Analysis of the Relationship between the Severity of Road Traffic Crashes and the Human factors involved: N4 Toll Route Case Study

by

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Abstract

Road safety is considered to be one of the most critical concerns in contemporary society. As a result, reducing road traffic crashes is, arguably, the most critical aspect that needs to be addressed within a roadway system. Injuries and fatalities resulting from traffic crashes are a serious problem. Globally, the number of road traffic deaths continues to rise, reaching a devastating 1.35 million fatalities in 2016, which equates to almost 3700 people being killed on the world's roads every day. Despite the efforts made by government agencies and the engineering community, the road crash fatality rate in South Africa remains higher than the global average. In 2016, approximately 25.9 people per 100 000 lost their lives on South African roads, in comparison, the global average of road fatalities is confirmed at 18 deaths per 100 000 of the population. The study focused on analysing the relationship between the severity of the road traffic crashes, which occurred on the N4 Toll Route in South Africa, and the interaction of the human factors involved in these crashes. Association Rule Analysis was the primary method used to determine the relationship between the crash severity and the human risk factors involved in these crashes. The study confirmed that the human factor plays a critical role in road traffic crashes. Of the almost 9000 crashes analysed, 16.1% of the crashes were caused by vehicle-, 8.7% by road and environmental- , 4.4% by unknown- , and 72.8% by human- factors. The study established that there exists a relationship between the various human factors and crash severity. Among the human factors, crashes that occurred as a result of negligent driving, illegal overtaking and travelling in the wrong direction proofed to pose the highest risk for fatalities or serious injury. Vehicle- pedestrian crashes proofed to be the most dangerous, leading to a fatality in 71.5% of the crashes. A survey was distributed to collect information about the perception that drivers have on the possible relationship between RTCs and the human factors involved in these crashes. In addition, the research was used to gather data on the behaviour of drivers while driving on the highway under South African conditions. Having to indicate what contributes the most towards road safety, 87.8% of the respondents listed 'Human behaviour' as the primary factor that leads to a road being deemed safe or unsafe.

Word Count: 391

Keywords: Road Safety, Road Traffic Crashes, Human Factors, Association Rule Analysis, Survey.

Opsomming

Padveiligheid word beskou as een van die beduidendste kwessies waarteen die moderne samelewing vandag te staan kom. Gevolglik is die belangrikste aspek wat binne ʼn padnetwerk aangespreek moet word die vermindering van padongelukke. Beserings en sterftes as gevolg van padongelukke is ʼn ernstige probleem. Die aantal sterftes wat wêreldwyd toegeskryf word aan padongelukke styg voortdurend, in 2016 alleen is daar ʼn verwoestende 1.35 miljoen sterftes aangemeld, wat beteken dat byna 3 700 mense per dag sterf op die wêreld se paaie. Ondanks verskeie pogings deur regeringsagentskappe, sowel as, die ingenieursgemeenskap bly die padongeluk sterftekoers in Suid-Afrika steeds hoër as die wêreldgemiddeld. In 2016 het ongeveer 25.9 mense per 100 000 van die bevolking hulle lewens verloor op Suid-Afrikaanse paaie, dit in ooreenstemming met die bevestigde wêreldgemiddeld van 18 mense per 100 000 van die sterftes binne die bevolking. Hierdie navorsing ontleed die verhouding tussen die intensiteit van ongelukke, en die interaksie met die bydraende menslike faktore tot hierdie padongelukke. Die studie fokus op ongelukke wat plaasgevind het op die N4-Tolpad in Suid-Afrika. Assosiasie reël analise is as primêre metode gebruik om die verhouding tussen die intensiteit van padongelukke en die bydraende menslike faktore te analiseer. Die studie bevestig die kritieke rol wat die menslike faktore in padongelukke speel. Vanuit die byna 9000 padongelukke wat ontleed is, is 16.1% van die padongelukke veroorsaak deur voertuigfaktore, 8.7% deur pad- en omgewingsfaktore, 4.4% deur onbekende faktore en 72.8% deur menslike faktore. Die studie bewys dat daar ʼn verhouding bestaan tussen die verskeie menslike faktore en die graad van intensiteit van padongelukke. Onder die menslike faktore, is bewys dat die hoogste risiko vir sterftes en of ernstige beserings toegeskryf kan word aan ongelukke wat plaasvind as gevolg van nalatigheid, die onwettige verbysteek, en om in die verkeerde rigting te ry. Daar is bevind dat voertuig en voetganger botsings die gevaarlikste is, wat kan lei tot ʼn sterfte koers van 71.5%. ʼn Menings opname was gebruik om inligting te bekom oor die persepsie wat bestuurders het oor die moontlike verhouding tussen padongelukke en die menslike faktore betrokke by ongelukke. Verder is hierdie opname gebruik om inligting te versamel oor die optrede van bestuurders wanneer hulle op ʼn hoofweg in Suid-Afrikaanse omstandighede bestuur. Gevra wat die meeste bydra tot padveiligheid, het 87.8% van die respondente aangedui dat menslike faktore die primêre faktor is wat bydra of ʼn pad as veilig of onveilig beskou kan word.

Woordtelling: 399

Sleutelwoorde: Padveiligheid, Verkeersongelukke, Menslike faktore, Assosiasie Reël Analise, Menings opname.

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List of Acronyms

AADT	: Annual Average Daily Traffic
AASHTO	: American Association of State Highway and Transportation Officials
ANE	: Administração Nacional de Estradas
CDC	: Centers for Disease Control and Prevention
COLTO	: Committee of Land Transport Officials
CR	: Crash Rate
DOT	: Department of Transport
FR	: Fatality Rate
GDP	: Gross Domestic Product
HSM	: Highway Safety Manual 2010
NDP 2030	: National Development Plan 2030
NRSS	: National Road Safety Strategy 2016-2030
RTCs	: Road Traffic Crashes
RTMC	: Road Traffic Management Corporation
SANRAL	: South African National Roads Agency SOC Ltd
TIDS	: Traffic Information and Data System
TRAC	: Trans African Concessions
TRH	: Technical Recommendations for Highways
UNDA	: United Nations Decade of Action for Road Safety 2011-2020
VKT	: Vehicle Kilometres Travelled
WHO	: World Health Organization

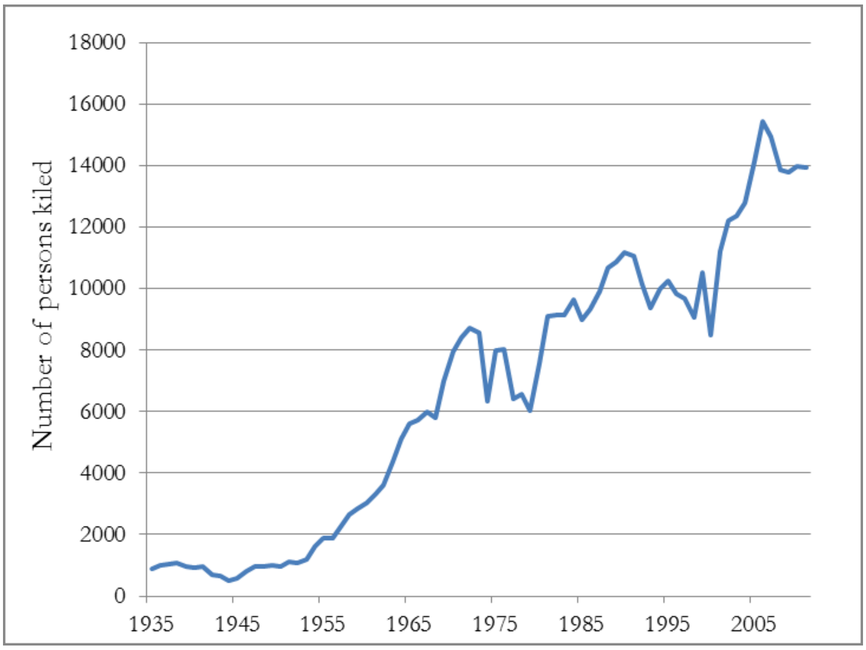
1. Introduction

Road safety is considered to be one of the most critical concerns in contemporary society. This research project was aimed at investigating the possible relationship that exists between the severity of Road Traffic Crashes (RTCs) and the human factors involved in the causation of these crashes. The research was furthermore aimed at identifying the perceptions that drivers have towards road safety in general and their awareness of the significance of the role human factors have in the causation of RTCs. With a better understanding of the above, the possibility exists for roadway systems to be designed in such a way that minimizes the occurrence of RTCs associated with human error. Research in traffic safety and dealing with RTCs, in particular, remain fundamental to ensure that the strategic interventions employed are both responsive and supported by definitive data.

Chapter 1 provides background information for the research study, highlights the objectives of the research, presents the problem statement and presents the research questions. The chapter furthermore outlines the significance, the scope and the limitations of the study.

1.1 Background Information

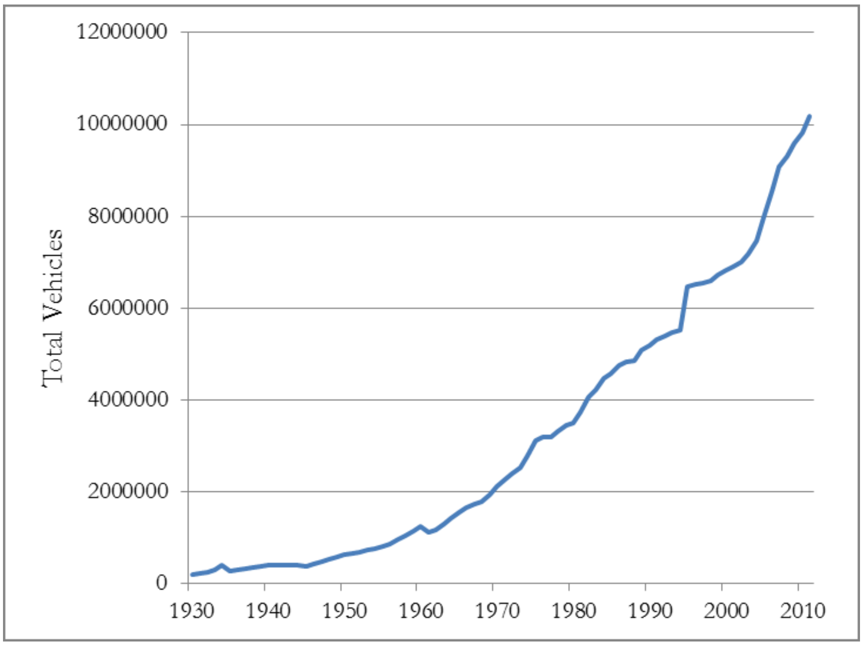
Reducing RTCs is, arguably, the most critical aspect that needs to be addressed within a roadway system. Providing safer roads and reducing road traffic injuries and fatalities have become some of the biggest problems traffic engineers and researchers have to face. Road safety has, therefore, been a focus of research studies for decades. To fully comprehend the severity of the situation, it is necessary to first understand the extent of the problem and to present the current perspectives and challenges in an illustrated way. Injuries and fatalities resulting from RTCs are a serious problem. Existing research suggests that this problem will only intensify in the foreseeable future due to economic growth and increasing vehicle ownership. Du Plessis *et al*. (2013) points out that there has been a steady increase in the number of fatalities from 1935 until 2011. Refer to Figure 1-1. However, it must be noted that, due to the economic fallout of the Covid-19 pandemic, the World Bank predicted economic growth in Sub-Saharan Africa to decline to -3.3% in 2020 (World Bank, 2020). Furthermore, Business Tech reported that “Nedbank revised its GDP forecasts for South Africa for 2020, 2021 and 2022 to -8.1%, 3% and 2.2% respectively. At these growth rates, South Africa will only return to 2019 output levels by 2024” (BusnessTech, 2020). The decline in economic growth predicted for the next few years might, therefore, retard vehicle ownership and in turn, reduce the number of RTCs.



Source: Du Plessis *et al*. (2013)

Figure 1-1: Number of fatalities (1930 – 2011)

Several contributory factors led to an increase in RTCs and fatalities over time. Bester (2001) points to "speed, vehicle ownership, state of infrastructure and the attitude of the driver population as possible factors for a country's fatality rate." Furthermore, in the latter years, South Africa has seen a steady increase in vehicle population on its roads. Figure 1-2 shows a steady increase in the total number of registered vehicles on South African roads (Du Plessis *et al*., 2013)



Source: Du Plessis *et al*. (2013)

Figure 1-2: Total vehicles registered (1930 – 2011)

Globally, the number of fatalities caused by road traffic crashes continues to increase. The World Health Organization (WHO) reports as follows:

> "Deaths from road traffic crashes have increased to 1.35 million a year. That's nearly 3 700 people dying on the world's roads every day…road traffic injury is now the leading cause of death for children and young adults aged 5 to 29 years (p.vii), and the eighth leading cause of death for all age groups" (p.xi).

Furthermore, Macharia *et al.*, noted that "more than 50% of the injuries and deaths emanating from road crashes occur within the ages of between 15 and 49 years,… which is considered the economically productive population group" (Macharia *et al*., 2009, p.20).

According to Zimmerman *et al.* (2011) "traffic crashes are also the main cause of physical disability for drivers, passengers and pedestrians in developing countries" (Zimmerman *et al*., 2011, p.1). The WHO (2020) reports that "Every year… as a result of a road traffic crash… [worldwide] between 20 and 50 million people suffer non-fatal injuries, with many incurring a disability as a result of their injury." The WHO (2008, p.30) predicted that "road traffic crashes would become the fifth leading cause of death by 2030 worldwide." This signifies the need for a change in the current agenda, which to date, has mostly ignored road safety as a global health issue.

The WHO (2018) further notes that "the burden of road traffic injuries and deaths is disproportionately borne by vulnerable road users and those living in low- and middle-income countries" (p. xi), and that, "the risk of dying from a road traffic injury is 3 times higher in developing countries, compared to developed countries" (p.6). Continually developing economies of middle-income countries contribute more to RTCs since the use of vehicles for transportation is on the increase. According to the Road Traffic Management Corporation (RTMC) "South Africa is classified as a middle-income economy" (RTMC, 2017, p.11). The WHO (2018) reports that "the road crash fatality rate in South Africa is significantly higher than the global average. In 2016, approximately 25.9 people per 100 000 lost their lives on the country's roads" (p.235), and in comparison, "the global average of road fatalities is around 18 deaths per 100 000 of the population" (p.8).

According to the RTMC, "the high number of Road Traffic Crashes (RTCs) and its associated consequences has a significant impact on the South African society which continues to hamper socio-economic development and impact on the well-being of all South Africans" (RTMC, 2017, p.8).

This impact is felt not only in terms of the lives lost but also as an ever-increasing burden to the economy. Labuschagne *et al*. note that "the total cost of road traffic crashes on South Africa's road network for 2015 amount to approximately R142.95 billion, or 3.4% of the GDP" (Labuschagne *et al*., 2017, p.479). Based on the 2019 inflation-adjusted rates, the costs of road traffic crashes increased to an estimated R175 billion.

The considerable impact of RTCs on the economy and society at large emphasizes the need to improve road safety in South Africa. It also provides a convincing case to do further research to try and alleviate the problem. The objective of this research was, therefore, ultimately focused on creating a safer roadway system, which in turn could lead to a reduction in the number of injuries and fatalities due to RTCs caused by the human factors.

1.2 Problem Statement

The RTMC estimates that the fatality rate of road crashes in South Africa is substantially greater than the global average. In 2017, RTCs in South Africa were responsible for approximately 14 050 deaths, and 524 000 people were injured (RTMC, 2017).

Despite the efforts made by government agencies and the engineering community, the fatality rate, as a result of RTCs in South Africa, remains greater than the global average (RTMC, 2017). The main reason behind the high road crash fatality rate might be the fact that the characteristics of the leading contributing factors to RTCs are not well understood. According to Austroads (2002), the three main contributing factors in RTCs are; "the human factors, the road environment factors, and the vehicle factors" (Austroads, 2002, p.4). Although most traffic crashes cannot be related to a singular causal event, human factors alone were found to have caused 67% of RTCs, while 95% of RTCs were found to be due to a combination of human and other factors (Austroads, 2002).

The human factors are, therefore, considered to be the leading cause of RTCs. Numerous studies have addressed the different aspects of human behaviour in safety, but very few have been carried out in developing countries such as South Africa. The research published to date has mainly focused on engineering concerns in relation to traffic and vehicle safety. There are very few studies concerning road user behaviour and the human factors relating to the causation of traffic crashes. Although human factors account for the majority of RTCs in South Africa, not much is known about the possible relationship that exists between the severity of RTCs and the human factors involved in the causation of these crashes.

Without a clear understanding of the characteristics and possible causes, it is not possible to identify potential countermeasures that could be employed to reduce the serious and fatal RTCs in South Africa. The need, therefore, exists for a better understanding of the possible underlying human factors behind the severity of the crashes and the high crash rate. The problem statement of this research project measures the human-related causes of RTCs in South Africa. Solutions, to the safety-related issues, can only be identified once these causes have been identified.

1.3 Research Objectives

The primary objective of this research was to study and analyse the relationship between the severity of the road traffic crashes, which occurred on the N4 Toll Route in South Africa, and the interaction of the human factors involved in these crashes.

Guided by the given framework, the specific aims were:

1. To investigate the relationship between the severity of the RTCs and the various human factors involved in crashes that occurred on a highway in South Africa.
2. To identify driver perceptions of the relationship that exists between RTCs and the human factors involved.
3. To study driver behaviour concerning road safety on highways in South Africa.
4. To identify the solutions and countermeasures that can be put in place to address RTCs, and the human factors involved in the RTCs on highways in South Africa.

1.4 Significance and Motivation

Internationally, there is a wide body of research that details the various aspects of human factors in road safety. However, hardly any studies have focused exclusively on highway crash trends and road safety in South Africa (RTMC, 2016b). Consequently, there has not been a comprehensive evaluation of the human factors involved in RTCs on highways in South Africa. The goal of this research is to bridge this gap by concentrating on road crash trends and road user perceptions regarding road safety in South Africa. This research project can furthermore contribute to road safety management, and ultimately form part of a greater research and development plan aimed at facilitating road research in South Africa.

The study provides insight into the characteristics of RTC trends and driving behaviour that can be used to establish better design guidelines, aimed at providing a safer highway driving environment. Better knowledge of the human factors involved in RTCs can inform a design of highways not only based upon the vehicle and road features but also on the human behavioural characteristics. It can furthermore inform the design development to accommodate driver needs and limitations. A better understanding of human factors can also lead to policymakers developing more effective regulations, especially in terms of road safety law enforcement, which play a vital role in reducing the high number of RTCs crashes and deaths on our roads.

Finally, being aware of the perceptions of drivers, relating to the human factors, can furthermore improve our understanding of the motives influencing driver performance, which can be useful for enforcement and education campaigns directed at specific road users. Therefore, this research study is relevant to alert designers, planners, and policymakers to the human factors, characteristics, and behaviour that affect road traffic safety, especially in the context of a developing world.

1.5 Scope and Limitations

The scope of this research was limited to the analysis of the highway traffic crashes which occurred within the South African section of the N4 Toll Route, starting in Pretoria, Gauteng, and terminating at the Lebombo border post, located at the South Africa / Mozambique border. The highway section spans a total length of approximately 504km. Refer to Addendum A for a Key Plan of the N4 South African Section (Pretoria to the Lebombo border post). Crash data, detailing the crash statistics for a 9-year analysis period, ranging from 2010 to 2018, was collected for this study.

