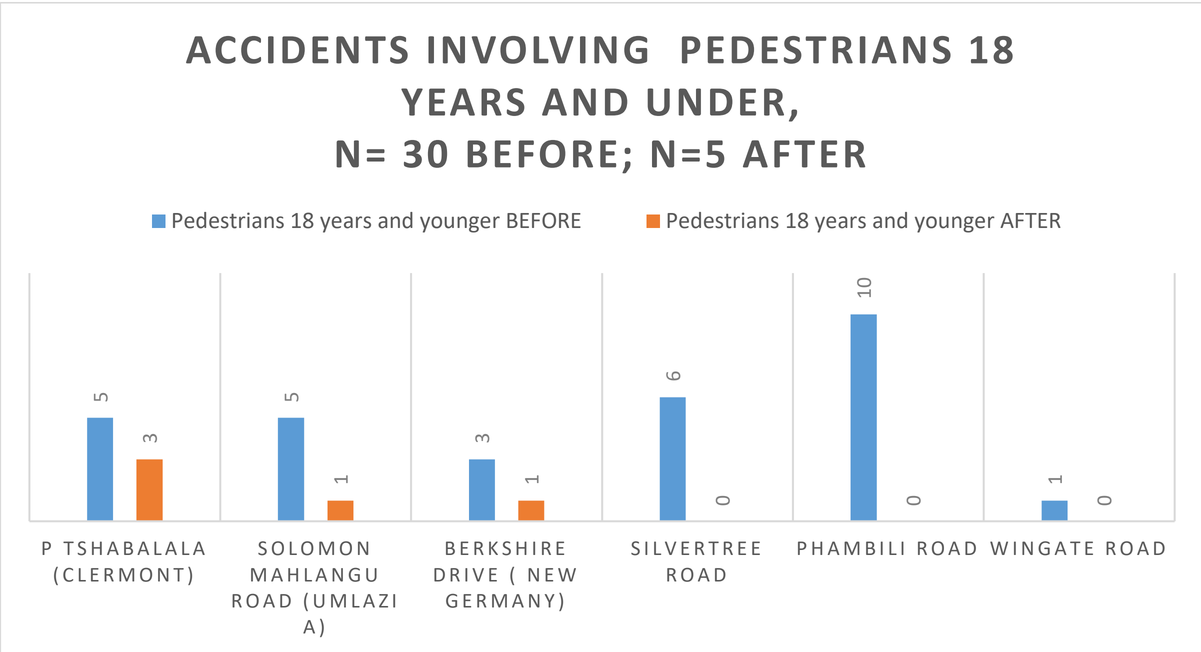


Figure 33 : Accidents involving pedestrians aged 18 years and below

In the three years before the implementation of speed humps, there were 30 accidents involving pedestrians 18 years or younger. After implementation of speed humps, the total number of accidents amongst pedestrians 18 years old or younger was reduced from 30 to 5, an 83% decline in accidents.

The biggest change between the number of accidents before and after implementation of speed humps, was observed on Phambili Road. There were 10 pedestrian victims before speed humps were installed and 0 number of pedestrian victims after speed humps were installed. Another notable change was on Silvertree Road. There were 6 pedestrian victims before speed humps were installed and 0 number of pedestrian victims after speed humps were installed. Roads that had 0 incidents before and after implementation of speed humps were not shown on Figure 33.

4.2.4 Change in Pedestrian Accidents – Pedestrians Walking on Roadway

The study further categorised pedestrian accidents by location and activity, particularly for pedestrians that were victims of crashes while they were walking on the roadway. It was important to understand if there was a change on the number of pedestrians that were knocked by vehicles after speed humps were implemented, and if this was the case, it was equally important to understand the extent, as well as the margin of statistical significance (if any). This information would be important as EThekwini's strategic goal is to be "*Africa's most liveable City by 2030*" (EThekwini IDP, 2015). To be a liveable city, pedestrians need to have a strong sense of safety when using roads, particularly residential roads.