Limitations experienced during the collection of crash data include:

- Gathering data and obtaining institutional permission from the different stakeholders was a lengthy process.
- Traffic crash investigators categorised many of the crashes causes under “Lost control” since the investigators lack the specific knowledge and skills to determine precise crash causes.
- Traffic crash investigators failed to collect some of the demographic information like the gender and age of the responsible drivers and merely captured them as “Unknown”.

These limitations affected the in-depth composition analysis of this research to some extent.

In addition to the crash data, an electronic survey was used to gain insight into the drivers' perceptions of the relationship between road crashes and the human factors involved. The survey was also used to gather information on drivers' perceptions of road safety when driving on a highway in South Africa. The results from the survey offered further explanations to the findings produced by the analysis of the crash data.

Limitations experienced during the distribution of the survey include:

- Considering South Africa's national state of disaster due to the COVID-19 pandemic, some critical safety measures were required to maintain a healthy research environment for all participants.
- Due to the threat of exposure to the Corona virus, the survey was distributed in electronic format only. Potential respondents were asked to complete an online questionnaire. This allowed for no physical contact, and no individuals being in close proximity to each other.
- The drawbacks to the electronic data collection method include the potential for selection bias and a lower response rate. It also limits the potential respondents to those who have access to an active e-mail account.

The information obtained from the electronic survey is still considered instrumental in assessing driver behaviour and driver perceptions towards road safety. However, when interpreting the results of the survey the abovementioned limitations should be kept in mind.

1.6 Research Questions

The research objectives were addressed by answering the following questions:

1. What is the relationship between the severity of the road traffic crashes that occurred on a highway in South Africa and the various human factors involved in these crashes?
2. How do drivers perceive the relationship between road traffic crashes and the human factors involved in these crashes?
3. How do drivers in general perceive road safety issues?
4. What measures can be implemented to address the human factors involved in the RTCs that occur on highways in South Africa?

These questions provided guidance in the analysis of the relationship between the severity of the road traffic crashes that occurred on a highway in South Africa and the various human factors involved in these crashes.

1.7 Chapter Overview

There are five chapters in the research report:

Chapter 1 Introduction

Chapter 1 provides background information for the research study, highlights the objectives of the research and presents the problem statement. The chapter furthermore outlines the scope area and motivates the significance of the research. The limitations are also discussed.

Chapter 2 Literature review

Chapter 2 starts with an introduction to the literature review completed. The chapter discusses the broad context of the theory base and presents the detailed findings of a comprehensive literature review on the areas considered relevant to the research and study topic.

Chapter 3 Methodology

Chapter 3 presents the research design and substantiates the significance of the methodology used for the specific research topic. The chapter discusses the research instruments and study procedures used to investigate the human factors involved in RTCs, and the road user behaviour study (survey). The crash data collection methods are explained, including all the issues faced in collection and organization. The crash data analysis techniques and procedures are also discussed. The chapter describes the procedures followed to obtain ethics approval from the University.

Chapter 4 Analyses, Results and Discussion

Chapter 4 provides the analyses and results of the study. The chapter documents the relationship that exists between the severity of the RTCs and the human factors involved in these crashes. Furthermore, findings from the driver behaviour survey are discussed in this chapter. The chapter discusses the most significant findings and results, followed by the identification of solutions and countermeasures that can be put in place to address RTCs.

Chapter 5 Conclusions

Chapter 5 presents the conclusions drawn from the research study. The chapter presents a summary of the most significant findings and recommendations on improvements in highway safety.

2. Literature review

Road Traffic Crashes (RTCs) occur when a driver collides with a road element, an obstacle or other road users, or when a driver fails to keep a vehicle on the road. RTCs are the result of a sequence of complex processes. Hermans *et al*. (2008), note "to increase the level of road safety, it is necessary to gain insight into the underlying factors responsible for RTCs." Road safety has, therefore, been a focus of research studies for decades. Chapter 2 presents a summary of previous studies relevant to the nature of the research topic. Furthermore, it presents a review of the existing theory relating to the problem statement and objective of the study set out in Chapter 1. It provides an overview of the different contributing factors involved in RTCs, together with, an identification of the consequences associated with these factors. The chapter also provides examples of road safety initiatives from across the globe and from South Africa.

2.1 Operational Definitions

Road traffic crash – "an event that occurred on a road, open to public traffic, involving at least one moving vehicle, colliding with another vehicle, pedestrian, animal, road debris, or other stationary obstruction, such as a tree, pole or building, which resulted in a human injury, a human fatality or material damages" (OECD, 2020).

Pedestrian-motor vehicle crash – "a pedestrian is a person travelling on foot, roller skates, skateboard, kick scooter, and also includes a person travelling with a pram. A pedestrian-motor crash is an event that occurred on a road, open to public traffic, where a vehicle in motion collided with one or more of the categories cited above, resulting in a human injury, a human fatality or material damages" (NHTSA, 2012).

Fatal crash – "a crash that results in injuries that causes immediate death or death within 6 days as a direct result of the crash" (Opperman & Upton, 1991, p.2.4).

Serious injury crash – "a crash that results in injuries that include fractures, concussions, severe cuts and lacerations, shock necessitating medical treatment and any other injury that requires hospitalisation or confinement to bed" (Opperman & Upton, 1991, p.2.5).

Slight injury crash – "a crash that results in injuries that include cuts, bruises, sprains and slight shock that do not requires hospital treatment" (Opperman & Upton, 1991, p.2.5).

Damage-only crash – "a crash in which there is no personal injury but damage to property" (Opperman & Upton, 1991, p.2.5).

2.2 Situational Assessment

In order to fully realise the extent of the road safety issue, it is necessary to gain an understanding of the existing situation and to discuss the facts that outline the current global and South African road safety challenges. The financial effect of road crashes in terms of the South African economy is another vital element addressed under Part 2.2 Situational assessment.

2.2.1 Road Safety: Global vs South African Status Quo

Injuries and fatalities resulting from RTCs are a severe problem, both locally and globally. Existing research, furthermore, suggests that this problem will only intensify in the foreseeable future.

According to the WHO (2018):

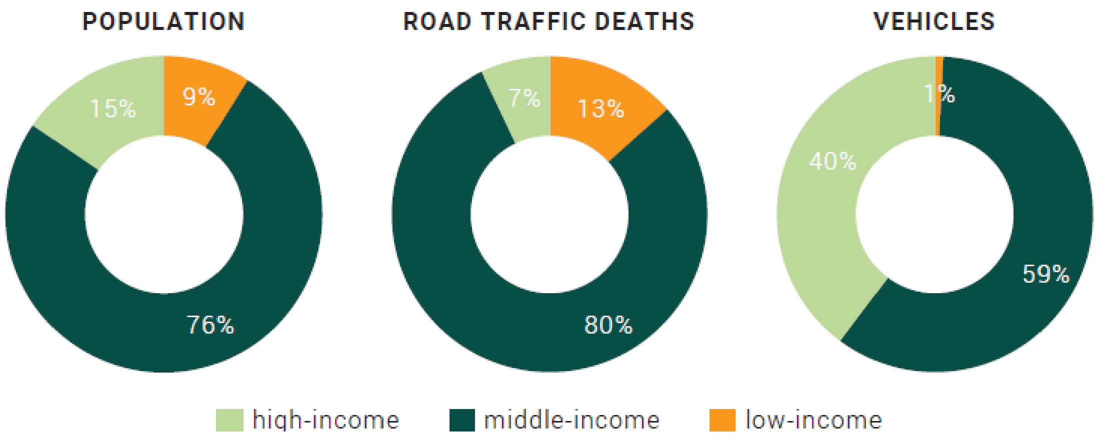
> "Deaths from road traffic crashes have increased to 1.35 million a year. That's nearly 3 700 people dying on the world's roads every day (p.vii)… Road traffic injury is now the leading cause of death for children and young adults aged 5–29... It is the eighth leading cause of death for all age groups surpassing HIV/AIDS, tuberculosis and diarrhoeal diseases. The burden of road traffic injuries and deaths is disproportionately borne by vulnerable road users and those living in low- and middle-income countries, where the growing number of deaths is fuelled by transport that is increasingly motorized. Between 2013 and 2016, no reductions in the number of road traffic deaths were observed in any low-income country, while some reductions were observed in 48 middle- and high-income countries. Overall, the number of deaths increased in 104 countries during this period" (p.xi).

The WHO (2008), furthermore, predicts that "road traffic crashes would become the fifth leading cause of death by 2030 worldwide" (WHO, 2008, p.30). This suggests the need for a change in the present agenda, which to date, has largely disregarded road safety as a global health issue. Progress in reducing road traffic fatalities differs considerably across regions and countries around the world. A strong link exists between the number of road fatalities and a country's income level.

The WHO (2018) confirms by stating:

> "With an average rate of 27.5 deaths per 100,000 of the population, the risk is more than 3 times higher in low-income countries than in high-income countries where the average rate is 8.3 deaths 100,000 population. [As shown in Figure 2-1] the burden of road traffic deaths is disproportionately high among low- and middle-income countries in relation to the size of their populations and the number of motor vehicles in circulation. Although only 1% of the world's motor vehicles are in low-income countries, 13% of deaths occur in these countries" (WHO, 2018, p.6).

As of 2016, at an average of 27.5 per 100 000, Africa had the highest global death rate, even though the region has the lowest motorization number, of less than 50 per 1000. The WHO (2018) further notes that, "globally, pedestrians and cyclists represent 26% of all road fatalities, with those using motorcycles comprising another 28%. Car occupants make up 29% of all deaths and the remaining 17% are unidentified road users. Africa has the highest proportion of pedestrian and cyclist mortalities with 44% of deaths" (WHO, 2018, p.10).



Source: WHO (2018:7)

Figure 2-1: Proportion of population, road traffic deaths, and registered motor vehicles by country income category, 2016

In addition, the lack of road safety also affects other public health sectors, as it may lead to inactivity. People are less likely to use roads for recreational activities such as walking, jogging, or cycling if the road conditions are deemed too dangerous. This-in-turn may lead to other societal health-related problems, like heart failure and diabetes. The WHO recognises this and state that "Simultaneously preventing road traffic deaths and encouraging active travel in safe environments will contribute to reducing the overall burden of preventable deaths" (WHO, 2018, p.5).

The road safety picture in South Africa appears to be much bleaker than that of high-income countries. According to the RTMC "South Africa is classified as a middle-income economy" (RTMC, 2017, p.11). The WHO (2018) reports that "the road crash fatality rate in South Africa is significantly higher than the global average" (p.235). In 2017, RTCs in South Africa were responsible for approximately 14050 deaths and 524 000 people were injured (RTMC, 2017). According to the WHO (2018), "in 2016, approximately 25.9 people per 100 000 lost their lives on the country's roads" (p.235), and in comparison, "the global average of road fatalities is around 18 deaths per 100 000 of the population" (p.8).

2.2.2 Cost of Crashes

The costs and financial impact of RTCs on the world economy is substantial. According to the Centers for Disease Control and Prevention (CDC), "RTCs cost the global economy approximately US $518 billion and US $65 billion in low- and middle-income countries each year" (CDC, 2016).

The main reference for the costs of RTCs in South Africa is the "Costs of Crashes in South Africa, Research and Development Report, 2016" (CoC 2016), compiled by the Road Traffic Management Corporation. CoC 2016 initially followed a Human Capital approach in its methodology. However, in order to address the social and environmental costs deficits of former RTC costing exercises, the CoC methodology was later extended. According to the CoC 2016 study, "the 'total cost of RTCs metric' is an important road safety indicator that serves as the departure point for understanding the extent and magnitude of the road safety problem in a country" (RTMC, 2016a, p.i).

Labuschagne *et al*. (2017) explains that:

> "On a national level, reported as a percentage of the Gross Domestic Product (GDP), the RTCs cost estimation relates to the consequences that these crashes have on the economy and social welfare of a country. The cost estimation of RTCs encompasses three main cost categories, viz.; the human casualty costs, the vehicle repair costs and the incident costs" (Labuschagne *et al*., 2017, p.475).

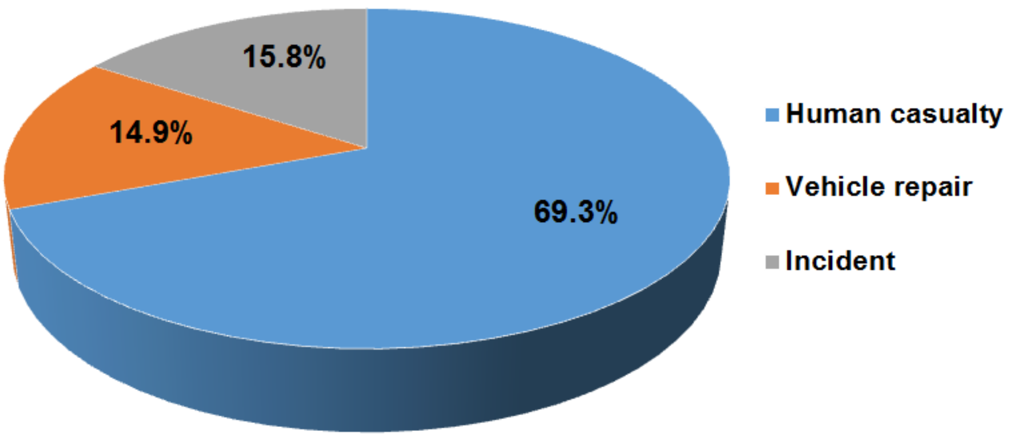
The cost categories and cost elements included in the cost of crashes are presented in Table 2-1 that follows.

Table 2-1: Cost categories and elements of the cost of crashes

Cost category	Cost element
Human casualty costs	Present and future lost productivity Pain, suffering and lost quality of life Medical and rehabilitation treatment Funeral Work place re-occupation
Vehicle repair costs	Vehicle damage Towing Assessor
Incident costs	Emergency response Legal RTC management (crash scene attendance, crash investigation and reconstruction, data management, etc.) Infrastructure damage Delay, congestion and emissions

Source: Labuschagne *et al*. (2017)

According to the RTMC, a better understanding of the mentioned cost categories and their respective cost elements will result in informed decision-making during the design stage, and the application of appropriate interventions, aimed at reducing road traffic crashes and their impacts (RTMC, 2016a). Labuschagne *et al*. note that "the total cost of road traffic crashes on South Africa's road network for 2015 amount to approximately R142.95 billion, or 3.4% of the GDP" (Labuschagne *et al*., 2017, p.479). Figure 2-2 below shows the percentage of total crash cost according to the respective cost category for 2015. The most notable is that the human casualty costs accounted for 69.3% or R99.03 billion, where the vehicle repair and incident accounted for only 14.9% or R21.32 billion and 15.8% or R22.95 billion, respectively (Labuschagne *et al.*, 2017, p.479).



Source: Labuschagne *et al*. (2017)

Figure 2-2: Percentage of total crash cost according to cost category, 2015.

Based on the 2019 inflation-adjusted rates, the costs of road traffic crashes increased to an estimated R175 billion. The unit costs of the RTCs, by severity, are shown in Table 2-2 below.

Table 2-2: Unit crash costs per RTC, by severity

Road Traffic Crash (per unit cost)				
Fatal	Major	Minor	Damage only	Any severity
R 5,435,261.00	R 765,664.00	R 152,244.00	R 48,533.00	R 171,727.00

Source: Labuschagne *et al*. (2017)

The high number of RTCs and the related effects has a substantial influence on the South African society, not only in terms of the lives lost but also as an ever-increasing burden on the economy (RTMC, 2017). Labuschagne *et al*. (2017) note that:

> "It is difficult to benchmark South Africa's road traffic safety performance against those of other countries as the method of calculating RTC costs differs from country to country. Some countries adjust RTC figures for underreporting, and some do not. The percentage of 3.4% of the GDP for South Africa, however, does not compare favourably with countries using similar methodologies" (Labuschagne *et al*.,2017, p.481).

The considerable effect of RTCs on the economy and society emphasizes the need to address road safety problem in South Africa. It also provides a convincing case to do further research to try and address the problem.

2.3 Measures to Improve Road Safety

In 2009, South Africa became a signatory to UNDA (United Nations Decade of Action for Road Safety 2011-2020). The National Road Safety Strategy 2016-2030 (NRSS) (2017) declared that:

> "As a participant of UNDA, South Africa has endorsed the global undertaking to save up to 5 million lives, and to contribute to the prevention of up to 50 million serious injuries by 2020 (p.13). Under this commitment, South Africa has the responsibility to align research programmes and interventions for road safety that embodies the principles of the Safe Systems Approach… the Safe System approach is an approach commonly used to achieve the vision of zero road fatalities and serious injuries. The Safe System approach requires that the road system be designed to expect and accommodate human error. Safe System principles require a holistic view of the road system and the interactions between the road, the vehicles, and the road users" (RTMC, 2017, p14).

UNDA laid the foundation for a guiding framework for actions to improve road safety to be developed, commonly referred to as: "the Five Pillars". According to the NRSS (2017),

> "The Five Pillars framework aims to support member states in effectively assessing and addressing deficiencies in the respective road safety measures by focusing on; Pillar One: Road Safety Management, Pillar Two: Safer Roads and Mobility, Pillar Three: Safer Roads, Pillar Four: Safer Road User, and Pillar Five: Post Crush Response" (RTMC, 2017, p.14).

2.3.1 South Africa's Response to reduce road fatalities

In line with the above, the *National Road Safety Strategy 2016-2030 (NRSS) 2016-2030*, was developed. The NRSS embodied the ideals of the "Safe Systems approach", and gave effect to the "Five pillars of the UNDA". The NRSS was a joint commitment between the public and private sector, the transport sector, government institutions, and academia.

The NRSS (2017) confirms that "in line with the UNDA, [South Africa] committed to reducing road fatalities by 50%, from the 2010 baseline figure of 13967 to 6984 in 2020" (RTMC, 2017:9). In recent years, South Africa has seen a reduction in the number of road deaths, with a gradual decrease from 15 419 in 2006 to 12 702 in 2014. However, the fatality rate has not decreased enough for South Africa to reach the reduction target by 2020, as set out by the UNDA. The National Development Plan 2030 (NDP 2030), widely regarded as South Africa's strategy blueprint, therefore, identified a revised target to decrease the number of injuries, fatalities and crashes by 50% from the 2010 levels by 2030, (RTMC, 2017). The NRSS 2016-2030 identified the following key strategic themes in accordance with the "Five pillars of the UNDA":

> "Identify and address high road safety risk and hazardous locations; Provide self-explaining and forgiving road environment for all road users; Implement road safety audit programme on new and upgraded road infrastructure projects; Increase vehicle safety standards; Ensure vehicles on the road network are roadworthy; Improve road user behaviour and involve communities in road safety education and awareness programmes; Improve enforcement effectiveness; Increase protection for VRU's; Increase effectiveness of first responses; Simplify access to post-crash care" (RTMC, 2017, p.36).

The NDP 2030 furthermore outlined the following to be monitored and controlled; "The roadworthiness of vehicles, Driver behaviour, Alcohol and substance abuse, and Weaknesses in law enforcement" (RTMC, 2017, p.14).

2.3.2 Road Safety Best Practices

Numerous road safety methods and approaches have been followed in the past. One such previous strategy to road safety, known as the Road User Approach (RUA), focused on human errors as the primary cause of road crashes. This approach meant that the particular driver was entirely responsible for the crash, even though other factors outside the control of the driver might have had an influence, such as the road and vehicle aspects (Peden *et al*., 2004).

Accordingly Peden *et al*. (2004) note that:

> "It is still widely held today that since human error is a factor in some 90% of road crashes, the leading response should be to persuade road users to adopt 'error-free' behaviour. According to this policy, information and publicity should form the backbone of road traffic injury prevention, rather than being one element of a much more comprehensive programme" (Peden *et al*., 2004, p.10).