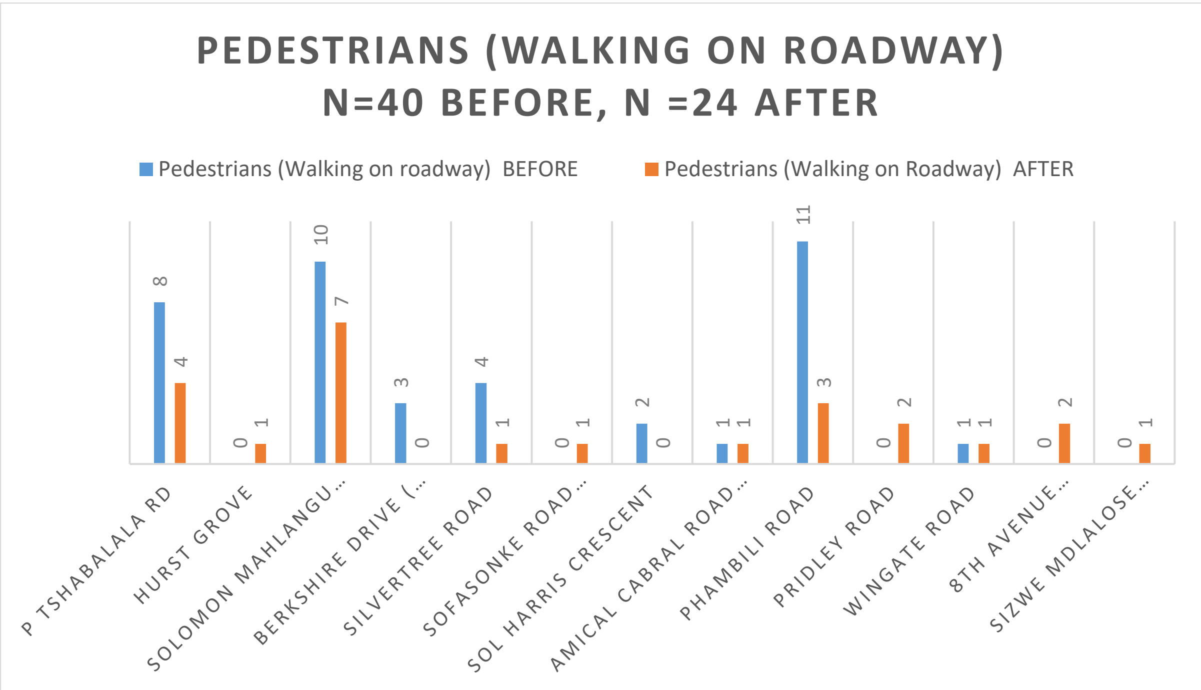


Figure 34 : Accidents by pedestrian location/activity

Before speed humps were implemented, there were 40 accidents of pedestrians walking on the roadway, a 40% reduction. The highest change was observed on Phambili Road, where the number of accidents was reduced from 11 before implementation of speed humps to 3, after speed humps were installed. P Tshabalala Road also had a significant change. The number of incidents was reduced from 8 to 4, a reduction by half. Only 5 roads had an increase in the number of accidents. Roads that had 0 incidents before and after implementation of speed humps were not shown on Figure 34.

4.2.5 Change in Accidents – Public Transport vehicles

In 2017, there was a total of 12 128 088 vehicles on South Africa's roads (eNATIS, 2017), and 65.09% of these were motor cars with only 3.44% of these being buses and taxis. The city of EThekwini municipality follows other South African cities in improving the use of Public Transport. The city's Integrated Public Transport Network (IPTN) project aims at ultimately provide up to 85% of all residents in Durban access to safe, affordable and good quality, scheduled public transport (Go Durban, 2013). It is against this backdrop that this research considered disaggregating accident data to further investigate the impact of speed humps in reducing public transport accidents.

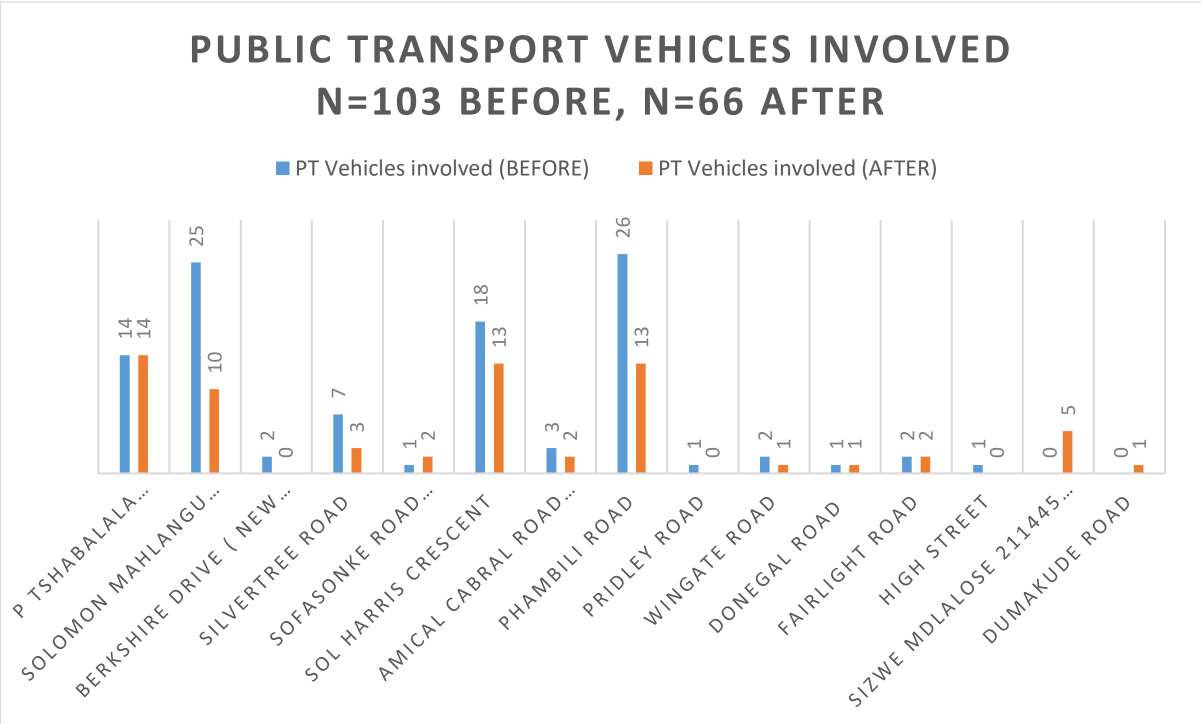


Figure 35 : Change in accidents – public transport vehicles

There was a total of 103 public transport vehicles (taxis and buses) involved in crashes before implementation of speed humps. After implementation of speed humps, the number of public transport vehicles involved was reduced to 66 vehicles. This translates to a 35.92% reduction in the number of public transport vehicles involved. The biggest change was observed on Solomon Mahlangu road. There were 25 crashes involving taxis and busses before speed humps were installed, and this number was reduced to 10 after speed humps were installed. There was no change in the number of vehicles involved on P Tshabalala road. The number remained at 14 before and after implementation of speed humps.