Hoverer, human error does not always have catastrophic results on the roads. Although it might lead to a crash, human error might not always be the primary cause. In reality, human behaviour is not only influenced by the experience and abilities of a person, but also by the surroundings in which the action is performed. Accompanying influences, such as the road design, vehicle design, traffic laws and the enforcement, affect the driver's behaviour in a great way (Peden et al., 2004).

Peden *et al*. (2004) note that:

> "For this reason, the use of information and publicity on their own is generally unsuccessful in reducing road traffic collisions. Errors can also be effectively reduced by changing the immediate environment, rather than focusing solely on changing the human condition. In the field of road safety, it has proved difficult to overcome the traditional overreliance on single approaches" (Peden *et al*., 2004, p.10).

William Haddon Jr (1980) created a matrix that defines crash risk factors for each stage - before, during and after - of the crash, concerning the driver, the vehicle and the environment. Haddon described road transport as "an ill-designed 'man-machine' system in need of comprehensive systemic treatment. Each phase – pre-crash, crash and post-crash – can be analysed systematically for the human, vehicle, road and environmental factors" (Peden *et al.*, 2004, p.12).

Peden *et al*. (2004: 12) clarifies the Haddon matrix as:

> "[Haddon] defined three phases of the time sequence of a crash event – pre-crash, crash and post-crash – as well as the epidemiological triad of human, machine and environment that can interact during each phase of a crash. The resulting nine-cell Haddon Matrix models a dynamic system, with each cell of the matrix allowing opportunities for intervention to reduce road crash injury" (Peden et al., 2004, p.12).

Table 2-3 below provide an illustration the Haddon matrix as presented by Mohan *et al*. (2006).

Table 2-3: Haddon road safety matrix

PHASE GOALS		FACTORS		
		Human	Vehicle and equipment	Road environment
Pre-crash	Crash Prevention	Information Attitudes Impairment Police enforcement	Roadworthiness Lighting Braking Handling Speed management	Road design/layout Speed limits Pedestrian facilities
Crash	Injury preventing during the crash	Use of restraints Impairment	Occupant restraints Other safety devices Crash protective design	Crash protective roadside objects
Post-crash	Sustaining life	First-aid set Access to medics	Ease of access Fire risk	Rescue facilities Congestion

Source: Mohan *et al.* (2006)

According to Mohan *et al.* (2006) the Haddon matrix can be defined as follows:

> "The Haddon matrix is an analytical tool to help in identifying all factors associated with a crash. Once the multiple factors associated with a crash are identified and analysed, countermeasures can be developed and prioritized for implementation over short-term and long-term periods. For the pre-crash phase, it is necessary to select all countermeasures that prevent the crash from occurring. The crash phase is associated with countermeasures that prevent injury from occurring or reduce its severity if it does occur. Finally, the post-crash phase involves all activities that reduce the adverse outcome of the crash after it has occurred" (Mohan et al., 2006, p.25).

Peden *et al*. noted that, "building on Haddon's insights, a wide range of strategies and techniques for casualty reduction has since been tested internationally, through scientific research and empirical observation." (Peden *et al*., 2004, p.12).

According to Mohan *et al.* (2006) the Haddon matrix can be defined as follows:

> "Traditionally, analysis of risk has examined the road user, vehicle and road environment separately. Furthermore, there is a tendency by researchers and practitioners to look for one or a few factors, when in actual fact they should be analysing multiple factors. [An essential tool for effective road crash injury prevention is the adoption of a 'Systems approach' to: identify problems, formulate strategy, set targets and monitor performance]. Building on Haddon's insights, the systems approach (where interactions between different components are taken into account) seeks to identify and rectify the major sources of error, or design weaknesses that contribute to fatal crashes or crashes that result in severe injury as well as to mitigate the severity and consequences of injury" (Mohan *et al*., 2006, p.25).

South Africa, like several countries around the world, has adopted the "4 E's strategy", namely: "Enforcement, Education, Engineering and Evaluation." In conjunction with the Systems approach, the 4 E's strategy indicates that to decrease the number of RTCs related fatalities, systematic progress in each of these areas is key. In a South African context, however, it must be noted that the evaluation of road safety has been impeded by the lack of comprehensive accident data. Inadequate South African accident reporting systems have prevented the application of quantitative and detailed statistical analyses (Sinclair, 2010). Therefore, to effectively identify what solutions and countermeasures can be implemented to prevent fatal road crashes, the crash data reporting in South Africa must become a more standardised, integrated, and all-inclusive system.

The "4 E's Strategy" can be described as follows:

***Enforcement* -** "For safer roads, road users need to abide by the traffic laws of the country. The focus should be on enforcing these laws consistently" (Janmohammed & Vanderschuren, 2017, p.17).

***Education* -** "This component includes educating road users about their environment and their bad behaviour that can create a crash risk. In the case of the environment, this may include teaching pedestrians about the benefits of using a pedestrian bridge when crossing highways. In the case of bad behaviour, it may include educating drivers on the benefits of seat-belt use" (Janmohammed & Vanderschuren, 2017, p.17).

Engineering **-** "Similar to education, two factors need to be considered in terms of engineering for road safety. Firstly, the standard of vehicles (condition, roadworthiness) used on the road has to be improved. Secondly, the infrastructure provided needs to ensure safety of road users." (Janmohammed & Vanderschuren, 2017, p.17).

Evaluation -"To prevent RTCs, roads where crashes generally occur, need to be evaluated. These evaluations include analysing the fatality data in the locations to determine trends and causes of the crashes, and, performing road audits to find localised problems and to identify the solutions" (Janmohammed & Vanderschuren, 2017, p.17).

2.3.2.1 Enforcement

Enforcement of traffic laws is regulated and governed by policy relating to road safety. Regulations such as the enforcement of speed limits and the presence of traffic police can lead to a decrease in road crashes. It is, furthermore, just as important that the public know that when they violate any regulation, they will be caught and face the consequences (DoT, 2015).

According to the National Road Safety Strategy (2011-2020) "the challenges in addressing road safety in South Africa are primarily that of human behaviour, such as the lack of knowledge of road rules, the willingness to abide by the rules, inadequate enforcement, the lack of follow up fines, and the culture of impunity in respect to the punishment of offenders" (DoT, 2011, p.7).

2.3.2.2 Education

Education relates to education on road safety and includes awareness campaigns, media, and public relations to driver training and education. An approximate 93% of the people have access to TV or radio, thereby ensuring wide coverage in South Africa of road safety awareness. Road safety awareness has increased even more in line with current social networking sites. Education programs target repeat offenders and groups who are deemed high-risk, public transit users, pedestrians, freight drivers, children and the elderly (DoT, 2015).

2.3.2.3 Engineering

Engineering focuses on vehicle design and road safety engineering. Vehicle design is critical, especially, the safety features such as airbags. The condition of the brakes, lights, steering, etc. is also important to ensure safety. With the national fleet over an age ten years and the fact that there is no controlled vehicle test, the condition of the vehicles plays a major role in South Africa's road traffic crashes. (DoT, 2015).

The South African Road Safety Manual (Volume 1) articulates as follows:

> "Road safety engineering plays a vital role in influencing driver behaviour as engineering measures, for example, traffic control rely heavily upon the driver to see, interpret, respond to and obey the measure. In this sequence, the road environment should assist the driver in making a series of correct decisions and, if not correct, provide a forgiving road environment to reduce the severity of the accident. Road safety engineering can create such an environment by, controlling the rate of decision-making to a level that a driver is able to accommodate, and by providing information to the driver in such a manner that it facilitates quick and correct decisions" (COLTO, 1999a, p.B2).

According to the National Road Safety Strategy, 2016-2030 (2017), a safe road design should focus on providing an environment intended on protecting its users. This approach recognizes that people can make mistakes, and as a result, the design of the road needs to protect the user from the human errors that result in crashes or severe injury as much as possible. To achieve this, forgiving and intelligent road design elements must be incorporated (RTMC, 2017).

2.3.2.4 Evaluation

Evaluation focuses on identifying high-risk areas and determining whether these areas are a contributing factor in RTCs. The identification of the high-risk areas allows for hazardous sections to be improved through methods like the provision of high visibility road signs and stock fences etc. The most effective road safety evaluation methods are scientifically based. Monitoring and evaluation are, therefore, only successful when accurate information is accessible, in the context of South Africa, road safety data requires further support. (DoT, 2015).

2.4 Contributory factors to vehicle crashes

Several factors lead to Road Traffic Crashes (RTCs). Due to the vast number of influences and probabilities that exists during the moment of crash occurrence, the analysis of crashes can become very intricate. The American Association of State Highway and Transportation Officials (AASHTO) in their Highway Safety Manual (HSM) reports that;

> "... most crashes cannot be related to a singular causal event. Instead, crashes are the result of a convergence of a series of events that are influenced by several contributing factors… These contributing factors influence the sequence of events… before, during and after a crash" (AASHTO, 2010, p.3.8).

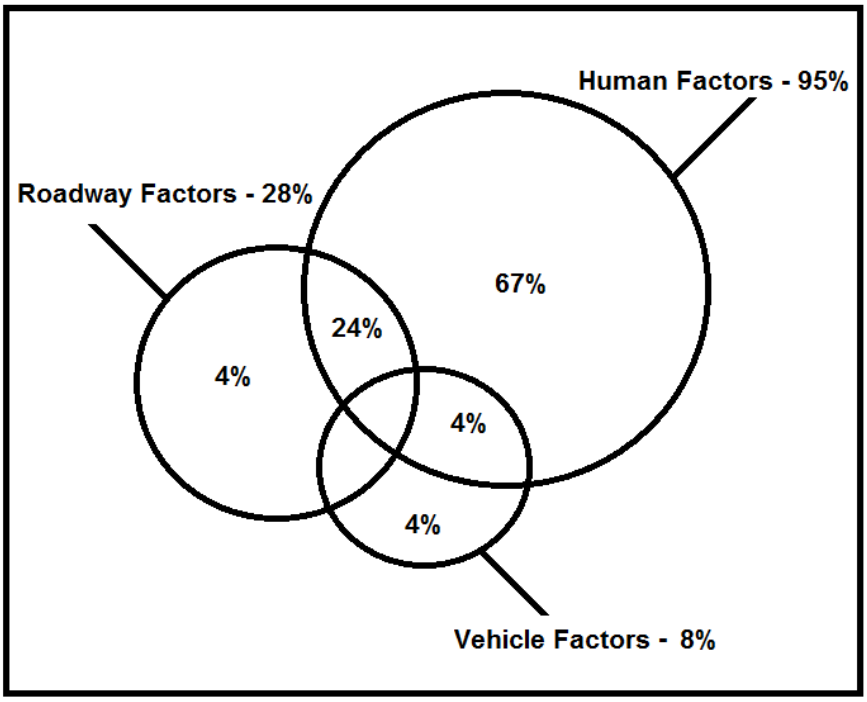
The three major contributors to RTCs are given as follows by Austroads (2002):

> "The Human factors, the road environment factors and the vehicle factors. The three factors often combine in a chain of events which result in an accident. Poor driving behaviour can combine with adverse weather, other road users, an unforgiving roadside environment or an inconsistent section of road with disastrous consequences" (Austroads, 2002, p.4).

Although many crashes cannot be associated with a single cause, the "human factors alone were found to have caused 67% of road traffic crashes, while 95% of road traffic crashes were found to be due to a combination of human and other factors" (Austroads, 2002, p.4).

Refer to Figure 2-3 for an illustration of the contributing factors in RTCs. The human factors, and the significant role they play in RTCs, are considered to be the leading cause of crashes. The analysis of local crash causes is particularly important in helping with the investigation of the unknown problems relating to the road traffic crash rates.

Vogel (2004) conducted a study into the causes of road crashes that occurred on the R44, located in the Western Cape. For this investigation, specific human-, vehicle- and environmental risk factors, were proposed for 14 types of crashes that occurred. The study found that human factors played the biggest role in road crashes. According to Vogel (2004) "out of the 404 crashes analysed, 77.7% was found to be caused by human factors, 8.7% by unknown factors, 7.2% by environmental factors and 6.4% by vehicle factors" (Vogel, 2004, p.iii). However, it must be noted that some problems with the data quality were reported.



Source: Austroads (2002)

Figure 2-3: Contributing Factors to Vehicle Crashes

The human factors can be described as that, which the driver did or did not do, during the moment of crash occurrence, i.e. driver behaviour and includes among others the following characteristics; speeding, negligence, alcohol and drug use, traffic violations, etc. The human factors can also be described according to driver distraction and driver performance, and include the following characteristics; mobile phone usage, fatigue, driver experience and skill etc. (Austroads, 2002). Human factors also relate to the physical ability of the driver.

The HSM (2010) stresses the fact that:

> "Drivers make frequent mistakes because of our physical, perceptual, and cognitive limitations… In transportation, driver error is a significant contributing factor in many crashes. For example, drivers can make errors of judgment concerning speed, gap acceptance, curve negotiation, etc. A driver can also be overwhelmed by the information processing required to carry out multiple tasks simultaneously, which may lead to error. To reduce their information load, drivers rely on some prior knowledge, based on learned patterns of response; therefore, they are more likely to make mistakes when their expectations are not met" (AASHTO, 2010, p.2.1).

Therefore, the errors and lapses in concentration come largely as a result of human physiology and our inability to be good road users because of our mental and physical ability.

The vehicle factors refer to the design, the manufacture, the condition or the mechanical faults of a vehicle. This also includes the maintenance and roadworthiness of the vehicle. The road factors include all aspects of road design and maintenance like geometric design, traffic control devices, surface friction, and construction activities. The environmental factors refer to weather conditions and problems with visibility due to rain and mist, etc. These three factors often combine in a sequence of events that result in a crash (Austroads, 2002).

2.4.1 Human Factors

According to the study done by Vogel (2004), human factors were found, to have caused 77.7% of RTCs on the R44, located in the Western Cape. In their "Status of Road Safety Report: Calendar: January - December 2018", the RTMC found that in South Africa, 89.2% of all the RTCs that occurred in 2018 were caused by human factors (RTMC, 2018). It must, however, be noted, that problems with the data quality exist for both of these study analysis results. These problems may include the limited list of crash factors considered in the crash reports, as well as, the under-reporting of many critical crash details. These results will, therefore, have to be compared to those obtained in this study. Regardless of the mentioned errors in the crash data used, the human factors as a cause in RTCs, still account for a frighteningly large percentage of all the crashes, confirming that many of these crashes are indeed avoidable and preventable.

Driving is a complex process in which a large number of variables with varying degrees of dependency engage with each other. The HSM (2010) suggests that to reduce crashes and crash severities, one would need to obtain a better understanding of the contributing factors and how they influence the sequence of events. Specific measures to target the contributing factors can then be developed and implemented (AASHTO, 2010). Even though human factors are proven to be the leading cause of RTCs, we know very little about the specifics of these factors in the South African road safety context.

The HSM (2010) further explains that:

> "The interdisciplinary study of the human factors applies knowledge from sciences such as psychology, physiology, and kinesiology to the design of systems, tasks, and environments for effective and safe use. The goal of human factors is to reduce the probability and consequences of human error within systems, and the associated injuries and fatalities, by designing for human characteristics and limitations" (AASHTO, 2010, p.2.1).

A substantial body of research exists worldwide, documenting and detailing the various aspects of the human factors in road safety. The literature review was divided into different sub-sections, which were used to further examine the human-related factors contributing to the severity of RTCs. The sub-sections studied are as follows:

- Driver Behaviour
- Driver Performance and Limitations
- Driver Inattention and Distraction
- Driving Task

2.4.1.1 Driver Behaviour

Disrespecting and breaking traffic laws are at the centre of road safety issues in South Africa, and can be directly attributed to unsafe human behaviour on the roads. Among the different human factors, driver behaviour has the largest effect on safety, bigger than driver performance and driver distraction. A variety of human behavioural factors are problematic, however, the most common factors resulting in fatal crashes are; failure to wear seatbelts, reckless driving, speeding and alcohol usage (RTMC, 2016c).

2.4.1.1.1 Speed

Speed is generally recognised as one of the biggest factors in road traffic crashes and road safety in general. According to Agbonkhese *et al*. (2013):

> "An increase in average speed is directly related both to the likelihood of a crash occurring and to the severity of the consequences of the crash. Travelling too fast for prevailing conditions or above the speed limit contributes to road traffic accidents. The risk of being injured increases exponentially with speed much faster than the average speed. The severity of accident depends on the vehicle speed change at impact and transfer of kinetic energy. Though vehicles travelling slower than average speed are also at increased risk of road traffic accidents, most involved speed too fast for the conditions" (Agbonkhese *et al*., 2013, p.92).

The severity of the crash is directly dependent on the deceleration rate of the vehicle during the time of impact. According to the SWOV (2012) "the possibility of a driver or passengers being killed in a vehicle travelling at a speed of 80 km/h is about 20 times higher than the possibility of being killed in a vehicle travelling at a speed of 32 km/h". Penden *et al*. (2004) cited the following factors cited as influencing the choice of speed: "the driver (age, gender, alcohol level and the number of people in the vehicle), the design of the road (quality of surface, width and layout), the vehicle (type, comfort and maximum speed limit), the traffic (volume, composition and prevailing speed), and the environment (weather, light and enforcement)" (Peden *et al*., 2004, p.76). A reduction in vehicle travel speed can, therefore, lead to a significant reduction in traffic crashes and road casualties.

2.4.1.1.2 Risky, Negligent and Aggressive driving behaviour

Many studies explain risky behaviour that leads to RTCs. When considering risky, negligent and aggressive driving behaviour, one must first differentiate between deliberate and unintended driver actions, in other words, between driver mistakes and violations.

According to Reason *et al.* (1990):

> "Recent analyses… have shown that unsafe acts… can be sub-divided into two distinct classes of behaviour: errors and violations… An error is defined as the failure of planned actions to achieve their desired outcome without the intervention of some chance or unforeseeable agency… Violations, on the other hand, may be defined as the deliberate infringement of some regulated or socially accepted code of behaviour... One way of distinguishing between them is through the issue of intentionality. An unintended infringement is… more likely to be an error than a violation. Deliberate infringements may be either malevolent…, or non-malevolent, in which no such intention was present. From the point of view of accident causation, non-malevolent violations are the class of greatest interest. Errors and violations differ both in their psychological mechanisms and in the kinds of remedial actions necessary to combat them. Errors arise as the result of information-processing problems; violations have a large motivational component. Errors may be understood in relation to the cognitive function of the individual (p.1036). Violations, however, are a social phenomenon and can only be understood in a broader organizational or societal context. Errors can be minimized by retraining, redesign of the human-machine interface, memory aids, better information and the like. Violations should probably be dealt with by attempting to change attitudes, beliefs and norms, and by improving the overall safety culture" (Reason *et al.*, 1990, p.1037).

According to the AAA Foundation for Traffic Safety (2016), aggressive driving activity in the US leads to a large proportion of fatal crashes. Aggressive driving activity is viewed as a significant threat to safety and appears to be progressively predominant. Research found the most common aggressive driving behaviours to be; tailgating another vehicle, blocking another vehicle, not allowing vehicles to change lanes, cutting off another vehicle in traffic, intimidating another driver to speed up or move over; and bumping or ramming another vehicle on purpose (AAA, 2016).

2.4.1.1.3 Alcohol use

International and South African research studies have indicated alcohol as a leading risk factor in RTCs. According to the RTMC (2009) alcohol is a factor in 60% of fatal RTCs in South Africa.

Zhao *et al*. (2014) conducted a study on the effects of alcohol on drivers and their driving performance. By using a driving simulator, they collected the subjective feelings and driving performance data of 25 individual drivers under different blood-alcohol concentration (BAC) levels. The results of the research conducted by Zhao *et al.* (2014) revealed that:

> "Alcohol affected drivers in different aspects; including attitude, judgment, vigilance, perception, and reaction. The controlling of the motor vehicle was also significantly impaired. Under the influence of alcohol, most drivers tend to be more impulsive and adventurous. The analysis of crash rates showed that higher BAC levels led to higher crash rates. Therefore, even in a simple driving environment, driving at a higher BAC level will be more dangerous. With regards to driving performance, the average speed, the standard deviation of the speed, the average lane position and the lane position standard deviation were significantly affected by alcohol intoxication, indicating changes in driving attitudes and behaviours. All of these performance indicators had a statistically significant linear trend as a function of the BAC level" (Zhao *et al*., 2014, p.7).

The use of alcohol is also a major contributing factor for pedestrians who are involved in RTCs. Dultz *et al*. (2011) investigated the influence of alcohol on pedestrian crossing patterns and behaviour. Data were collected between December 2008 and September 2010 on all pedestrians who were admitted to a trauma centre after being hit by a road vehicle. The results from the study revealed that alcohol-impaired pedestrians engaged in risky street-crossing behaviours. Pedestrians who were intoxicated were less likely than non-impaired pedestrians to cross the street at a dedicated, signalised pedestrian crossing and more likely to cross either in the crosswalk against the pedestrian signal or at midblock. Furthermore, alcohol use was related to both a higher injury severity score and longer hospital stay, compared to those who were not intoxicated. The study concluded that alcohol use is a major risk factor for pedestrians-vehicle crashes (Dultz *et al*., 2011).

2.4.1.1.4 Drug abuse

It has been widely recognised that "alcohol use impairs driving ability and increases crash risk" (Zhao *et al*., 2014, p.7). However, lately, there has been an increase in interest concerning the occurrence of drug use in driving and its contribution to road crashes. Drummer *et al*. (2003) researched the incidence of drugs in 3398 driver fatalities in Australian road traffic crashes. The study was steered in three Australian states, from 1990 to 1999. This study of drug-involved driving has indicated a substantial incidence of drug use other than alcohol. Drummer *et al.* described their findings as follows:

> "The results of this research revealed that in 29.1% of all drivers an alcohol level over 0.05 g/100 ml (%) was present, and in almost 10% of the cases both alcohol and drugs were involved. Drugs (other than alcohol) were present in 26.7% of cases and psychotropic drugs in 23.5%. These drugs comprised of cannabis (13.5%), opioids (4.9%), stimulants (4.1%), benzodiazepines (4.1%) and other psychotropic drugs (2.7%). Opioids consisted mainly of morphine, codeine and methadone, while stimulants consisted mainly of methamphetamine, MDMA, cocaine, and ephedrine… The prevalence of drugs increased over the decade, particularly cannabis and opioids, while alcohol decreased. The results of the study strongly suggest that driving under the influence of prescribed or illegal drugs increases the risk of having road crashes, just like driving under the influence of alcohol… As responsibility analyses suggest there is a need to recognize that recreational drugs are a significant cause of road traffic crashes, and therefore, there is a need to provide effective counter-measures to reduce the use of recreational drugs by drivers" (Drummer *et al*., 2003, p.162).

2.4.1.1.5 Seat-Belts, child restraint and helmet usage

Seat-belts, child restraints and helmets are safety devices provided to safeguard drivers and passengers during a crash. According to Agbonkhese *et al*. (2013) "seat belts are safety device provided to safeguard a driver in the course of an accident. The use of vehicle seatbelts also helps to ensure that the driver is in an upright and comfortable position thus enabling him/her to proper operate the vehicle. However, this provided safety device has been grossly abused thus increasing the risk of fatality among front-seat and of rear-seat passengers" (Agbonkhese *et al*., 2013, p.93).

According to the WHO, "the seat-belt is the single most effective safety feature to reduce the severity of injuries to the vehicle occupants in the event of a road traffic crash. All occupants should, therefore, be adequately restrained when travelling in a motor vehicle. Failure to use a seat-belt is a major risk factor for road traffic fatalities and injuries among vehicle occupants" (WHO, 2009: xix). "Like seat-belts, child restraints in vehicles are intended to keep a child firmly secured so that in the event of a collision the child is not thrown against the interior or ejected from the vehicle" (Elvik & Vaa, 2004, p.610). A review by the WHO (2009) on the effectiveness of seat-belts has found that "the risk of death for drivers and front-seat passengers is reduced by 40 to 50%, and the risk for rear-seat passengers is reduced by 25%. On the effectiveness of child restraints it was found that the risk of death for infants is reduced by 70% and by 47 to 54% for children aged 1 to 4 years" (WHO, 2009: 12). Elvik & Vaa explained that;

> "The effect of child restraints varies depending on the type of child restraint used. The use of the appropriate type of child restraint for a child's age, height, weight and physical limitations reduces deaths of children by between 50% and 75%. Children should, therefore, use restraints that are suitable for their size. A child up to 4 years of age has a 50% lower risk of injury in a forward-facing child restraint and 80% lower risk in a rear-facing seat, compared to an injury reduction of only 32% when an adult seat-belt is used. For children aged 5 to 9 years, child restraints reduce injury by 52%, whereas for seat-belts alone the reduction is only 19%. For children aged 10 to 14 years, seat-belts usage reduces injury by 46%" (Elvik & Vaa, 2004, p.611).

The World report on traffic injury prevention shows that wearing a helmet in motorised two-wheelers reduces head injuries by 45% and fatalities by 20% (Peden *et al*., 2004).The use of safety devices has, however, been grossly neglected, thus increasing the risk of fatalities and injuries among drivers and passengers. The rates of seat-belt usage vary greatly between countries. The use of safety devices is governed by the type of laws, as well as, the degree to which these laws are enforced. "In South Africa, it was found that 81% of drivers, 50% of front-seat passengers and 8% of rear-seat passengers use seat-belts regularly. The use of child restraints is common in many high-income countries, with usage rates as high as 90%" (WHO, 2009). Sadly though, in low- and middle-income countries child restraints are still seldom used. Restraints are also frequently misused, placing the child at an increased risk of injury. Choosing and installing the appropriate child restraint system is important.

Kling *et al.* note that; "despite the extraordinary success in reducing deaths and serious injuries, the rate of use of appropriate child restraints in motor vehicles in South Africa remains dismal. Usage rates as low as 10% have been observed" (Kling *et al*., 2011, p.1).

In terms of the safety laws the WHO explains as follows: "The enforcement of laws and adoption of safety standards, such as the availability of seat-belts and fitments for car occupants in both front and rear seats, remain challenging in many countries" (WHO, 2018, p.xii). Seat-belt and child restraint usage, in South Africa, is regulated under Regulation 213 of the National Road Traffic Act, 93 of 1996. On October 31, 2014, South Africa's Minister of Transportation issued amendments to the National Road Traffic Regulations of 2000, which are under the National Road Traffic Act of 1996. These amendments included an extension to the child restraint regulations, which previously had only applied to children above the age of three, to now also cover infants.

The Government gazetted, amended regulations (2014) state that; "the driver of a motor vehicle operated on a public road shall ensure that an infant (a person under the age of three years) travelling in such a motor vehicle is seated on an appropriate child restraint." The regulations further require that "a driver of a motor vehicle must ensure that a child (all persons between the ages of three and fourteen, except those taller than one and a half meters) in the vehicle use a child restraint if one is available, or wear a seat-belt in a seat that is equipped with one. If no seat-belt is available and the vehicle is equipped with a rear-seat, the driver must ensure that the child is seated in the rear-seat" (Republic of South Africa, 2014). However, Greathead (2017) points out that "these requirements do not apply to the transportation of infants in a minibus, midibus or bus operating for payment. Current laws do, therefore, not adequately address overloading."

According to Regulation 231 (2014), of the Republic of South Africa, when transporting children in a single-vehicle, the children may be counted as follows:

"Any child under the age of three is not counted; two children between the age of three and six are counted as one person, and three children between the age of six and 13 are counted as two people."

Greathead (2017) further notes that "this means in an eight-seater minibus taxi, there can legally be more than 16 children seated within that vehicle depending on their age. It is, therefore, essential to re-evaluate the current legislation to protect the most vulnerable members in our society. We urgently need to address overloading of children in vehicles" (Greathead, 2017).

2.4.1.2 Driver Performance and Limitations

The causes of RTCs are complex and broadly depend on the performance and limitations of drivers. This part reviews driver limitations and capabilities which can have an impact on safety. Study topics covered are driver's age and gender, driver's experience, vision capability, night-time driving, and the driver's potential for risk-taking. "Factors such as inexperience, lack of skill, and risk-taking behaviours are associated with the crashes of young drivers. In contrast, visual, cognitive, and mobility impairment crashes are more associated with older drivers" (Rolison *et al*., 2018, p.11). Approximately 90% of the information that drivers use is visual. Visual acuity determines how well drivers can see details at a distance. It is essential for guidance and navigation tasks, which require reading signs and identifying potential objects ahead (AASHTO, 2010, p.2.4).

2.4.1.2.1 Driver's Age

The driver's age is generally regarded to be a key contributing factor to the occurrence of fatal crashes. Studies have shown that the youngest and oldest drivers have a much higher crash risk than drivers in the middle-age ranges. Wei & Eustace (2010) conducted a study in the United States into The role of driver age and gender in Motor Vehicle Fatal Crashes. Wei & Eustace (2010) found that:

> "Younger drivers (16 to 19 years of age) and the elderly (those 75 and older) were responsible for a disproportionate number of fatal crashes. When combined, these two groups accounted for only 6% of the total kilometres driven in 2001 but they were responsible for 83% of the fatal crashes attributed to driver-related errors. The youngest drivers tended to be carrying the highest number of passengers when they were involved in fatal crashes" (Wei & Eustace, 2010, p.26).

Jonah (1986) notes that "young drivers are less likely to anticipate hazardous situations, are more likely to travel with shorter headways, accept narrower gaps in traffic, change lanes improperly, exceed the speed limit and not use their seat belts, compared to their older counterparts" (Jonah, 1986, p.271). Due to the deterioration of coordinating systems, older drivers are more involved in serious or fatal crashes (Karthaus & Falkenstein, 2016). Older drivers are more likely to have cognitive and motor perceptual deficits that affect driving performance, however, the older driver is usually able to compensate for minor functional declines, and therefore, it is key to determine fitness to drive in light of a multi-dimensional evaluation (Morgan & King, 1995). Driver perception-reaction times should also be considered in relation to ageing drivers. Older drivers require more time to process information and make decisions (Lerner, 1994).

2.4.1.2.2 Driver's Gender

Several road safety research studies have addressed the association between the gender of the driver and an elevated crash-risk (Regev *et al*., 2018). Female are generally considered safer drivers than males (Massie *et al.*, 1997). Some research; however, propose that while women tend to be involved in fewer fatal crashes, they have a higher risk of being involved in injury related crash (Massie *et al*., 1995; Santamariña-Rubio *et al*., 2014). The gender of the responsible driver has shown to affect the severity of crashes. The difference in fatal crashes per gender is astounding, with males accounting for 75% and females for only 22% of fatal crashes, with 3% being unknown (RTMC, 2018). Traditionally, researchers have accounted these differences to the amount of travel exposure (Massie *et al*., 1995). Özkan & Lajunen (2006) however, presented a study, which found that being a safe driver is regarded as having feminine characteristics; this is because femininity is highly related to possessing certain safety skills. According to Taylor *et al.* (2011) "women report higher levels of anxiety and fear about driving than men... In general, women also more often evaluate the situation from an emotional perspective. Men are more likely to crash because of an incorrect evaluation of the situation. They tend to misinterpret the situation and as a result, take the wrong action. Other known contributing factors are; inattention, unfamiliar roads, lack of experience, and others" (Taylor *et al*., 2011, p.65).

In their study, Wei and Eustace (2010) found that "Driver operating error was listed as the contributing factor in 73% of fatal motor vehicle crashes when the driver was male and 83% of the crashes when the driver was female. Failing to stay in the proper lane and driving too fast for road conditions were the two most frequent driver operating errors contributing to fatal crashes for male and female drivers" (Wei & Eustace, 2010, p.28).

2.4.1.2.3 Driver experience and skill

Several road safety research studies have addressed driver experience and skill and an elevated crash-risk. According to Alfonsi *et al*. (2018):

> "Driving inexperience constitutes a deficiency that can lead to operating errors. Driving experience plays an important role in the development of several cognitive and behavioural skills, like hazard recognition, information processing, and vehicle manoeuvring. In general novice drivers and drivers with fewer years of experience are related to a higher crash risk when compared to more experienced drivers. Lack of driving experience, in terms of kilometres

> driven, affects vehicle manoeuvring such as steering competence. It also increases the tendency to commit operative errors like hard braking or close following, and therefore, increases the probability to be involved in crashes and near-miss crashes" (Alfonsi *et al*., 2018, p.2).

"The lack of driving experience and familiarity with hazards in the road environment also accounts for the heightened risk of youthful morbidity and exacerbates crash risk" (Zhang *et al*., 1998).

2.4.1.2.4 Medical Conditions

Lindsay & Baldock (2008) conducted a study on medical conditions as a contributing factor in crash causation. According to Lindsay & Baldock they found that:

> "Nearly 50% of the drivers and pedestrians, involved in the crashes under investigation, had at least one pre-existing medical condition. But an even more significant finding is that a medical condition was the primary causal factor in 13% of the fatality crashes investigated. This finding demonstrates that medical conditions and acute medical events contribute to the risk of crash involvement and further indicates that the contribution is likely to be higher than those found by previous studies" (Lindsay & Baldock, 2008, p.612).

In a, 1996 study, conducted by Sjogren *et al*., the researchers proposed that intrinsic medical factors were probably the underlying cause of approximately 6% of crashes (Sjogren *et al*., 1996). Lindsay & Baldock (2008) may have found higher than previously reported percentages, because of the diversity in data sources accessed in their study, and their ability to incorporate additional medical information gathered at the scene for each crash under investigation. "The inclusion of in-depth interviews with participants provides a further dimension to the general understanding of the events leading to the collisions and the role of the medical condition in the crash. It must, however, be noted, that the crashes investigated in this study were not a representative sample of all metropolitan fatality crashes; more than 90% of those crashes investigated, occurred between 8 am and 10 pm, Monday to Friday. This fact can potentially result in a bias towards the elderly, who tend to travel mainly during daylight hours, and away from young, and alcohol-impaired drivers. Further research of this under-explored area of road safety is, therefore, necessary to confirm these findings and inform road safety policymakers and the medical profession when considering future countermeasures" (Lindsay & Baldock, 2008, p.620).

Furthermore, some existing medical conditions, like epilepsy, for example, have been identified as conditions that are associated with increased risk should a person suffering from these diseases be allowed to drive (Bekibele *et al*. 2007). It should be noted that many common drugs and acute psychological stress affect driving ability by reducing concentration levels, thereby raising the risk of a crash. Often, long-distance drivers neglect their health issues and drive with headaches and other impairments or take self-help pain-relieving medications because they do not have enough time to see a doctor. As a result, they risk being involved in an accident and harming other road users.

2.4.1.2.5 Vision related issues

The driving task is a highly visual one. An approximate 90% of the information used while driving is visual (Hills, 1980). It is, therefore, of the utmost importance that information is communicated to the driver so that the driver's visual capacity variation is taken into account, allowing them to see, understand and respond appropriately to the message. “The amount of time and distance needed by a driver to react to a stimulus (e.g., road hazard, traffic control device, or sign) depends on the human elements, including information processing, driver alertness, driver expectations, and vision” (AASHTO, 2010, p.2.20).

Driver eye fixations have been an interest of study for researchers over many years, particularly, using eye fixations as a means of studying the process by which drivers acquire visual information. The term "eye fixations" refers to where the subject is looking with central (foveal) vision (Olson *et.al.*, 1989). The driver has a limited ability to process input, due to the “rate at which the eye can move from one object to another and re-focus” (Ogden, 1996). Research by Cole & Jenkins (1982) revealed that a rate of 1 to 1.5 fixations is reasonable for normal driving. It can, therefore, be concluded that, although the brain can process more information per second, the fixation rate is the limiting factor. Apart from the fixation rate, Cole (1972) notes that the vision field of the driver also plays a vital role. For a driver to see visual information, the information needs to be in the vision field of the driver. For a stationary driver, the driver will see and understand visual input within 10 to 12 degrees of the line of sight, observe objects in peripheral vision to 90 degrees right and left, 60degrees above the line of sight and 70 degrees below the line of sight. When the driver is driving, the visual field narrows as the eye focuses further ahead. At 30 km/h the visual field decreases from 180 to 100 degrees, and at 100 km/h it is about 40 degrees (Cole, 1972).

Shinar *et.al*, (1977) found that "drivers use perceptual and road message cues to determine a speed they perceive to be safe. Information, taken in through peripheral vision may lead drivers to speed up or slow down depending on the distance from the vehicle to the roadside objects." The researchers furthermore found considerable differences in eye scanning behaviour comparing straight and curved highway sections. In general, eye fixations on curves were of shorter duration than those on straight sections (Shinar *et.al*., 1977). When studying car-following patterns, Mourant & Rockwell (1970), discovered that the presence of a lead car alters eye fixation patterns significantly. Their results show that the spatial distribution of eye fixations is narrowed significantly under car-following conditions, with the lead car becoming the focus point for many drivers (Mourant & Rockwell, 1970).

Adams (2011) points out that various medical and visual disorders can also have an adverse effect on vision. "Good visual acuity, good stereopsis, normal colour vision, satisfactory eye co-ordination and the ability to adapt to various levels of illumination is essential to a driver to avoid RTCs" (Pepple & Adio, 2014, p.1). Good vision is also essential for jobs involving driving, as drivers with a noticeable lack of visual acuity or visual field would not be able to drive safely, as they may not detect other vehicles or potentially dangerous situations. Since good vision is necessary for safe driving, workers whose jobs involve driving and who have reduced vision can be a threat to their own safety as well as co-workers, the public and the environment. It is, therefore, essential that their health is regularly evaluated to check that they meet the fitness standards to drive with respect to vision (Adams, 2011).

2.4.1.2.6 Driving at night

Night-time driving is arguably one of the most dangerous activities modern society has to face during everyday life. This is because of the disproportionate incidence of fatal crashes compared to the volume of traffic for the same period. Even though there is considerably less traffic present on the roads during the hours of darkness, much more crashes and fatalities occur. A study by Gaza & Kiec (2013), conducted on the national roads in Poland, found that about 40% of all crashes took place during insufficient road lighting conditions, i.e. night, dusk and dawn. The study also found that while the share of traffic during the night, which is the measure of risk exposure, was more than 20%, the share of fatalities was more than 50% for the same period. The fatality risk was, therefore, found to be about 4-times higher on roads at night-time when compared to daytime (Gaza & Kiec, 2013).

According to Plainis *et al*. (2006) "our visual world is relatively impoverished under dim conditions; the spatial and temporal resolution is poor, contrast sensitivity diminishes, and the colour vision is distorted or absent." Adams (2011) notes**,** that ageing can also decrease a person's ability to adapt to light variations and heighten their sensitivity to glare, which further impair night driving ability (Adams, 2011).

2.4.1.2.7 Risk homeostasis

Wilde (2014, p.7) provides the following definitions to describe the principle of Risk Homeostasis:

- To take a Risk: "to expose oneself to potential loss".
- Target Risk: "the level of risk a person chooses to accept in order to maximize the overall expected benefit from an activity".
- Homeostasis: "a regulating process that keeps the outcome close to the target by compensating for disturbing external influences".
- Risk Homeostasis: "the degree of risk-taking behaviour and the magnitude of loss due to crashes are maintained over time, unless there is a change in the target level of risk".