4.3 Analysis of findings

The findings from each of the investigations had to be checked if they are statistically significant or were simply not enough as conclusive results. T-tests were used to check if each the results obtained were statistically significant or not. The first T-test was done on total EANs before implementation of speed humps and after implementation of speed humps. The second T-test was conducted for change in pedestrian accidents and a third was for pedestrian location. The third T-test conducted was for pedestrians younger than 18-years and the fourth was for pedestrians walking on the roadway. The last T-test was done for minibus taxis and bus users. A Summary of T-tests is shown on Table 10 and results of each T-test are shown on Appendix C. The study used Microsoft Excel 2013 for T-Test calculations.

Table 10 : Summary of T-test results

Type of data	P-value	T-critical	Significant
Total EANs	0.006	-4.11	**YES**
Pedestrian incidents	0.8392	-1.82	**NO**
Pedestrians 18 years and below	0.2917	-30.3	**YES**
Pedestrians walking on roadway	0.15446	-1.52	**NO**
Public Transport users	0.09747	-1.74	**NO**

Although each of the five before-and-after studies showed reductions, it was important to understand beyond absolute numbers. The research used a T-test to then assess if each of these changes was statistically significant or not. From the T-test, the only significant changes are on the total EANs and pedestrians 18 years and younger. No significant statistical differences were obtained for ‘pedestrian incidents’, for ‘pedestrians walking on roadway’ and for ‘public transport users’. From a road safety point of view, it is important to note that the total aggregated accident comparison (total EANs) yields significant T-test results.

5 CONCLUSION AND RECOMMENDATIONS

What is the impact of speed humps on the total number on speeds and accidents?

Literature shows that speed humps are an effective traffic calming measure used to reduce speeds. This research has shown this to be true through results of a speed survey. The results of the survey proved that speed humps are effective in slowing down vehicular speeds. In the study, 85th percentile speeds were kept all below the design speeds of 40km/h. The study shows that even when operating speeds increase immediately after driving off a speed hump, the spacing between the two humps does not allow for extremely high speeds and vehicles slow down when approaching speed humps, thus keeping operating speeds at a level that allows for residential roads to preserve their primary functional classification of providing accessibility.

The effectiveness of speed humps in reducing accidents severity and probability of fatality during accidents is done in two ways, first by the speed survey and then secondly by comparing accident counts before and after implementation of speed humps. In the first instance, the reduction of operating speeds that was proven in the study also proves another point in the effectiveness of speed humps. By proxy, this study can therefore conclude that speed humps do reduce the severity of accidents as crashes occur under low travel speeds. Secondly, the number of EAN's was reduced by 20% after implementation of speed humps. Using these results, along with T-test results, it can be concluded that speed humps are effective in reducing accidents. However, since the study does not consider factors that could impact driver behaviour, it presents a limitation on the conclusiveness of the research as some drivers could have been impaired or in a state of mind that affected their driving abilities and reaction time.

What is the impact of speed humps on pedestrian safety? Is there a change in the number of pedestrians involved in accidents?

From the results, it is observed that speed humps reduce the number of accidents of pedestrians walking on the roadway. This affirms that speed humps help in promoting walking. This means pedestrians can walk relatively easier and are safer than walking on the roadway without speed humps. This is particularly important in roads where the road reserve is narrow and both pedestrians and vehicles use the same road space. This is also important in cases where there could be sidewalks in place but not usable due to poor maintenance or some materials obstructing the pedestrian sidewalk. With the reduction of speeds even in cases where road crashes involve pedestrians, this happens at lower speeds and the probability of fatality is reduced. However, it is important to note that T-test results show an insignificant change in pedestrians affected before and after implementation of speed humps. The reduction however, is important for road safety and the economy in general as road fatalities are costing South Africa billions annually. A sense of safety to pedestrians translates into more trips (Dumbaugh & Rae, 2009), this making neighbourhoods liveable. The study did not take cognitive abilities of pedestrians and vehicles into account. This is important to note as cognitive abilities do have an impact on how pedestrians and drivers make judgments, including on accidents. The absence of this information could affect the conclusiveness of this study on the effectiveness of speed humps in reducing accidents.

Do speed hump lower accident amongst young pedestrians?

The study was seeking to establish if speed humps were also effective in lowering the number of accidents that involve young pedestrians who are aged 18 and below. This finding was very important as Household Travel Survey revealed a lot of kids walk long distances to school, particularly in townships (StatsSA, 2013). In the study, the number went from 30 to 5. This clearly shows that speed humps do assist in lowering the number of accidents amongst young pedestrians. The margin of change was, proven to be significant according to the T-test, which makes this finding very important in this research.

What role do speed humps play in communities where there is inadequate NMT facilities such as sidewalks?

To answer the question about the role of speed humps in communities where there are no sidewalks, or, in some instance, no verge at all, the research used accidents that involved pedestrians walking on the roadway. From the results, there was a reduction in the number of pedestrians. This information is particularly important in neighbourhoods where, for some reason, pedestrians are forced to walk on the roadway. T-test showed an insignificant change in the before-and-after study, which is critical in deciding on the importance of the reduction. Notwithstanding results of the T-test, it is important to note the reduction of accidents unloving pedestrians walking on the roadway.

Do speed humps have an impact in reducing public transport (minibus taxis and buses) accidents?

There were 103 public transport vehicles (busses and minibus taxis) involved in crashes before speed humps were installed and this dropped to 66 vehicles after speed humps were implemented, a reduction by 35.92%. A T-test carried out on public transport study indicated no significant change. Using results of this T-test, we can conclude that, speed humps, in this case, do not effect a significant change in reducing public transport crashes on the road. Although the reduction is statistically important, it is important to understand the change. Although the study looked at accidents involving minibus taxis and busses, it did not look at the state of roadworthiness of these vehicles. This is very important to note as some accidents could have occurred because of mechanical failures attributed to vehicles that are not roadworthy. This presents a limitation on the conclusiveness of the study.

Recommendations

There are questions of interest within traffic calming and speed humps that this research fell short of investigating. This research will make recommendations on what future researchers could expand on for more knowledge to be acquired and more refined conclusions to me made. The researcher also noted systemic deficiencies in both policy and implementation and further made recommendations on actions policy makers and implementing agencies could take in improving the effectiveness of traffic calming.

Literature suggest evidence of a relationship between network configuration and travel behaviour. This relationship clearly shows how pedestrian and vehicle travel behaviour is influenced by network configuration and land use patterns in an area (Behrens, 2002b). However, this research did not look into broader network configuration and land uses but only looked specifically on individual roads where traffic calming was implemented. The study area only included the 20 roads under study. This means any potential impact of network configuration and land uses was ignored. Future research could look into network configuration and land uses in the area of influence to the study area, not limited to roads under study. This data is important as it affects travel behaviour, which is equally important in accident studies. This information along with land use information before, during and after the study period, could be used to study how travel patterns of pedestrians and vehicles are affected and then help improve the quality of results.

In future, researchers could also look at vehicle ownership statistics in the study area. This will assist and studying a possible relationship(s) between vehicle ownership in the area and its impacts on accidents. In doing so, authorities can make informed policy decisions when it comes to implementation of traffic calming. An example could be to put priority in areas where there are high pedestrian volumes or where there are is high vehicle ownership. The quality of road infrastructure could also be looked at as it affects how pedestrian and vehicles use the road. In cases where there are no sidewalks, or where sidewalks are in a poor state, pedestrians are forced to walk on the roadway, thus increasing potential risk for accidents on the road. On roads where there are potholes or some other distractive objects on the roadway, driver reaction could be affected and this could have an impact on road safety as well as accidents on the road.

During observation of vehicular speeds on the road, this research did not take into account any possible incidences that could lead to traffic abnormalities on the road under observation. This includes additional trips that could either divert from adjacent roads to the roads under study. Other researchers could extend their study area to include this information and take such trips into account. This will help identify anomalies and extend on further conclusions. The potential impact of cognitive abilities of vehicle drivers that might affect driver behaviour and reaction towards traffic calming was not adequately covered in this research. The research only looked at one category which is change in accidents on people aged 18 aged and below before and after implementation of speed humps. There was no information available for other factors affecting cognitive behaviour such as suspected tiredness, the elderly and alcohol usage on people involved in accidents. This information could be recorded in future. It will assist in improving the quality of the research and could even be expanded to answer other road safety-related question for future research.

From a local network design point of view, South Africa is still largely living the legacy of apartheid spatial planning that resulted in longer trips for people in townships. Longer trips to commute to work are also a factor in driver behaviour and higher speeds. In this case, speed humps are effective in curbing speeds around residential areas. However, South Africa still has an opportunity for improved designs in new Greenfields. This includes improving network design practices that will require a realignment of priorities in which networks need to be designed first to meet the travel needs of pedestrians, bicycles and public transport, and then to accommodate motor cars as Behrens (2005) argues. EThekwini municipality only has information about implementation year of speed humps. Actual date (day and month) of installation of speed humps was not available. This limitation could have implications on the effectiveness of speed humps on some of the roads. It would be very helpful for authorities to keep record of actual dates of installation of speed humps. Other researchers could use this information to test other road safety variables.

Speed humps remain very popular as traffic calming measures in EThekwini and other cities in South Africa. This type of traffic calming might not be as expensive as speed tables or roundabouts but it is still costly compared to most passive mitigating measures such as educational campaigns. The practice of using obstructions and active mitigating measures as a first point of addressing road safety is not a panacea to the problem of speeding. It also does not necessarily change how vehicle drivers perceive roads. The municipality of EThekwini has an opportunity to allocate funds to educational campaigns to raise awareness amongst roads users. This is not mutually exclusive to implementation of speed humps and could be done while speed humps are being implemented.