According to Wilde (2014, p.32), "a variety of factors determine the extent of the crash risk that different people are willing to take. When the expected benefits of risky behaviour are high and the expected costs are perceived as relatively low, the target level of risk will be high."

The target level of crash risk is determined by four categories of motivating factors (Wilde 2014, p.32).

1. "The expected advantages of comparatively risky behaviour alternatives: for example, gaining time by speeding".
2. "The expected costs of comparatively risky behaviour alternatives: for example, vehicle repair costs."
3. "The expected benefits of comparatively safe behaviour alternatives: for example, insurance discount for crash-free driving."
4. "The expected costs of comparatively safe behaviour alternatives: for example, using an uncomfortable seatbelt."

Wilde (2014) explains that:

> "Some of the motivating factors in all four categories are economic; others are of a cultural, social or psychological kind. They are usually so thoroughly internalized that most people, most of the time, are not consciously aware of them. Individual road users experience or anticipate, at any moment, a certain amount of danger, and they compare this with their target level of risk. The level of traffic crash risk that is perceived by a person at any moment derives from three sources: the person's experience with traffic, the person's assessment of the crash potential of the immediate situation, and the degree of confidence the person has in possessing the necessary decision-making and vehicle-handling skill to cope with the situation. Road users continuously monitor the perceived amount of crash risk, compare this with their target level, and attempt to reduce any difference, be it positive or negative, between the two" (Wilde 2014, p32).

According to Wilde (1982):

> "The crash rate is ultimately dependent on one factor only, the target level of risk in the population concerned, which acts as the reference variable in a homeostatic process relating crash rate to human motivation. Various policy tactics to modify this target level of risk have been pointed out and therefore no strategy for countermeasure design or future research in the areas of human behaviour which leads to traffic crashes can be rationally developed without an acceptable working theory of human behaviour in these domains" (Wilde, 1982, p.215).

2.4.1.3 Driver Inattention and Distraction

Several road safety research studies have addressed driver inattention and distraction and an elevated crash-risk. Driver distraction and inattention in its various forms is thought to play a role in 20-30% of all road traffic crashes. According to the HSM (2010):

> "Driver attention and the ability to process information are limited. These limitations can create difficulties because driving requires the division of attention between control tasks, guidance tasks, and navigational tasks. As with decision making of any sort, error is possible during this process. A driver may neglect a piece of information that turns out to be critical, while another less-important piece of information was retained" (AASHTO, 2010, p.2.2).

Wang *et al*. (1996) states: "Distraction is caused by a competing activity, event or object from inside or outside the vehicle." Drivers not only look at the road but also at the various in-vehicle displays and mirrors. In-vehicle displays like touch screen radios, climate control, traffic monitoring systems, and vehicle gauges may force the driver's visual attention away from the road for long periods (Olson *et.al.*, 1989). Zhang *et al*. (2013) define a hazard as "any possible source of danger from any direction, on or near the road that could lead to a crash." Agbonkhese *et al*. (2013) note some practices which pose as distractions, with a tendency to cause crashes. These include "paying attention to billboard signs, mobile phone usage or text messaging, driver fatigue, listening to music, applying makeup, eating, and interaction with passengers." (Agbonkhese *et al.*, 2013). These distractions create longer reaction times in emergencies; lead to reduced capability to maintain a safe following distance, and results in drifting towards other driving lanes (Oluwole *et al*., 2014).

Bungum *et al*. (2005), furthermore, found pedestrian distraction to be a main contributing factor in pedestrian-vehicle crashes. Bungum *et al*. (2005) defined distracted pedestrians as "those wearing headphones, talking on a cell phone, eating, drinking, smoking or talking as they crossed the street" and concluded that "approximately 20% of walkers were distracted as they crossed the street" (Bungum *et al.*, 2005, p.269). Hatfield & Murphy (2006) further found that distractions such as mobile phones reduce the road crossing speeds of pedestrians (Hatfield & Murphy, 2006, p.197).

2.4.1.3.1 Mobile phone usage

Mobile phone usage while driving has become a serious safety risk. According to Dragutinovic & Twisk (2005) "distraction is caused by a competing activity, event or object from inside or outside the vehicle. Safety problems related to driver distraction are expected to escalate in the near future as more technologies become available for use in motorised vehicles. A relatively new technology, already widely accepted, is the mobile phone" (Dragutinovic & Twisk, 2005, p.3).

According to Hutton (2011) "Africa is in the midst of a technological revolution, and nothing illustrates this fact more than the proliferation of mobile phones. More Africans have access to mobile phones than to clean drinking water. In South Africa, the continent's largest economy, mobile phone use has gone from 17% of adults in 2000 to 76% in 2010. Today, more South Africans use mobile phones than radio (28 million), TV (27 million) or personal computers (6 million)" (Hutton, 2011).

Dragutinovic & Twisk (2005) further reports as follows on mobile phone usage:

> "While it is clear that mobile phones enhance business communication and increase personal convenience, the use of mobile phones while driving has become a serious road safety concern. The vast majority of drivers internationally (60 to 70%) report using their mobile phone at least sometimes while driving, and it is estimated that at any given moment during the day, 1 to 4%

of the drivers is using a mobile phone. The mobile phone distracts drivers in two ways; it causes physical distraction and cognitive distraction. Physical distraction occurs when drivers have to simultaneously operate their mobile phone (i.e. reach, dial, hold) and operate their vehicle. Cognitive distraction occurs when a driver has to divert part of his/her attention from driving to the telephone conversation. However, the ability to divide one's attention between two simultaneous tasks is limited. Mobile phone use while driving could, therefore, negatively affect driving performance. The results of epidemiological studies strongly suggest that using a mobile phone while driving can increase the risk of being involved in a road crash up to four times" (Dragutinovic & Twisk, 2005, p.3).

2.4.1.3.2 Driver Fatigue

Fatigue is considered a major contributory factor in road crashes. Fatigue is associated with a reduction in mental and physical performance, which in turn could lead to reduced driving performance (Thiffault & Bergeron, 2003). Various studies have found that fatigue affects driving behaviour by; slowing a driver's reaction time in an emergency, reducing vigilance, reducing the ability to process information, and by affecting short term memory (Philip *et al*. 2005).

Driving at night-time, existing health issues, medication, substance abuse, inadequate sleep, sleep disorders and prolonged working hours, are all situations likely to increase fatigue-related crashes (Venter *et al*., 2013). Fatigue is the effect of various factors that impact consciousness, and lead to drowsiness. All of these are connected and contribute to crash causation (Sagberg *et al*., 2004). Muviringi (2012, p.16) states that "driver fatigue is common in commercial and public transport drivers due to long hours of work and long distance travelling especially for the cross-border vehicles."

Komba (2006), notes that "the possible reasons for exceeding the allowable driving hours by commercial drivers, while fatigued, are incentives given to them for delivering services in time and also the limited number of parking spaces for trucks in rest areas forcing them to continue driving. Fatigue-related crashes typically involve only one vehicle, which may have steered off the road, and typically occur at night-time" (Komba, 2006, p.37).

Fatigue-related crashes also frequently happen over weekends or during the early morning hours, at speeds higher than normal and tend to lead to more serious outcomes. Furthermore, it is highly recommended that areas of rest be planed before drivers start a long journey (Muviringi, 2012).

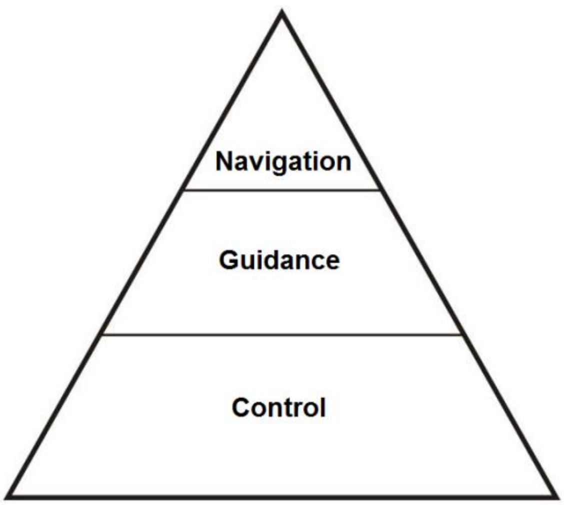
2.4.1.4 Driving Task

Driving consists of several sub-tasks, some of which must be carried out simultaneously. According to the HSM (2010) the three main sub-tasks are:

> "*Control* - Keeping the vehicle at a desired speed and heading within the lane; *Guidance* - Interacting with other vehicles (following, passing, merging, etc.) by maintaining a safe following distance and by following markings, traffic control signs, and signals; and, *Navigation* - Following a path from origin to destination by reading guide signs and using landmarks" (AASHTO, 2010, p.2.1).

The HSM (2010) further explains that:

> "Each of these sub-tasks involves observing different information sources and various levels of decision-making. [The relationship between the sub-tasks can be illustrated in a hierarchical form, as shown in Figure 2-4]. The hierarchical relationship is based on the complexity and primacy of each sub-task to the overall driving task. The navigation task is the most complex of the subtasks, while the control sub-task forms the basis for conducting the other driving tasks. A successful driving experience requires smooth integration of these three tasks, with driver attention being switched from one to another task as appropriate for the circumstances. This can be achieved when high workload in the sub-tasks of control, guidance, and navigation does not happen simultaneously. One way to accommodate for human information processing limitations is to design roadway environments in accordance with driver expectations. When drivers can rely on experience to assist with control, guidance, or navigation tasks there is less to process because they only need to process new information" (AASHTO, 2010, p.2.2).



Source: AASHTO (2010)

Figure 2-4: Driving Task Hierarchy

2.4.1.4.1 The Driving Task Hierarchical Structure

To date, various researchers developed Driving Task Hierarchical Structures and frameworks. One of the key contributions in this field was research done by John A. Michon. Michon allocated the task of driving into a hierarchical behavioural framework whereby the driving task was divided into strategic, tactical (or manoeuvring), and control (or operational) levels. The following part discusses Michon's Driving Task Hierarchical Structure in more detail.

Michon (1985) describes the theory as follows:

> "Human mobility is embedded in a social, as well as in a technological environment. Traffic and transportation issues should thus be treated, in terms of, the characteristics of a system in which the human being is only one of the many components, albeit an important one (p.488). The most characteristic feature of the human component in this system is its behaviour as an intelligent problem solver. Taking this point of view one may outline a descriptive framework which allows the specification of a number of basic tasks that together constitute the set of relations between people and the environment in which they attempt to satisfy their mobility needs. In this context, it is possible to distinguish four stable levels at which humans are in systematic interaction with the transport and traffic system as such. These levels may be defined by reference to a person's role as an active road user, a transportation consumer, an active social being, and a psycho-biological organism, satisfying several basic needs respectively. [Table 2-4] specifies these four functional levels relative to the (problem-solving) context in which they appear. One should keep in mind that these levels are coupled with what we can probably best be described as a nested hierarchy" (Michon, 1985, 489).

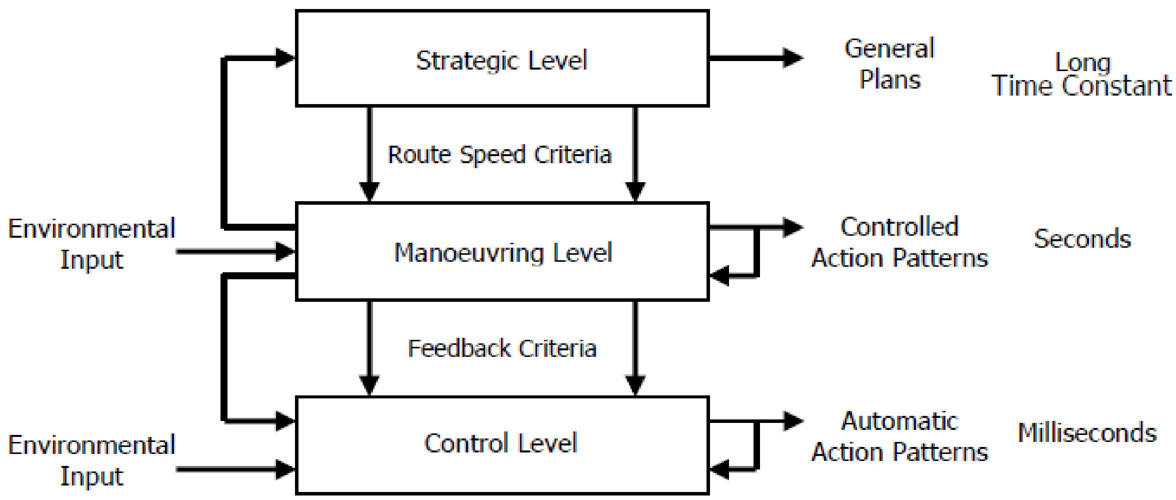
Table 2-4: The hierarchical structure of problem solving tasks in traffic and transportation

	BEHAVIORAL LEVEL			
	I	II	III	IV
Human Quality as a Problem Solver	Road User	Transportation Consumer	Social Agent	Psycho-Biological Organism
Problem to be Solved	Vehicle Control	Trip Making	Activity Pattern (Communication)	Satisfaction of Basic Needs
Task Environment	Road	Road Network (Topographical Structure)	Socio-Economic Structure	Nature (Environment)
Task Aids	Vehicles, Signs, etc.	Transport Mode	Transport System	"Culture" Technology

Source: Michon (1985)

Michon (1985) continues by suggesting that:

> "The generalized problem solving task of the *driver-qua* [the driver, in his/her capacity of a] road user-may be further divided in three levels of skills and control: strategical (planning), tactical (manoeuvring), and operational (control) respectively. [Figure 2-5 represents the performance structured at the three levels, comparatively coupled, with the internal and external outputs indicated]. The strategical level defines the general planning stage of a trip, including the determination of trip goals, route, and modal choice, plus an evaluation of the costs and risks involved. Plans derive further from general considerations about transport and mobility, and also from concomitant factors such as aesthetic satisfaction and comfort. At the tactical level drivers exercise manoeuvre control allowing them to negotiate the directly prevailing circumstances (p.489). Although largely constrained by the exigencies of the actual situation, manoeuvres such as obstacle avoidance, gap acceptance, turning, and overtaking, must meet the criteria derived from the general goals set at the strategical level. Conversely these goals may occasionally be adapted to fit the outcome of certain manoeuvres. A comprehensive model of driver behaviour should not only take the various levels into account, but should also provide an information flow control structure that enables control to switch from one level to the other at the appropriate points in time" (Michon,1985, p.490).

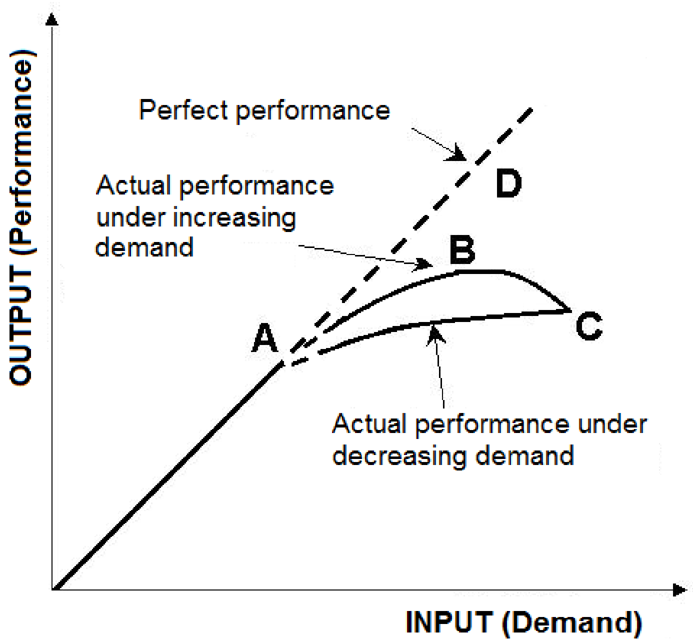


Source: Michon (1985)

Figure 2-5: The hierarchical structure of the road user task

2.4.1.4.2 The Hysteresis Effect and Information Processing Process

According to Cumming & Croft (1973) the hysteresis effect refers to the phenomenon where, when a driver is significantly overloaded, the performance output of the driver will decrease even if the demand on the driver is reduced. Figure 2-6 represents the rate of input demand (frequency at which different tasks are given to the driver) and the output performance **(**resultant frequency at which decisions are processed).



Source: Cumming & Croft (1973)

Figure 2-6: Basic Model of Information Processing

Cumming & Croft (1973) explains the process as follows:

- When demand is low, the output performance equals demand, resulting in the correct processing of all demand inputs, and the decisions are all appropriate.
- As input demand increases to point A, the rate of output performance decreases to a point below the rate of input demand.
- Navigation, explained by Cumming & Croft (1973) as the process of “following (a) path from origin to destination by reading guide signs and using landmarks.”
- If input demand increases beyond point A, the output performance will increase but at a much a lower rate than input demand. A gap will then be created between the input and the output.
- At point B, the driver’s output performance reaches a peak, where after it will fall away with an information overload, which is a direct result from the continued input demand increase.

- At point C, the driver is significantly overloaded. At this point, the driver performance output will continue to reduce even after the demand input gets reduced, this is indicated by the lower curve CA.
- The difference between line AD and line ABC indicates the gap between input demand and output performance and, shows an error, a failure to detect input demand information which is, shed selectively and deliberately.

Ideally, the road traffic system should allow for the driver to shed some information which is not immediately important, for the driving task to ensure that the overall demand does not increase beyond point A. Unfortunately, drivers tend to engage in self-pacing, i.e. setting a pace for themselves, that is at or slightly beyond the rate that allows for some error in performance (near point A). In the case where additional demand is then added, the driver will, miss a signal, or mistakenly shed the wrong information, resulting in a crash (Cumming & Croft, 1973).

2.4.1.4.3 Reaction Time

Lumenfield & Alexander (1984) defines reaction time as the period between the appearance of input (usually visual) and the physical reaction of the driver in response to it. Reaction time increases with an increase in decision complexity and content of the information. It is important to note that a complex decision will take longer and will decrease the available time to attend to other input, thus increasing the probability of driver error (Lumenfield & Alexander, 1984).

According to Garber & Hoel (2009), reaction time consists of the following four elements:

- Perception – The driver uses his/her visual capabilities to see a visual signal/ input.
- Identification – The driver understands the stimulus and identifies the signal.
- Emotion – The driver decides how to respond to the stimulus (e.g. to turn the steering wheel or to apply the brakes).
- Volition – The driver executes the action decided upon.

(Garber & Hoel, 2009)

The safety of a design or operation can be improved by reducing the average reaction times and the variance of reaction times, especially the longer reaction times (Garber & Hoel, 2009).

2.4.2 Vehicle factors

According to Vogel (2004), vehicle factors were found, to have caused 6.4% of RTCs on the R44, located in the Western Cape. In their "Status of Road Safety Report: Calendar: January - December 2018", the RTMC found that in South Africa, 7.5% of all the RTCs that occurred in 2018 were caused by vehicle factors (RTMC, 2018). The contribution of the vehicle factors in RTCs, in South Africa, is markedly higher, when compared to studies conducted in America and Australia, where the vehicle factor contribution is only 2%. The reason for this variance can be explained when investigating the high number of un-roadworthy, un-licenced and poorly maintained vehicles on South African roads. According to the RTMC (2018), a total number of 1 170 166, un-roadworthy and un-licenced, vehicles were recorded from December 2017 until December 2018 on South African roads. Considering that a total number of 12 465 979 vehicles were registered for the same period, it can be said that one out of every ten vehicles on South African roads are un-roadworthy (RTMC, 2018).