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APPENDIX A – SPEED SURVEY RESULTS

Location: Tracy Watts Road west of Steere Road - Point A
Speed Limit: 40 km/h
Date: 27 August 2019 to 29 August 2019

Actual Data

Direction:		Eastbound				Westbound				Road
Speed Class (km/h)										
From	To	27-Aug	28-Aug	29-Aug	Total	27-Aug	28-Aug	29-Aug	Total	Total
0	10	47	50	38	135	13	4	3	20	**155**
11	20	1367	1436	1395	4198	522	422	404	1348	**5546**
21	30	2026	1923	2018	5967	1474	1494	1558	4526	**10493**
31	40	84	77	92	253	93	90	101	284	**537**
41	50	1	0	2	3	2	2	1	5	**8**
51	60	0	0	0	0	0	0	0	0	**0**
61	70	0	0	0	0	0	0	0	0	**0**
71	80	0	0	0	0	0	0	0	0	**0**
81	90	0	0	0	0	1	0	0	1	**1**
91	100	0	0	0	0	0	0	0	0	**0**
101	110	0	0	0	0	0	0	0	0	**0**
111	120	0	0	0	0	0	0	0	0	**0**
121	130	0	0	0	0	0	0	0	0	**0**
131	140	0	0	0	0	0	0	0	0	**0**
141	150	0	0	0	0	0	0	0	0	**0**
150	over	0	0	0	0	0	0	0	0	**0**
Total		**3525**	**3486**	**3545**	**10556**	**2105**	**2012**	**2067**	**6184**	**16740**

Direction:		Eastbound				Westbound				Road	
Speed Class (km/h)		27-Aug	28-Aug	29-Aug	Total	27-Aug	28-Aug	29-Aug	Total	Total	
85 Percentile Speed		23	23	23	23	24	24	24	24	24	Read from chart
% Below	40km/h	100.0%	100.0%	99.9%	100.0%	99.9%	99.9%	100.0%	99.9%	99.9%	

Accumulative Percentage

Direction:		Eastbound				Westbound				Road
Speed Class (km/h)										
From	To	27-Aug	28-Aug	29-Aug	Total	27-Aug	28-Aug	29-Aug	Total	Total
0	10	1.3%	1.4%	1.1%	1.3%	0.6%	0.2%	0.1%	0.3%	0.9%
11	20	40.1%	42.6%	40.4%	41.0%	25.4%	21.2%	19.7%	22.1%	34.1%
21	30	97.6%	97.8%	97.3%	97.6%	95.4%	95.4%	95.1%	95.3%	96.7%
31	40	100.0%	100.0%	99.9%	100.0%	99.9%	99.9%	100.0%	99.9%	99.9%
41	50	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
51	60	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
61	70	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
71	80	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
81	90	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
91	100	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
101	110	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
111	120	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
121	130	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
131	140	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
141	150	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	150+	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

50%	85%	
50%	85%	5
50%	85%	15
50%	85%	25
50%	85%	35
50%	85%	45
50%	85%	55
50%	85%	65
50%	85%	75
50%	85%	85
50%	85%	95
50%	85%	105
50%	85%	115
50%	85%	125
50%	85%	135
50%	85%	145
50%	85%	150+

Speed Limit: 40 km/h
Date: 27 August 2019 to 29 August 2019

Actual Data

Direction:		Eastbound				Westbound				Road
Speed Class (km/h)		27-Aug	28-Aug	29-Aug	Total	27-Aug	28-Aug	29-Aug	Total	Total
From	To									
0	10	1	0	0	1	1	2	0	3	**4**
11	20	64	44	26	134	86	65	48	199	**333**
21	30	777	730	638	2145	1029	927	848	2804	**4949**
31	40	2222	2257	2332	6811	894	921	1067	2882	**9693**
41	50	539	524	646	1709	65	64	55	184	**1893**
51	60	20	23	34	77	1	1	5	7	**84**
61	70	2	0	0	2	0	0	0	0	**2**
71	80	0	0	0	0	0	0	0	0	**0**
81	90	0	0	0	0	0	0	0	0	**0**
91	100	0	0	0	0	0	0	0	0	**0**
101	110	0	0	0	0	0	0	0	0	**0**
111	120	0	0	0	0	0	0	0	0	**0**
121	130	0	0	0	0	0	0	0	0	**0**
131	140	0	0	0	0	0	0	0	0	**0**
141	150	0	0	0	0	0	0	0	0	**0**
150	over	0	0	0	0	0	0	0	0	**0**
Total		**3625**	**3578**	**3676**	**10879**	**2076**	**1980**	**2023**	**6079**	**16958**

Direction:		Eastbound				Westbound				Road	
Speed Class (km/h)		27-Aug	28-Aug	29-Aug	Total	27-Aug	28-Aug	29-Aug	Total	Total	
85 Percentile Speed		35	35	38	36	33	33	33	33	34	Read from chart
% Below	40km/h	84.5%	84.7%	81.5%	83.6%	96.8%	96.7%	97.0%	96.9%	88.3%	