The condition of the vehicles travelling on the road may determine whether a crash would occur or not. Research studies identify vehicle factors as a contributing factor to RTCs. The vehicle factors influencing the risk and severity of RTCs include among others; the vehicle type, the vehicle design, the mechanical condition of the vehicle and tyres, the on-board safety devices such as seatbelts, side mirrors, wiper blades, the braking system, and the condition of the head- and break-lights. All of these have an influence on a driver's ability to maintain control of the vehicle to avoid a road traffic crash. Malfunction of any vehicle factor can cause serious problems, which in turn may result in a traffic crash.

Agbonkhese *et al*. (2013), explains that:

> "The reliability of the vehicle is itself a function of the condition of the vehicle at every given time. Vehicle components and vehicle maintenance are the two main conditions which affect vehicle factors as it relates to causes of road traffic crashes... The assembled components of a vehicle working effectively uniformly or abnormally as a unit will determine the occurrence of a traffic crash" (Agbonkhese *et al*., 2013, p.93).

2.4.2.1 Vehicle Design

The maximum load-carrying capacity of a vehicle is considered an important design element. Adhering to the specified carrying capacity of a vehicle not only ensures the stability of the vehicle when negotiating the road alignment but also ensures the operating condition of the vehicle is not unnecessarily compromised. Subjecting a vehicle to loads higher than the maximum specified carrying capacity may lead to the premature failure of some design elements such as the brakes and steering. Once a vehicle has been subjected to such conditions, defects in the vehicle design may also be exposed, which in turn can result in road traffic crashes (Agbonkhese *et al*., 2013, p.93).

2.4.2.2 Vehicle Brakes

The ability to apply brakes, and safely bring a motor vehicle to a complete stop, is considered a critical requirement for safe driving, as well as, to avoid traffic crashes. Safe braking is especially vital for pedestrians and cyclists, as these vulnerable road users often fall victim to inattentive drivers. With new technologies, including Autonomous Emergency Braking (AEB), vehicle manufacturers are constantly trying to improve on the design of braking systems to advance vehicle safety and minimize RTCs. Vehicles use a combination of the accelerator and the braking mechanisms to synchronize the speed of the vehicle. A malfunction in the braking system would, therefore, be considered serious, and could potentially lead to an unavoidable crash (Agbonkhese *et al*., 2013, p.94).

2.4.2.3 Vehicle Tyres

The type and condition of tyres is considered a key factor in determining the stability of any road vehicle. Tyres are designed for and specified for use in specific temperatures, road surface conditions and terrain. Agbonkhese *et al*. (2013), notes that:

> "Vehicle owners do not take the specification of tyres into consideration when buying and fixing tyres onto their vehicles and this has been known to cause tyre raptures thus leading to traffic crashes. Some other tyre related causes of road crashes could be due to one or a combination of overinflated tyres, underinflated tyres, [and the] thread of tyres" (Agbonkhese *et al*., 2013, p.93).

2.4.2.4 Vehicle Type

George *et al*. (2016) investigated the severity of road crashes per vehicle type involved. For their investigation, the investigators developed separate crash severity models for each vehicle type. The effects of the specific type of crash and the weather conditions, on crash severity, were investigated for each vehicle type. George *et al.* (2016) found that:

> "In general, good weather conditions and crashes during the night were found to be associated with increased crash severity… crash types were found significant in most models severity is investigated. However, the influence is not always the same and depends on the vehicle type involved. Therefore, it can be concluded that crash type plays an important role when accident severity is examined" (George *et al*., 2016, p.2082).

Refer Table 2-5 below for the distribution of injuries per vehicle type. It should be noted "that the largest percentage of fatalities occur when trucks are involved (12.7%), while the lowest percentage (3.6%) when a bus is involved" (George *et al*., 2016, p.2077).

Table 2-5: Injuries distribution per vehicle type

Vehicle Type	Car	Truck	Bus	Scooter (<50cc)	Motorcycle (>50cc)
Fatalities	8.40%	12.70%	3.60%	6.30%	5.30%
Severe injuries	9.00%	9.90%	5.40%	12.30%	9.80%
Slight injuries	82.60%	77.40%	91.00%	81.40%	84.90%

Source: George *et al*. (2016)

2.4.2.5 Vehicle Lights

Vehicle headlights illuminate the road ahead and provide light which allows the driver to keep the vehicle within the travelling lane, detect obstacles, other vehicles, road signs, road markings, animals, pedestrians and other targets in times of darkness, and poor lighting conditions. Headlights also make the vehicle detectable for other traffic and road users (Boyce, 2003).

Agbonkhese *et al*. (2013) note that "the failure of vehicle light(s) is a major factor in road traffic crashes. Failure of vehicle lights has a tendency to misinform and mislead other road users thereby providing a good opportunity for an accident to occur" (Agbonkhese *et al*., 2013, p.94).

2.4.2.6 Vehicle Engine

The engine is the power train of the vehicle and is responsible for bringing the other parts into motion. Failure of the engine sub-system may be catastrophic and can lead to a severe crash, especially during high traffic volume conditions on a highway. Agbonkhese *et al*. (2013) note that; "even when the traffic is reasonably low, mismanagement of the situation by an inexperienced driver could cause a road traffic crash" (Agbonkhese *et al*., 2013, p.93).

2.4.2.7 Vehicle Maintenance

The design specifications of a vehicle are not always sufficient to prevent the vehicle from being involved in a crash. Adhering to a maintenance schedule and conducting regular quality inspections are essential safety and performance measures on any vehicle, as deterioration of the mechanical sub-systems can lead to the vehicle becoming a higher crash risk. A well-maintained vehicle is less likely to malfunction and thus less likely to be involved in a crash. A well-maintained vehicle, with a proper drive-train and braking-system, is more controllable and, therefore, better prepared to avoid a crash. Thus, to enhance the probability for a vehicle to deal with unexpected situations, inspections and maintenance should be routinely conducted (Agbonkhese *et al*., 2013, p.93).

2.4.3 Road and Environmental factors

The road and environmental factors can be defined as the road surface conditions, the geometric design aspects, the traffic control devices, the state of road maintenance, the degree of visibility, the prevailing weather conditions, and any other non-driver or non-vehicle related factors. According to Vogel (2004), road and environmental factors were found, to have caused 7.2% of RTCs on the R44, located in the Western Cape. In their "Status of Road Safety Report: Calendar: January - December 2018", the RTMC found that in South Africa, 3.3% of all the RTCs that occurred in 2018 were caused by the road and environmental factors. This rate is slightly higher than the results obtained from studies performed in the United States and Australia, where only 2% of crashes were found to be as a result of road and environmental factors (RTMC, 2018).

According to the RTMC (2018), the main causes of the crashes that occurred as a result of road or environmental factors are:

- Sharp curves/bends - 17.4%
- Poor visibility - 14.5%
- Wet/slippery road surface - 12.6%

- Stray/wild animals – 11.4%
- Poor road surface – 9.6%

South African road engineers use the Technical Recommendations for Highways (TRH) documents as the guidelines for roadway design, road rehabilitation and road maintenance standards. The TRH series offers a comprehensive overview of the suggested highway engineering practices and standards that have been limited to address the functional requirements for the South African road traffic conditions.

As previously mentioned, “most crashes cannot be related to a singular causal event. Instead, crashes are the result of a convergence of a series of events that are influenced by several contributing factors” (AASHTO, 2010, p.3.8). One can, therefore, argue that the most significant causes found by the RTMC (2018), namely; sharp curves/bends, poor visibility and wet/slippery road surface may probably be the result of a combination of the specific road or environmental factor and a human factor like speeding or distractive driving. What is of great concern is the large number of fatal crashes that occurs as a result of a poor road surface condition, especially considering, that these crashes could have been prevented by the implementation of proper road maintenance.

2.4.3.1 Road Design, Construction and Maintenance factors

Roads are planned, designed, and constructed according to; specific standards, the traffic demand, the environmental factors, the available construction material, and the financial model and available costing budget. Furthermore, within the time period, from the design phase, to the construction phase, to the asset utilization, several external conditions can change, such as the traffic volume, the road user, the adjacent land-use, the climatic conditions and the budget allocation.

The South African Road Safety Manual (Volume 7) states that a safe road design should:

> “Warn and inform road users of changes in the approaching road environment. Guide and control road users safely through the road environment. Provide a forgiving roadside environment. Provide a controlled release of information. Maintain road user interest and concentration. Provide no surprises to road users. Give consistent messages to road users. Provide good visibility for all road users” (COLTO, 1999b, p.2.1).

According to Hermans et al. (2008), the efficiency of a road system in terms of its safety is the product of the road environment, the traffic, the functionality, the homogeneity, and the predictability of the network (Hermans et al., 2008). Peden et al. (2004) note that road design has a direct influence on crash risk as it defines how road users perceive the road environment. Agbonkhese et al. (2013) note that the road alignment, the grade and curvature, the cross-section design, the number of lanes, the design speed, the surface skid-resistance, and routine maintenance are all associated with the crash occurrence. All of these road situations influence traffic safety and operations. Road guidance, warning and safety measures, in particular the signs and markings, form a vital part of the roadway system as they convey a substantial amount of information to the driver of the vehicle. The road signs and markings should display a clear message to all users (Agbonkese et al. 2013). However, for the above road safety measures should be adequately maintained, to remain efficient and effective, as they deteriorate under sunlight and rain, and are subject to damage by vehicles and vandalism.

2.4.3.2 Weather and Lighting Conditions

Weather and lighting are natural and physical phenomena, of which humans do not have any control over. As these atmospheric conditions change, so does the possibility of traffic crash occurrence. Weather conditions like rain, mist and sandstorms limit visibility and may lead to RTCs. Excessive rains leading to floods, rock falls and landslides can also create problems that lead to RTCs (Muviringi, 2012). Although rain cannot be the cause of crashes, rainfall may create driving hazards such as aquaplaning that can lead to RTCs (Mondal *et al*., 2011). Wet road surface conditions are considered the most significant weather-related factor responsible for an increase in the possibility of a traffic crash (Edwards, 1999).

Lighting conditions also influence the occurrence of crashes. A study conducted by Gaza & Kiec (2013), found that about 40% of all crashes took place during insufficient road lighting conditions. Elvik (1995), furthermore, emphasized the effect of poor lighting conditions on pedestrian fatalities, with pedestrians being 3 to 7 times more exposed, during the night-time (Elvik, 1995).

2.5 Pedestrians and Cyclists

The most common mode of transport is walking. According to the RTMC, "a total number of 10 564 fatal crashes were recorded on South African roads for 2018" (RTMC, 2018, p.7). According to the report jay-walking (run into the road) contributed 33% to the occurrence of crashes, followed by hit and run at 14% and crashes with a cyclist at 2%. The jay-walking and hit and run as depicted in this report correlate with the high number of fatalities for pedestrians (RTMC, 2018). According to Hunter *et al*. (1996, p.23) "pedestrian contributing factors are the main cause of pedestrian-vehicle crashes." The main contributing factors within this group are; jay-walking, alcohol impairment and failure to yield (Hunter *et al*., 1996). Although at a lower casualty rate than pedestrians, cyclist safety has become a major concern on South Africa roads. According to Arrive Alive (2020), the number of fatal road crashes involving cyclists has risen substantially, with road fatalities among cyclists climbing from 320 in 2015 to 451 in 2016. The lack of visibility is a significant factor in crashes between cyclists and vehicles (Arrive Alive, 2020).

The use of alcohol is a major risk factor for pedestrians and cyclists involved in road traffic collisions. Dultz *et al*. (2011) investigated the influence of alcohol on pedestrian crossing patterns and behaviour. The results of the study revealed that alcohol-impaired pedestrians engaged in risky street-crossing behaviours. The study showed that the use of alcohol is a major risk factor for pedestrians who are involved and hit by vehicles. (Dultz *et al*., 2011). According to Bungum *et al*. (2005) inattention and distraction caused by mobile phone usage, eating, drinking, smoking and talking while crossing, also contribute to a large extent to pedestrian-vehicle crashes (Bungum *et al*., 2005). Hunter *et al*. (1996) further emphasized "failure to yield right-of-way" as the principal "driver contributing factor" associated with pedestrian-vehicle crashes. This contributing factor was mostly linked to speeding (Hunter *et al*., 1996, p.90).

2.6 Conclusion

Chapter 2 provided a theoretical analysis of the literature on various models, principles and factors associated with the occurrence of RTCs. Road safety has been a focus of research studies for decades. The chapter provided for a summary of previous studies relevant to the scope of the research topic. It furthermore provided an overview of the different contributing factors involved in RTCs, together with, an identification of the consequences associated with these factors. The chapter also illustrated the current road safety strategies and initiatives, globally and within South Africa.

Chapter 3 focus on the methodology and provided the methods followed to realise the objectives of this research study, as presented in Chapter 1. Chapter 3 will also present the research design and will substantiate the significance of the methodology used for the specific research topic. The data collection methods, and the crash data analysis techniques and procedures, will also be discussed.

3. Methodology

Chapter 3 provides an overview of the research design and substantiates the significance of the methodology used for the specific research topic. The chapter discusses the research instruments and study procedures used to investigate the human factors involved in RTCs, and the road user behaviour study (survey). The crash data collection methods are explained, including all the issues encountered during the data collection and organization. The crash data analysis techniques and procedures are also discussed. The chapter describes the procedures followed to obtain ethics approval from the University.

3.1 Introduction: Methodology and Data Analysis

Careful analysis of traffic crash data is crucial to identifying factors that are closely associated to crashes. Existing data mining techniques may be used with crash datasets to find some valuable information. Data mining make use of various techniques and algorithms to discover relationships in large data sources. According to Li *et al*. (2017):

> "Association rule mining algorithm is a popular methodology to identify the significant relations between the data stored in a large database, and also plays an important role in frequent itemset mining. A classical association rule mining method is the Apriori algorithm who's main task is to find frequent itemsets, which is the method we use to analyze the roadway traffic data" (Li *et al*., 2017, p.363).

This section covers the various statistical analysis approaches used during the analysis of traffic crash data, as well as the different ways crash risk factors are being identified. This section also investigates the existing techniques and algorithms related to crash rate prediction analysis, and explore the advantages and disadvantages of these techniques. The aim was to establish a solid understanding of the existing traffic crash analysis models to identify those that are best suited for the research objectives. Statistical data analysis methods such as Correspondence- and Multiple Correspondence Analysis, Association Rule Mining, Chance Variation, Apriori Algorithm, Multiple Regression and Naïve Bayes Classification were considered in this section.

The research design was used as a framework to assess and plan how to gather and interpret quantitative and qualitative data for the analysis of the relationship between different human factors and the RTCs.

3.2 Research Design

The research design determined the methods to be applied during the study in order to meet the proposed research objectives. Existing research subjects considered relevant to the study topic also assisted to frame the research problem concerning the human factors and the severity of RTCs. The literature review information, furthermore, helped to develop the research methodology. Data collected from TRAC and data obtained through the survey results were analysed using statistical analysis techniques. The analysis was used to gain an understanding of the relationship between the human factors, the severity of RTCs on highways and driver behaviour.

The following tasks were completed in order to achieve the research objectives:

1. Review of the past literature: The researcher conducted an in-depth study of past research to establish a solid understanding of the issue.

   The literature review mainly provided the following:

   a) A revision of previous studies relating to the research subject proposed.
   b) A description of the different types of contributing factors involved in RTCs.
   c) A study of the past research done on the human factors involved in RTCs.
   d) Review of the methodology available for application in this research project.

2. Data Collection: The researcher obtained road traffic crash data from the Trans African Concessions (TRAC) database, as well as, TRAC's Annual Accident Reports (2010 to 2018). In addition to the crash data, a survey was distributed to collect information about the perception that drivers have on the possible relationship between RTCs and the human factors involved in these crashes. The survey furthermore gathered information on the behaviour of drivers when driving on a highway under South African conditions

3. Data Reduction and Analysis: Based on the data obtained, the road crashes and driver behaviour were systematically analysed using statistical analysis techniques.

4. Conclusions and Recommendations: At the end of the analysis, the researcher critically evaluated the data analysis and provided recommendations based on existing knowledge. Improvements for highway safety were recommended, and the expected impacts of these recommendations were assessed to determine whether it can be implemented successfully.

During the last couple of years, several RTC related studies were conducted employing regression modelling. According to Chang & Wang (2006) "these models need a fixed hypothesis and a predefined relationship between the dependent and the independent variables. Erroneous estimations could, therefore, be produced if the hypotheses of these models are not fulfilled. In addition, hidden knowledge that exists in the databases cannot be extracted by these traditional methodologies." Recently, several data mining techniques were applied to overcome these shortcomings. Li *et al*. (2017) emphasise that, "data mining uses different techniques and algorithms to discover the relationships in a large amount of data. Association rule mining algorithm is a popular methodology to identify the significant relations between the data stored in a large database and also plays a very important role in frequent item set mining" (Li *et al*., 2017, p.363).

The proposed study will follow the data mining and analysis approach, as shown in Figure 3-1 below.

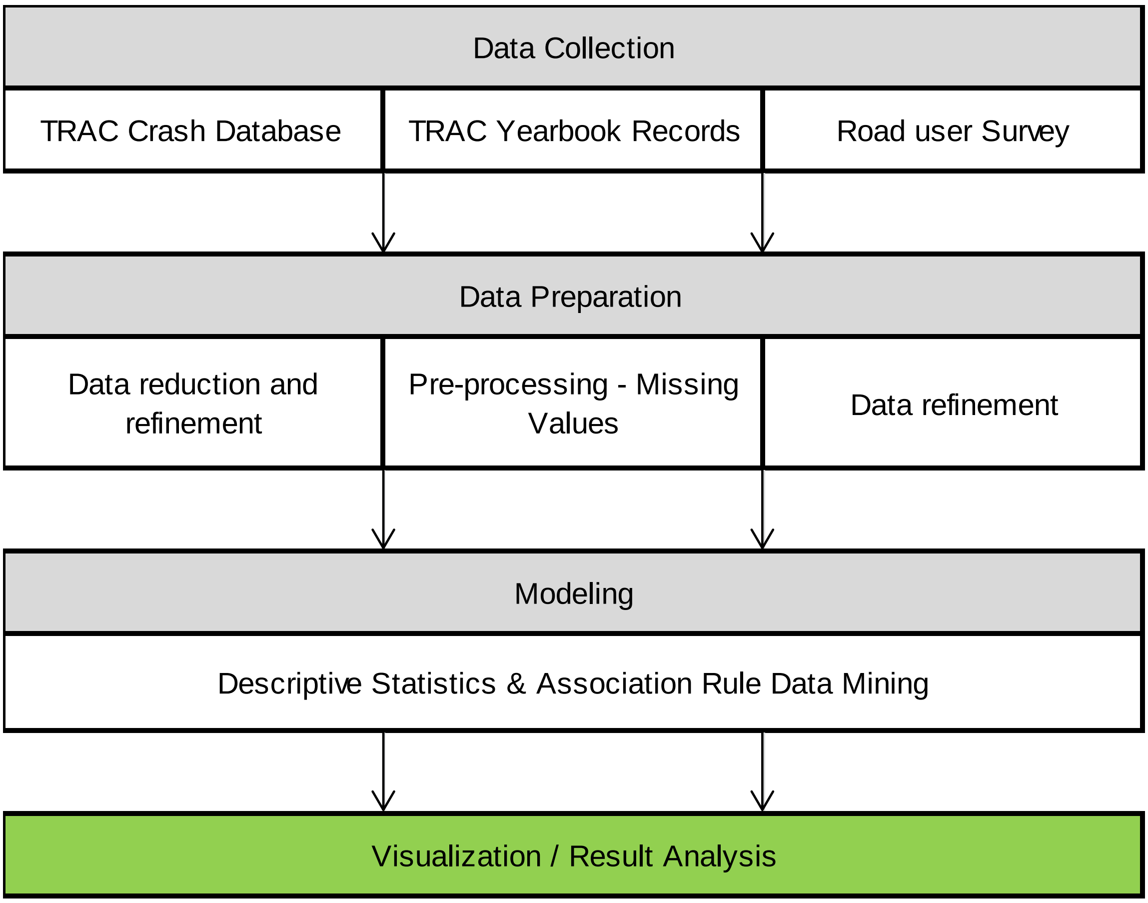


Figure 3-1: Study approach

3.3 Data Collection: Highway Crash Data: N4 case study

According to Bai & Li (2006), actual crash data is regarded as the best source for identifying safety deficiencies, and for the development of effective countermeasures (Bai & Li, 2006). Trans African Concessions (Pty) Ltd. (TRAC) is a Southern African Concessionaire for the approximated 570 km N4 Toll Route between Pretoria, South Africa, and Maputo, Mozambique. After committing to a 30-year concession contract in 1997, TRAC manages the N4 Toll Route, in conjunction with SANRAL and ANE, until the concession contract expires in 2027.

TRAC is not only contractually committed to providing a safe roadway to all of its users but also recognizes the responsibility of ensuring that the N4 Toll Route meets world-class standards in terms of road safety requirements. TRAC has, therefore, developed several systems that enable it to evaluate the toll road system's performance. The systems used include:

- Traffic Count Program to reflect the number of road users;
- Incident Management System;
- TRAC Helpdesk, TRAC Assist Route Patrol Services;
- Accident Response Units and roadside assistance;
- Traffic and Information Data System (TIDS).

Through these systems, comprehensive crash data has been collected and is available today. This data can be used in the application of quantitative and detailed statistical analyses. To ensure safer roads for all road users in the future, TRAC agreed to make their databases available for this external and independent analysis. This research study obtained the crash data information captured in TIDS, which is computerised software, developed to capture information relating to incidents that occur along the N4. Traffic volumes were obtained from the Traffic Count Program.

The area of study was focused on the RTCs which occurred on the South African part of the N4 between 2010 and 2018. The length of the section under investigation is approximately 504km, spanning from Pretoria, Gauteng up to the Lebombo border post, located at the border between South Africa and Mozambique. Refer to Addendum A for a Key Plan of the N4 South African Section (Pretoria to the Lebombo border post).

The data analyses required simplified, formatted and comprehensive information that could be readily fed into the analysis software. The TIDS spreadsheet has been developed to include all the data contained in the original crash records, and contains approximately 9000 crash reports for the 9-year analysis period, ranging from 2010 to 2018. An example of the TRAC Traffic and Information Data System (TIDS) can be viewed in Addendum B.

A list of the variables as per the major categories is provided below:

1. Responsible Diver - This category included the basic information of the driver. The identity of the responsible driver is confidential and therefore was not be included in the data. TRAC only provided the following information, where available, regarding the responsible driver:
    - The gender of the driver (male and female).
    - The age of the driver.

2. Time details - The time variables of the crash were included in this category.
    - The time of the crash.
    - The date of the crash.

3. Environment - This category included the environmental and weather information.
    - The lighting conditions.
    - The weather condition.

4. Crash Information - The category included crash information.
    - The crash severity in terms of injury severity.
    - The crash type.
    - The number of vehicles involved.

5. Road Conditions - The road condition variables are described in this category.
    - Road section Description.
    - Km location where the crash occurred.

6. Contributory Factors - The factors listed as the cause of the crash were in included in this category. The crash causes were divided into categories to enhance the statistical analyses.
    - The Human factors - speeding, negligent driving, alcohol, fatigue, misunderstandings, lapses in concentration etc.
    - The Road and Environmental factors - poor visibility, animals, etc.
    - The Vehicle factors - tyre burst, brakes, etc.
    - Pedestrians/Cyclists.

The following information of the crashes that occurred on the N4 between 2010 and 2018 was obtained from the TIDS database, as well as, the Annual Accident Reports (2010 to 2018):

- Number of Crashes per Annum
- Number of Fatalities and Fatal Crashes per Annum
- Average Crash and Fatality Rates (per million vehicle kilometres) per Annum
- Number of Monthly Crashes per Annum
- Crash severity by time of day
- Causes of road Crashes
- Weather during Crashes
- Vehicle types involved in Crashes
- Types of Crashes (Head-on, sideswipe, etc.)
- Crash details per road section

3.4 Data Collection: Road User Survey

Besides, the crash data, an electronic survey was distributed to collect information about the perception that drivers have on the possible relationship between RTCs and the human factors involved in these crashes. In addition, the survey gathered information on the behaviour of drivers when driving on a highway under South African conditions. Surveys provide a reliable source of real-world data, which can easily be analysed and illustrated using descriptive statistical methods. Surveys also provide invaluable data, like, personal views and experiences of drivers, which cannot be obtained from any crash database.

Data on the following specific topics were collected from the survey questionnaire;

1. Demographic details and driving experience.
2. Drivers' perceptions of road safety.
3. Drivers' perceptions of the significance of human factors in the contribution towards RTCs
4. Frequency of irregular driving behaviour.
5. Risk perception of certain factors like the use of prescribed medication and mobile phone usage.

To reduce the risk of erroneous responses, technical and generalised questions were avoided. Care was taken not to ask leading or ambiguous questions, to allow potential respondents to express contrasting views. The questionnaire was initially tested on a representative sample, and then revised according to the feedback received. The questionnaire was only officially distributed once the researcher had full confidence in the readiness and quality of the survey. Considering South Africa's national state of disaster due to the COVID-19 pandemic, some critical safety measures were required to maintain a healthy research environment for all participants. Due to the threat of exposure to the Coronavirus, the survey was distributed in electronic format only. Potential respondents were asked to complete an online questionnaire. The online survey allowed for no physical contact. The drawbacks to the electronic data collection method include the potential for selection bias and a lower response rate. It also limits the potential respondents to those who have access to an active e-mail account.

The electronic collection method has the additional benefit, over the paper collection method, of allowing for the responses to be submitted directly into the software database, with no need for manual data capturing. The only participation criterion was a valid driver's license. Participation was entirely voluntary, and potential participants were allowed to decline to participate. The participants were also allowed to decline to answer any particular question. Furthermore, even if they had agreed to participate in the survey, they were allowed to leave the study at any given time. All submissions were treated as confidential, and no individual can be linked to any information obtained from the surveys. The survey findings led to a detailed account of driving behaviour. The results also offered some further explanation into the findings obtained through the crash data. Refer to Addendum C for a copy of the survey questionnaire.

3.4.1 Survey Sampling and Size

According to Fridah (2002), "a population sample is expected to reflect the population from which it comes; however, there is no guarantee that any sample will be exactly representative of the populace from which it comes." As a result, inferential statistics must be used to define the characteristics of the population by looking specifically at just a fraction of the population. The researcher can then draw conclusions from a population sample. Before the size of the representative sample can be determined, the population of the study must first be defined. Because of constraints, such as the available funding or time, the determination of sample size can become an intricate process.

Fridah notes that “these constraints influence the sample size, as well as, the sample design and data collection procedures. In general, sample size depends on the nature of the analysis to be performed, the desired precision of the estimates one wishes to achieve, and the kind of comparisons that will be made” (Fridah, 2002).

Therefore, before the size of the representative sample could be determined, the population of the study had to be defined. After studying the different high-risk areas as evaluated in Part 4.4 of this study, Section 6N has shown a dramatic increase in the crash rate over the past couple of years. Crashes increased from 50 in 2015 to 127 in 2018. It was, therefore, decided to focus on Section 6N of the N4 and to use its measured Annual Average Daily Traffic (AADT) as the population size for the survey sample determination. The section experienced an AADT of approximately 4500 vehicles over the past couple of years.

Slovin’s formula to determine the initial sample size was used for the survey at a 95% confidence level and 5% margin of error.

$n = N \,/\, 1{+}Ne^2$ (Slovin’s Formula)

Where;

n = Number of samples

N = Total population [Annual Average Daily Volume (AADT)]

e = margin of error

Using the above formula, the initial sample size (*n*), was calculated at 350 participants for a 95% confidence level, and a 5% margin of error. REDCap online platform was used to develop and distribute the electronic survey link. A random sampling method was used in the distribution of the survey. Before the survey could be distributed, the researcher first contacted the owners and directors of various randomly selected companies and businesses, to formally apply for institutional permission to conduct research within their institutions. The researcher purposely decided on a diverse range of institutions. These institutions included consulting firms, construction companies, fitness clubs, running clubs, and living and beauty product distributors. After first explaining the purpose of the research study, the researcher requested permission to distribute an electronic survey to all employees and clients. Once permission was granted, the researcher provided the directors and owners of the institutions with an email link to the online questionnaire to distribute to staff members and clients.

The only participation criterion was a valid driver's license. Survey participation was voluntary, and treated as confidential. All potential participants were also allowed to decline to participate.

3.4.2 Ethics Approval

The University's Policy for Responsible Research Conduct declares the following "Stellenbosch University (SU) is committed to applying the values of equity, participation, transparency, service, tolerance and mutual respect, dedication, scholarship, responsibility and academic freedom in all its activities. This includes, by definition, all the research conducted at the University. The policy applies to all those conducting research under the auspices of Stellenbosch University" (SU, 2013, p.1). As per the policy guidelines, each prospective research participant was, first notified of the objectives of the research, and the potential benefits gained by the investigation, before being asked to sign an electronic consent form. Institutional ethics approval was first obtained before the survey was distributed to the potential participants.

3.5 Research Instruments

The following research instruments were used:

a) REDCap (Research Electronic Data Capture) browser-based software was used to develop and distribute the electronic survey.

b) Excel and Statistica software packages were used in the data analysis.

3.6 Data Analysis

Using the mentioned study methods, data on RTCs and driver perceptions were collected and reduced for analysis. Statistical methods were used to identify the most significant crash factors. Association Rule Analysis was the primary method used to investigate the possible relationship that exists between the crash severity [dependent variable] and the human risk factors involved in these crashes [independent variables]. The following sub-sections describe the data analysis steps taken in this study.

3.6.1 Data Preparation

Data preparation is an important task, which must be performed before the data can be analysed. During the data preparation process, irrelevant and duplicate attributes are removed from the dataset, and the missing value fill-up processes are performed. Because real-world data was used, and the fact that manual filling can lead to inefficient results, data transformation processes were applied to some of the attributes. Moreover, data preparation was performed to reduce complexity and dimensionality. All records with omitted or absent values were either filled or removed. Certain crash types with faulty classifications like "unknown", or "other" could then be corrected to more accurate classifications for this study. This was done to ensure the risk factors were set up correctly. The irrelevant attribute removal and missing values fill-up processes were done with great caution and only when it is obvious that the current classification is wrong.

3.6.2 Modelling

To determine the relationship between the severity of RTCs [dependent variables], and the human risk factors involved [independent variables], the factors with the highest crash rates were identified. After performing basic statistics the most prominent attributes were considered and selected as affecting the injury and fatality rate. Several basic statistics were calculated from the dataset to show the elementary characteristics of the crashes.

The following statistical analysis methods were used during the data analysis:

1. **Association Rules:** "A data mining technique used to detect relationships or associations between specific values of categorical variables in large data sets" (Van Niekerk, 2007, p.34).
2. **Survey Analysis:** Descriptive statistical methods were used to analyse and describe the results of the survey.

3.6.2.1 Association Rules

Association Rule data mining was used to find possible relationships between specific values of categorical variables present in the large data sets. This technique aids in the extraction and refining of valuable knowledge from the large dataset to uncover hidden patterns which cannot be found from simple inspection of frequency tables, or large tables of raw data. Descriptive analytics reveals important rules that frequently occur together in a dataset and show varying category conditions. Different algorithms can be employed to find associated rules for extracting useful information from the data. According to Li *et al*. (2017) “A classical association rule mining method is the Apriori algorithm who’s main task is to find frequent itemsets” (Li *et al*., 2017, p.363). Before the association rule analysis results can be interpreted and discussed, it is necessary to define some of the terminology used. It is important to know these terms to comprehend how Association Rules are interpreted.

Van Niekerk (2007) explains as follows:

Support Value **–** “the relative frequency of the Body or Head of the rule” (Van Niekerk, 2007, p.47).

Confidence Value **–** “the conditional probability of the Head of the association rule, given the Body of the association rule” (Van Niekerk, 2007, p.47).

Correlation Value **–** “support for Body and Head, divided by the square root of the product of the Support for the Body and the Support for the Head” (Van Niekerk, 2007, p.47).

Lift Value **–** “A value which measures how much better the rule is for prediction than a random guess. Lift values > 1 imply a useful rule. It is a ratio indicating how much more likely an item in the Head can be found in the Body subset, than in the whole population. It is the Confidence value divided by the Support Value for the Head” (Van Niekerk, 2007, p.47).

Rule Extraction **–** “A formal presentation of the rule and parameters of confidence, support, and lift which quantify a rule is given below. The general form of the rule is as follows: “IF event X occurs THEN event Y occurs as well, in M% of times, and this pattern occurs in N% of all events in the dataset”. Where, M is the Confidence, and N is the Support. Support represents the probability that both events X and Y occurred simultaneously in the dataset. Confidence presents the probability that event Y will occur while event X has already occurred. Confidence is the conditional probability of event Y, while event X has already occurred, the Lift value is the ratio of the probability that Y will occur” (Bigham, 2014, p.444).

3.7 Conclusion

Chapter 3 presented a description of the research analysis and supported the significance of the methodology used for the particular subject under investigation. The chapter discussed the research instruments and study procedures used to investigate the human factors involved in RTCs, and the road user behaviour study (survey). The methods used in the collection of the crash data were explained, and the techniques and procedures used in the data analysis were discussed. The chapter described the procedure followed to obtain ethics approval from the University.

Chapter 4 will present the results and findings of the study conducted into the possible relation between the severity of RTCs and the interaction with the human factors involved in these crashes. Furthermore, the results of the behaviour study (survey) will be discussed in Chapter 4.

4. Analyses, Results and Discussion

Chapter 4 presents the findings and results of the analysis of the relationship between the severity of RTCs and the interaction with the human factors involved in these crashes. As discussed in Chapter 3, different data collection and analysis methods were used in this study. These measures include the collection of actual crash data and survey response data. The analysis of the crash data is presented in the first part of this chapter, followed by the results obtained from the road user behaviour and driver perceptions survey. The chapter concludes with a discussion of the most significant findings and results, followed by the identification of solutions and proposal of countermeasures that can be put in place to address RTCs, and the human factors involved in the RTCs on highways in South Africa.

4.1. Introduction

The primary objective of this research was to analyse the relationship between the severity of RTCs which occurred on the N4 Toll Route in South Africa and the association with the human factors involved in these accidents.

The following outcomes were used to develop the research design for this study:

1. To investigate the relationship between the severity of the RTCs and the various human factors involved in crashes that occurred on a highway in South Africa.
2. To identify drivers' perceptions of the relationship that exists between RTCs and the human factors involved.
3. To study driver behaviour concerning road safety on highways in South Africa.

The research design was used as a framework to determine how to collect quantitative and qualitative data, needed to analyse the relationship between the human factors and RTCs, as well as, the driver behaviour and driver perceptions regarding the role of human factors in road safety.

As previously discussed under Part 2.3.2, of this document, a crash can be divided into three different stages namely: "the pre-crash, the crash; and the post-crash". The road designer/roads authority can influence each one of these phases to ensure that the impact of a crash is reduced. There are, accordingly, several possible actions that can be implemented for each stage to minimise the impact of the crash or to stop it from happening altogether. The designer, along with the road authority, may attempt to influence the road (design, maintenance), the vehicle (travel speed, vehicle condition with the assistance of law enforcement) or the driver (road user behaviour through road safety campaigns and road safety signs and messages).

As discussed under Part 2.3.2 of this report, William Haddon Jr (1980) created a matrix that "defines crash risk factors for each stage - before, during and after - of the crash, concerning the driver, the vehicle and the environment... Each phase – pre-crash, crash and post-crash – can be analysed systematically for the human, vehicle, road and environmental factors" (Peden et al., 2004, p.12). According to Mohan *et al.* (2006) "The Haddon matrix is an analytical tool to help in identifying all factors associated with a crash. Once the multiple factors associated with a crash are identified and analysed, countermeasures can be developed and prioritized for implementation over short-term and long-term periods" (Mohan et al., 2006, p.25).

This chapter addresses the different phases through an analysis of the collected data, and was accordingly divided into the following subdivisions to present the results in a reliable, rational and coherent manner:

Crash and Post-Crash Data Analysis**:** *This part provides details on the crashes that occurred annually from 2010 to 2018. The existing TRAC crash database was accessed to help evaluate and identify the potential causes of the crashes.*

The Traffic and Information Data System (TIDS), which is a computerized software package, developed to capture information relating to the crashes that occur along the N4, was used for the collection of crash data. The TIDS database contains approximately 9000 records of crashes that occurred within the South African part of the N4 Toll Road during the 9-year review period.

TRAC's Accident Yearbooks (2010 to 2018), which report on the annual crash statistics, were also accessed as a source of data during the Post-Crash Data analysis. Traffic volumes were obtained from TRAC's Traffic Count Program.

Pre-Crash Data Analysis**:** *This section focuses on the prevailing road conditions, and details road user behaviour and driver perceptions towards road safety. The results from the road user survey were accessed to help evaluate and identify road user behaviour that may lead to RTCs.*

Based on the outcomes and conclusions drawn from this analysis, effective solutions can be developed and countermeasures recommended to prevent future crash occurrence and to mitigate the severity and frequency of crashes when they do occur.

4.2 N4 Toll Route Information

Trans African Concessions (Pty) Ltd. (TRAC) is a Southern African Concessionaire for approximated 570 km N4 Toll Route. The route spans between Gauteng through Mpumalanga to Mozambique. The route starts at Pretoria and ends at the port in Maputo. The study section was, however, restricted to the analysis of the RTCs which occurred within the South African section of the N4 Toll Route, starting in Pretoria, Gauteng, and terminating at the Lebombo border post, located at the border between South Africa and Mozambique. Figure 4-1 below presents a graphical illustration of the South African highway section spanning a total length of approximately 504km. The route is divided into various sections based on measurable traffic and geometric segments with similar properties (refer Table 4-8).

Figure 4-1: The South African section of the TRAC N4 Toll Route

Crash data, detailing the crash statistics for a 9-year analysis period, ranging from 2010 to 2018, was collected for this study. TRAC developed several systems that enable it to reach its safety goals and to evaluate the performance of the toll road system. These systems include: a traffic count program to reflect the number of road users, an incident management system, a helpdesk, route patrol services, accident response units, roadside assistance, and a traffic and information data system (TIDS). The following section provides a detailed description of the 9-year trend analysis. To assess the current situation in regards to road safety on the N4 Toll Road, the most recent crashes were evaluated and compared with previous years' statistics to note trends, determine high risk areas and find solutions to reduce the crash rate and crash severity.

4.3 Annual Road Traffic Crash Trend Analysis

This section provides details on the annual crashes that occurred from 2010 to 2018. TRAC's Annual Accident Yearbooks (2010 to 2018), which report on the annual crash statistics, were accessed as the main data source for analysis. The traffic volumes along the route were obtained from TRAC's Traffic Count Program. Refer to Addendum D for a summary of the recorded traffic volumes for 2017 and 2018.