Accumulative Percentage

Direction:		Eastbound				Westbound				Road
Speed Class (km/h)		27-Aug	28-Aug	29-Aug	Total	27-Aug	28-Aug	29-Aug	Total	Total
From	To									
0	10	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
11	20	1.8%	1.2%	0.7%	1.2%	4.2%	3.4%	2.4%	3.3%	2.0%
21	30	23.2%	21.6%	18.1%	21.0%	53.8%	50.2%	44.3%	49.4%	31.2%
31	40	84.5%	84.7%	81.5%	83.6%	96.8%	96.7%	97.0%	96.9%	88.3%
41	50	99.4%	99.4%	99.1%	99.3%	100.0%	99.9%	99.8%	99.9%	99.5%
51	60	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
61	70	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
71	80	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
81	90	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
91	100	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
101	110	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
111	120	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
121	130	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
131	140	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
141	150	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	150+	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

50%	85%	
50%	85%	5
50%	85%	15
50%	85%	25
50%	85%	35
50%	85%	45
50%	85%	55
50%	85%	65
50%	85%	75
50%	85%	85
50%	85%	95
50%	85%	105
50%	85%	115
50%	85%	125
50%	85%	135
50%	85%	145
50%	85%	150+

Location: Point C
Speed Limit: 40 km/h
Date: 27 August 2019 to 29 August 2019

Actual Data

Direction:		Eastbound				Westbound				Road Total
Speed Class (km/h)		27-Aug	28-Aug	29-Aug	Total	27-Aug	28-Aug	29-Aug	Total	
From	To									
0	10	38	25	23	86	25	19	21	65	**151**
11	20	1655	1601	1578	4834	1392	1329	1285	4006	**8840**
21	30	1929	1978	2023	5930	653	633	737	2023	**7953**
31	40	63	54	79	196	5	3	2	10	**206**
41	50	1	0	2	3	0	0	0	0	**3**
51	60	0	0	1	1	0	0	0	0	**1**
61	70	0	0	0	0	0	0	0	0	**0**
71	80	0	0	0	0	0	0	0	0	**0**
81	90	0	0	0	0	0	0	0	0	**0**
91	100	0	0	0	0	0	0	0	0	**0**
101	110	0	0	0	0	0	0	0	0	**0**
111	120	0	0	0	0	0	0	0	0	**0**
121	130	0	0	0	0	0	0	0	0	**0**
131	140	0	0	0	0	0	0	0	0	**0**
141	150	0	0	0	0	0	0	0	0	**0**
150	over	0	0	0	0	0	0	0	0	**0**
Total		**3686**	**3658**	**3706**	**11050**	**2075**	**1984**	**2045**	**6104**	**17154**

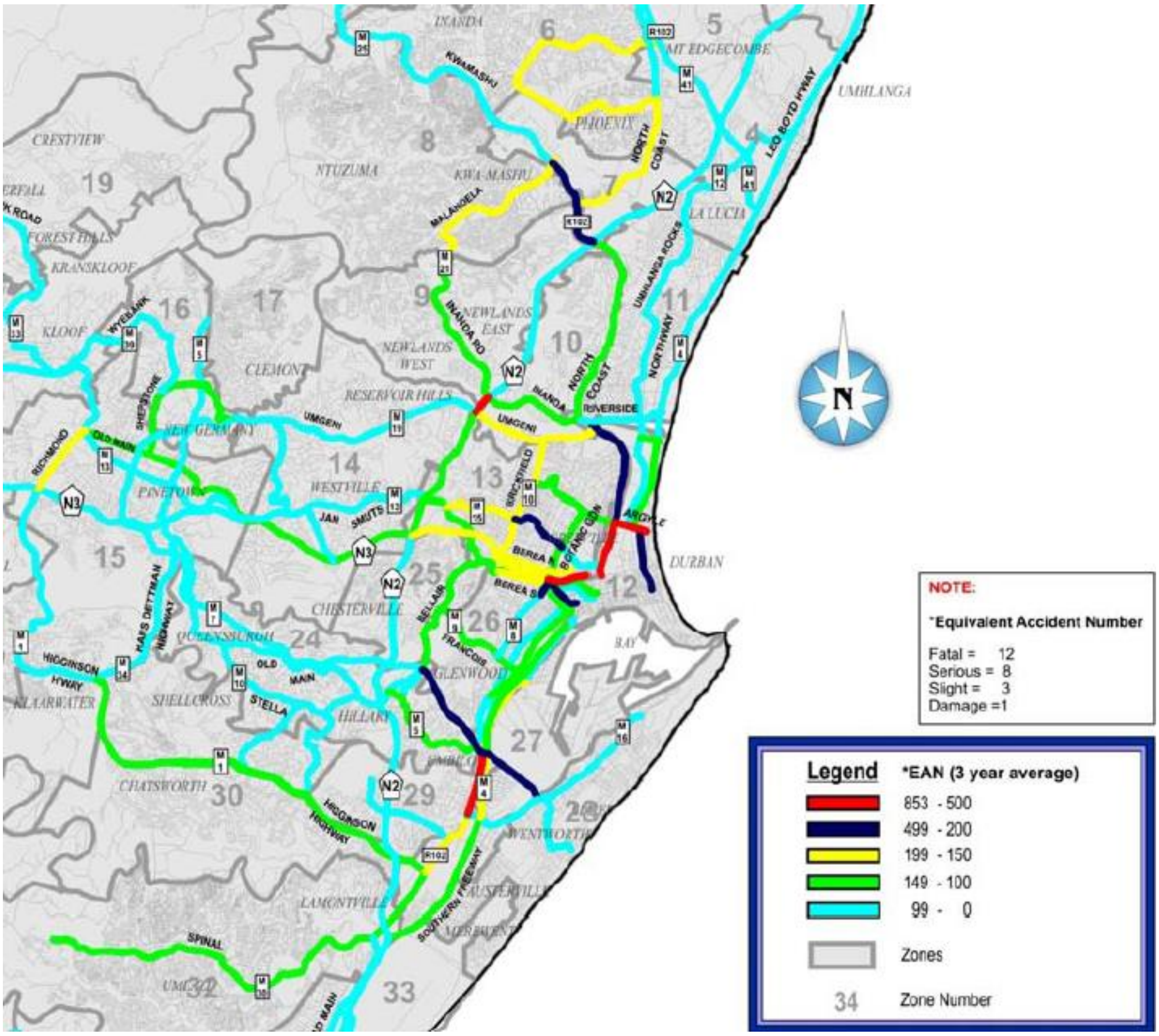
Direction:		Eastbound				Westbound				Road Total	
Speed Class (km/h)		27-Aug	28-Aug	29-Aug	Total	27-Aug	28-Aug	29-Aug	Total		
85 Percentile Speed		23	23	23	23	20	20	21	20	22	Read from chart
% Below	40km/h	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	

Accumulative Percentage

Direction:		Eastbound				Westbound				Road Total			
Speed Class (km/h)		27-Aug	28-Aug	29-Aug	Total	27-Aug	28-Aug	29-Aug	Total		50%	85%	
From	To												
0	10	1.0%	0.7%	0.6%	0.8%	1.2%	1.0%	1.0%	1.1%	0.9%	50%	85%	5
11	20	45.9%	44.5%	43.2%	44.5%	68.3%	67.9%	63.9%	66.7%	52.4%	50%	85%	15
21	30	98.3%	98.5%	97.8%	98.2%	99.8%	99.8%	99.9%	99.8%	98.8%	50%	85%	25
31	40	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	50%	85%	35
41	50	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	50%	85%	45
51	60	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	50%	85%	55
61	70	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	50%	85%	65
71	80	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	50%	85%	75
81	90	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	50%	85%	85
91	100	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	50%	85%	95
101	110	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	50%	85%	105
111	120	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	50%	85%	115
121	130	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	50%	85%	125
131	140	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	50%	85%	135
141	150	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	50%	85%	145
	150+	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	50%	85%	150+

Change in Total Accidents - EANs

APPENDIX B – EAN Map of Durban



APPENDIX C – T-TEST RESULTS

C.1 - Change in Total EANs

Treatment 1	Treatment 2	*Diff* (T2 - T1)	*Dev* (Diff - M)	*Sq. Dev*
106	91	-15	-1.2	1.44
66	53	-13	0.8	0.64
267	229	-38	-24.2	585.64
61	38	-23	-9.2	84.64
75	38	-37	-23.2	538.24
35	35	0	13.8	190.44
72	37	-35	-21.2	449.44
115	89	-26	-12.2	148.84
42	36	-6	7.8	60.84
167	124	-43	-29.2	852.64
69	78	9	22.8	519.84
59	46	-13	0.8	0.64
28	19	-9	4.8	23.04
10	3	-7	6.8	46.24
27	19	-8	5.8	33.64
25	15	-10	3.8	14.44
85	81	-4	9.8	96.04
31	31	0	13.8	190.44
3	1	-2	11.8	139.24
3	7	4	17.8	316.84

Significance Level:

- ○ 0.01
- ◉ 0.05
- ○ 0.10

One-tailed or two-tailed hypothesis?:

- ○ One-tailed
- ◉ Two-tailed

Difference Scores Calculations

Mean: -13.8
$\mu = 0$
$S^2 = SS/df = 4293.2/(20-1) = 225.96$
$S^2_M = S^2/N = 225.96/20 = 11.3$
$S_M = \sqrt{S^2_M} = \sqrt{11.3} = 3.36$

T-value Calculation

$t = (M - \mu)/S_M = (-13.8 - 0)/3.36 = -4.11$

The value of t is -4.105635. The value of p is .0006. The result is significant at $p < .05$.

EANs

C.2 - Change in Pedestrian Accidents – Total Pedestrians

Treatment 1	Treatment 2	*Diff* (T2 - T1)	*Dev* (Diff - M)	*Sq. Dev*
10	6	-5	-1.33	1.78
0	1	-2	3.67	13.44
14	9	-8	-2.33	5.44
4	2	0	0.67	0.44
9	1	2	-5.33	28.44
0	0	-1	2.67	7.11
0	2	0	4.67	21.78
2	1	-12	1.67	2.78
1	1	0	2.67	7.11
16	4	-2	-9.33	87.11
0	0	0	2.67	7.11
2	0	0	0.67	0.44
1	1	2	2.67	7.11
0	0	0	2.67	7.11
0	2	0	4.67	21.78
0	0	0	2.67	7.11
0	0	1	2.67	7.11
0	0	0	2.67	7.11
0	1	-28	3.67	13.44
0	0		2.67	7.11
59	31	M: -2.67	-25.33	641.78

Significance Level:

- ○ 0.01
- ◉ 0.05
- ○ 0.10

One-tailed or two-tailed hypothesis?:

- ○ One-tailed
- ◉ Two-tailed

Difference Scores Calculations

Mean: -2.67

$\mu = 0$

$S^2 = SS/df = 902.67/(21-1) = 45.13$

$S^2_M = S^2/N = 45.13/21 = 2.15$

$S_M = \sqrt{S^2_M} = \sqrt{2.15} = 1.47$

T-value Calculation

$t = (M - \mu)/S_M = (-2.67 - 0)/1.47 = -1.82$

The value of *t* is -1.818987. The value of *p* is .08392. The result is *not* significant at p < .05.

C.3 - Accidents involving Pedestrians 18 Years and under n= 30 before n=5 after

Treatment 1	Treatment 2	*Diff* (T2 - T1)	*Dev* (Diff - M)	*Sq. Dev*
5	3	-2	2.17	4.69
5	1	-4	0.17	0.03
3	1	-2	2.17	4.69
6	0	-6	-1.83	3.36
10	0	-10	-5.83	34.03
1	0	-1	3.17	10.03
		M: -4.17		S: 56.83

Significance Level:

- 0.01
- (●) 0.05
- 0.10

One-tailed or two-tailed hypothesis?:

- One-tailed
- (●) Two-tailed

Difference Scores Calculations

Mean: -4.17

$\mu = 0$

$S^2 = SS/df = 56.83/(6-1) = 11.37$

$S^2_M = S^2/N = 11.37/6 = 1.89$

$S_M = \sqrt{S^2_M} = \sqrt{1.89} = 1.38$

T-value Calculation

$t = (M - \mu)/S_M = (-4.17 - 0)/1.38 = -3.03$

The value of *t* is -3.027247. The value of *p* is .02917. The result is significant at p < .05.

C.4 - Change in Pedestrian Accidents – Pedestrians Walking on Roadway

Treatment 1	Treatment 2	*Diff* (T2 - T1)	*Dev* (Diff - M)	*Sq. Dev*
8	4	-4	-2.77	7.67
0	1	1	2.23	4.98
10	7	-3	-1.77	3.13
3	0	-3	-1.77	3.13
4	1	-3	-1.77	3.13
0	1	1	2.23	4.98
2	0	-2	-0.77	0.59
1	1	0	1.23	1.51
11	3	-8	-6.77	45.82
0	2	2	3.23	10.44
1	1	0	1.23	1.51
0	2	2	3.23	10.44
0	1	1	2.23	4.98
		M: -1.23		S: 102.31

Significance Level:

- 0.01
- (●) 0.05
- 0.10

One-tailed or two-tailed hypothesis?:

- One-tailed
- (●) Two-tailed

Difference Scores Calculations

Mean: -1.23
$\mu = 0$
$S^2 = SS/df = 102.31/(13-1) = 8.53$
$S^2_M = S^2/N = 8.53/13 = 0.66$
$S_M = \sqrt{S^2_M} = \sqrt{0.66} = 0.81$

T-value Calculation

$t = (M - \mu)/S_M = (-1.23 - 0)/0.81 = -1.52$

The value of t is -1.519794. The value of p is .15446. The result is *not* significant at $p < .05$.

C.5 - Change in Accidents – Public Transport vehicles

Treatment 1	Treatment 2	*Diff* (T2 - T1)	*Dev* (Diff - M)	*Sq. Dev*
14	14	0	1.8	3.24
0	0	0	1.8	3.24
25	10	-15	-13.2	174.24
2	0	-2	-0.2	0.04
7	3	-4	-2.2	4.84
0	0	0	1.8	3.24
1	2	1	2.8	7.84
18	13	-5	-3.2	10.24
3	2	-1	0.8	0.64
26	13	-13	-11.2	125.44
0	0	0	1.8	3.24
1	0	-1	0.8	0.64
2	1	-1	0.8	0.64
0	0	0	1.8	3.24
0	0	0	1.8	3.24
1	1	0	1.8	3.24
2	2	0	1.8	3.24
1	0	-1	0.8	0.64
0	5	5	6.8	46.24
0	1	1	2.8	7.84

Significance Level:

- 0.01
- (selected) 0.05
- 0.10

One-tailed or two-tailed hypothesis?:

- One-tailed
- (selected) Two-tailed

Difference Scores Calculations

Mean: -1.8
$\mu = 0$
$S^2 = SS/df = 405.2/(20-1) = 21.33$
$S^2_M = S^2/N = 21.33/20 = 1.07$
$S_M = \sqrt{S^2_M} = \sqrt{1.07} = 1.03$

T-value Calculation

$t = (M - \mu)/S_M = (-1.8 - 0)/1.03 = -1.74$

The value of *t* is -1.743129. The value of *p* is .09747. The result is *not* significant at $p < .05$.