4.3.1 Number of Crashes per Annum

The number of crashes that occurs within a road section is generally used to assess the safety of the section. Figure 4-2 presents the number of road crashes recorded per annum within the South African part of the N4 Toll Road (2010-2018). The number of crashes per annum has fluctuated over the 9-year review period (2010-2018). From 2012 to 2013, the number of crashes increased from 877 to 1074, representing an increase of 18.3%. From 2015 to 2016, the number of crashes has decreased slightly from 1002 to 955, representing a reduction of 4.7%. From 2016 to 2018, the number of crashes, however, again increased from 955 to 1106 and 1138 respectively for 2017 and 2018. This represents a 15.8% increase from 2016 to 2017 and a 2.9% increase from 2017 to 2018. Refer to Addendum D for the complete annual breakdown of the crashes that occurred from 2010 to 2018.

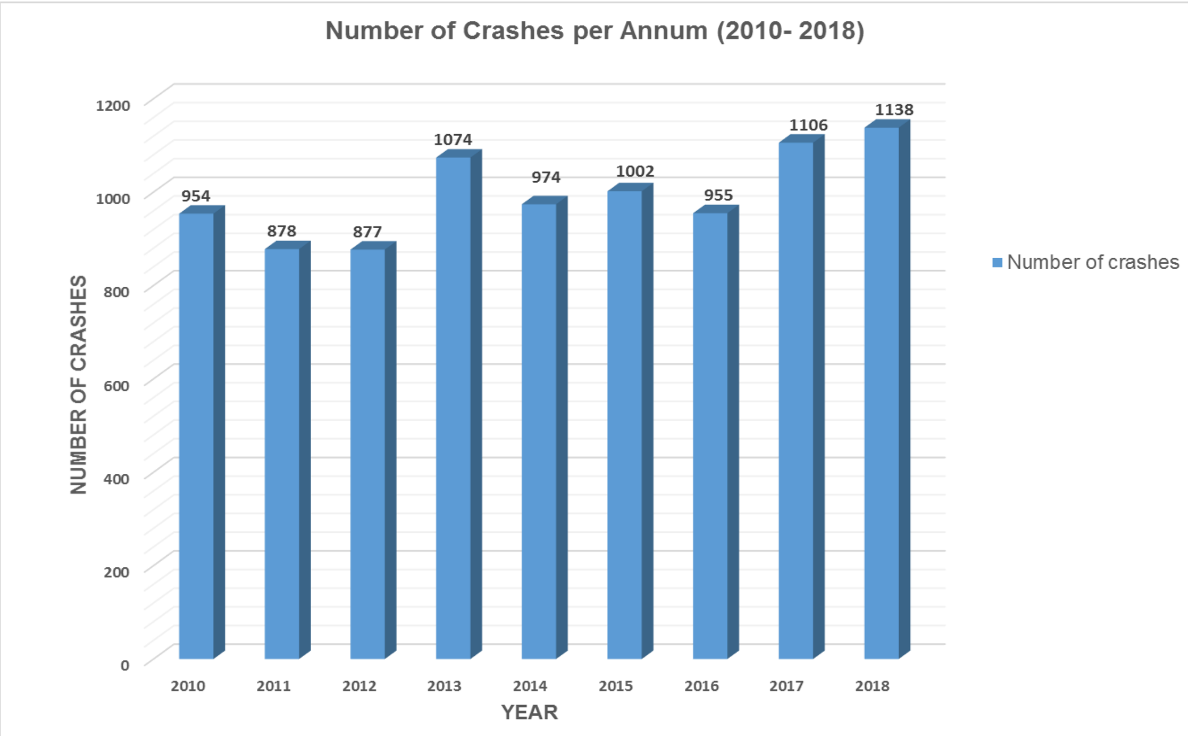


Figure 4-2: Number of RTCs per Annum (2010-2018) TRAC N4: South African Section

4.3.2 Annual number of Fatalities and Fatal Crashes

Table 4-1 presents the annual number of fatalities and fatal crashes recorded within the South African part of the N4 Toll Road. In 2017, the South African section recorded 125 fatal crashes with a total number of 182 fatalities. 59 Pedestrian related crashes took place in which 40 pedestrian-related fatalities occurred. The number of fatal crashes reduced to 101 in 2018, compared against the 125 from the previous year (2017). Fatalities in 2018 were also lower than for 2017. 32 of the 101 fatal crashes (32%) were pedestrian-related, resulting in 37 fatalities. A graphical illustration is presented in Figure 4-3 below.

Table 4-1: Number of Fatalities and Fatal RTCs per Annum (2010-2018)

Year	No. of fatal crashes	No. of fatalities
2010	112	219
2011	102	157
2012	97	153
2013	107	145
2014	109	157
2015	99	106
2016	106	151
2017	125	182
2018	101	160

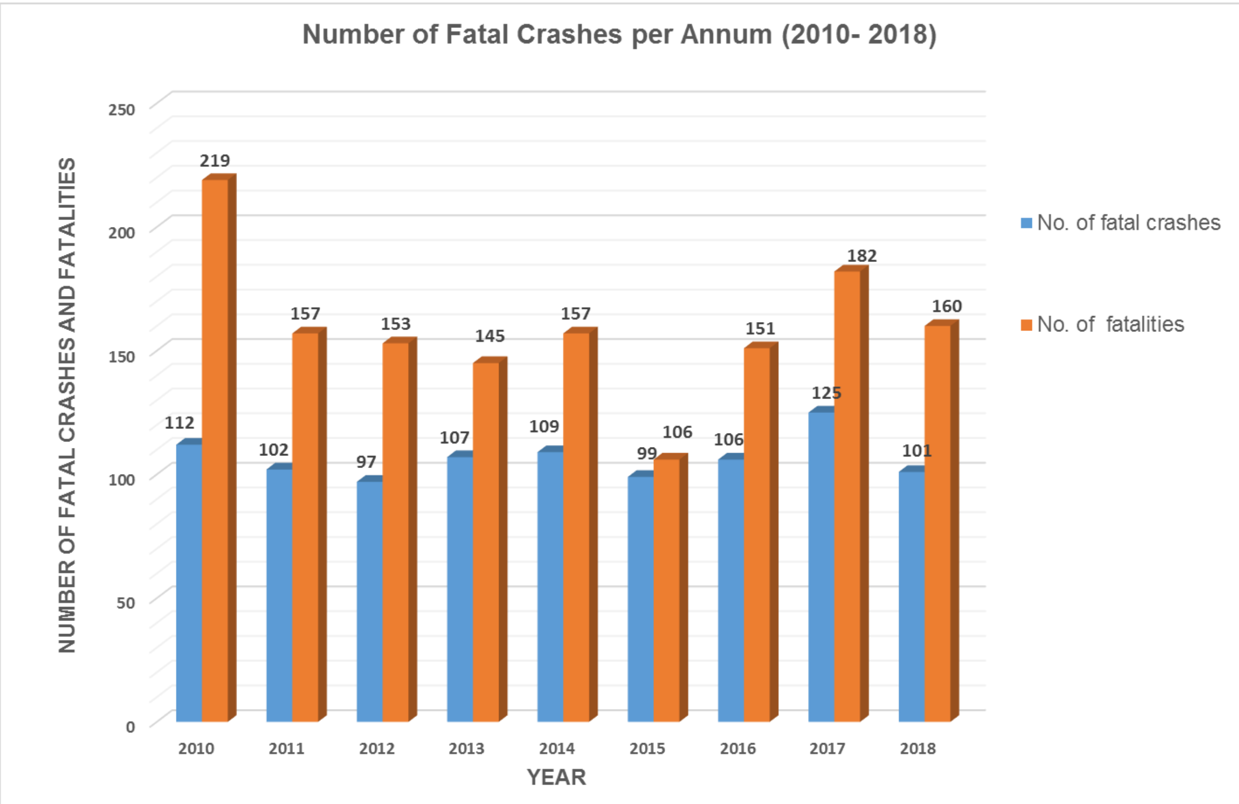


Figure 4-3: Number of Fatal RTCs and Fatalities per Annum (2010-2018)

4.3.3 Average Crash and Fatality Rates

It is said that the number of crashes that occurs within a road section generally represent how safe the section of road is, however, only taking the number of crashes into account and disregarding the number of vehicles that travelled along the segment of the road, can lead to an erroneous interpretation of the number of crashes as the sole indicator of the safety of the road. For this reason, using the crash rate per million km travelled is recommended. Crash rates (CR) per million vehicle kilometres (mvkm) were calculated for all the different road sections along the route and can be seen in Part 4.3.10 of the report. These rates are ratios that incorporate the traffic volumes and distances travelled, for the time under investigation. This enables a fair comparison of the different sections along the route.

The crash and fatality rates are calculated by using the following formulae:

$$\text{Crash rate (CR)} = \frac{Ca \times 10^6}{365 \text{ days} \times AADT \times km}$$

Where:

- *Crash rate: Calculated crash rate (expressed as crash rate per million vehicle kilometres)*
- *Ca: Annual number of crashes which occurred on that specific road section*
- *AADT: Average annual traffic on that road section*
- *Km: Kilometre distance of that specific road section*

$$\text{Fatality rate (FR)} = \frac{Fa \times 10^6}{365 \text{ days} \times AADT \times km}$$

Where:

- *Fatality rate: Calculated fatality rate (expressed as fatality rate per million vehicle kilometres)*
- *Fa: Annual number of fatalities which occurred on that specific road section*
- *AADT: Average annual traffic on that road section*
- *Km: Kilometre distance of that specific road section*

The average crash and fatality rates of the South African part of the N4 Toll Road as calculated for the 9-year review period (2010-2018) are provided in Table 4-2. The crash and fatality rates per annum have fluctuated over the 9-year review period (2010-2018). The crash and fatality rates have decreased from 0.495 in 2017 to 0.483 in 2018 (by 2.5%) and 0.083 in 2017 to 0.068 in 2018 (by 22%) respectively. A graphical illustration is presented in Figure 4-4.

Table 4-2: Average Crash and Fatality Rate per Annum (2010-2018)

Average Crash and Fatality Rate per Annum (mvkm)		
Year	**Average Crash rate (CR)**	**Average Fatality rate (FR)**
2010	0.443	0.099
2011	0.397	0.071
2012	0.371	0.065
2013	0.492	0.066
2014	0.443	0.071
2015	0.454	0.062
2016	0.426	0.067
2017	0.495	0.083
2018	0.483	0.068

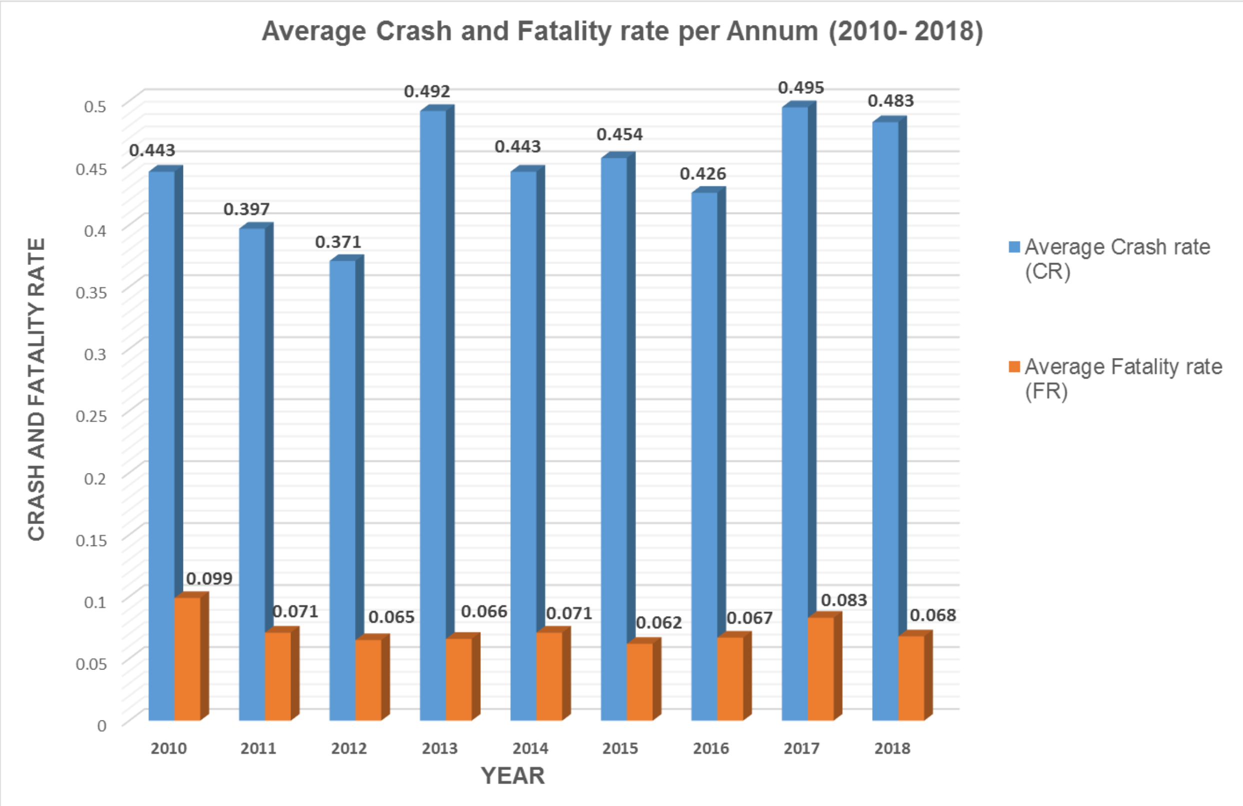


Figure 4-4: Average Crash and Fatality Rate per Annum (2010-2018)

4.3.4 Crashes per month

Table 4-3 present the total sum of monthly crashes recorded for the analysis period from 2010 to 2018. The number of crashes per month fluctuates from month to month over the 9-year review period. However, a seasonal trend is evident for the monthly recorded road crashes. The month of December recorded the highest number of crashes for each one of the years analysed (2010-2018). A high number of crashes also occurred in March, April and June, which includes the Easter break and the June school holidays. Refer to Addendum D for the complete annual breakdown of the number of crashes that occurred per month. A graphical illustration is presented in Figure 4-5.

Table 4-3: RTCs per Month (2010 to 2018)

Total Crashes per Calendar Month (2010-2018)		
Month	**Number**	**Percentage (%)**
Jan.	680	7.57%
Feb.	691	7.69%
Mar.	777	8.65%
Apr.	771	8.58%
May.	655	7.29%
Jun.	741	8.25%
Jul.	660	7.35%
Aug.	661	7.36%
Sep.	695	7.74%
Oct.	766	8.53%
Nov.	786	8.75%
Dec.	1101	12.26%

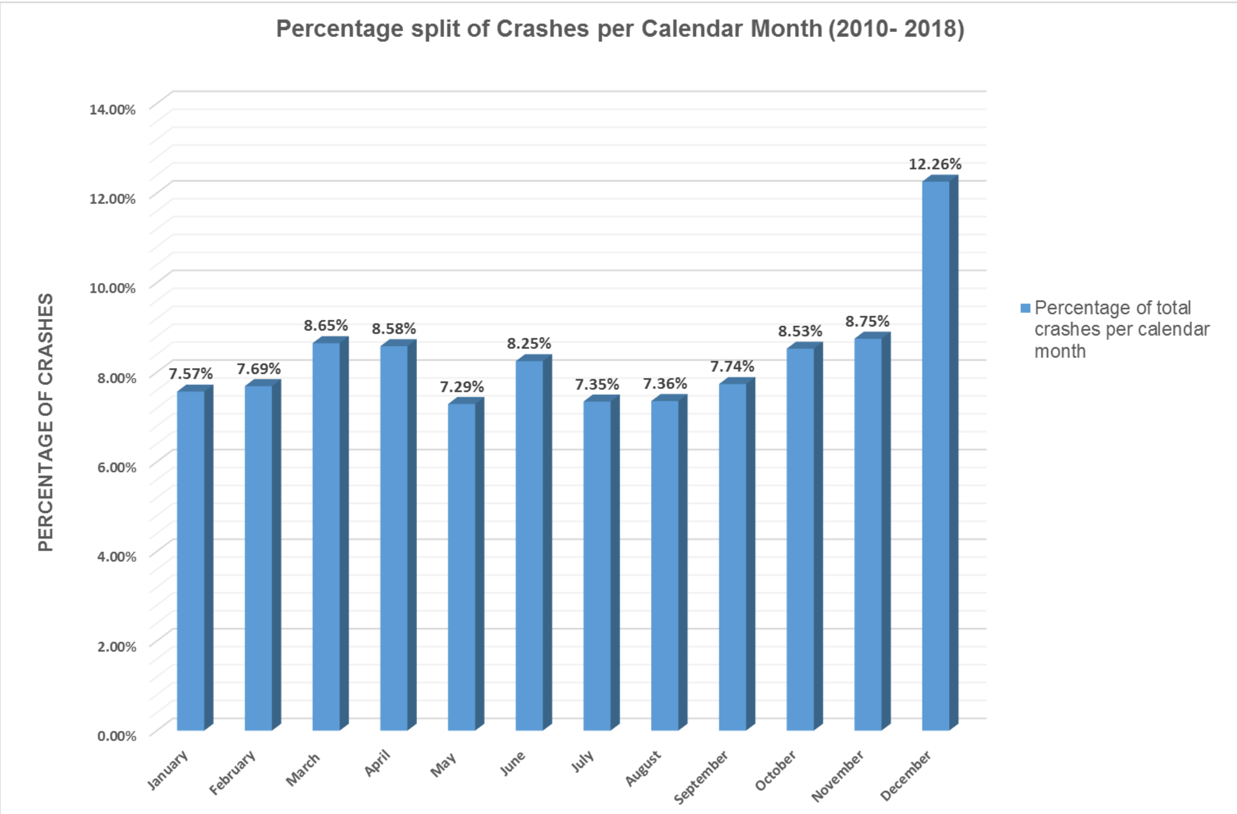


Figure 4-5: Percentage split of RTCs per Calendar Month (2010 to 2018)

4.3.5 Crash Severity by time of day

The time of day influences the occurrence of crashes (refer to Part 2.4 of this report). A study conducted by Gaza and Kiec (2013), found that about 40% of all crashes took place during insufficient road lighting conditions. Elvik (1995), furthermore, illustrated the impact of bad lighting conditions on pedestrian deaths caused by vehicle crashes, by emphasising the fact that pedestrians are three to seven times more at-risk during the night-time (Elvik, 1995).

The results obtained from this study support these findings. Table 4-4 indicates that most fatal crashes occurred at night-time (almost 60%). The majority of serious-, slight injury and damage-only crashes occurs during the day. The percentage of crashes that occurred during the day, versus the crashes that occurred during the night, varies only by 10% (55% and 45% respectively). This is significant considering that the majority of traffic flow occurs during the daytime, with less than 25% of the traffic travelling during the hours of darkness. A graphical illustration is presented in Figure 4-6 below. Refer to Addendum D for the complete annual breakdown of the day- versus the night-time crashes.

Table 4-4: Crash Severity by Time of Day (2010-2018) TRAC N4: South African Section

Crash severity	Total		Percentage	
	Day	Night	Day	Night
Fatal	390	565	40.84%	59.16%
Serious injury	910	741	55.12%	44.88%
Slight injury	1017	756	57.36%	42.64%
Damage Only	2632	1972	57.17%	42.83%
		TOTAL	**55.09%**	**44.91%**

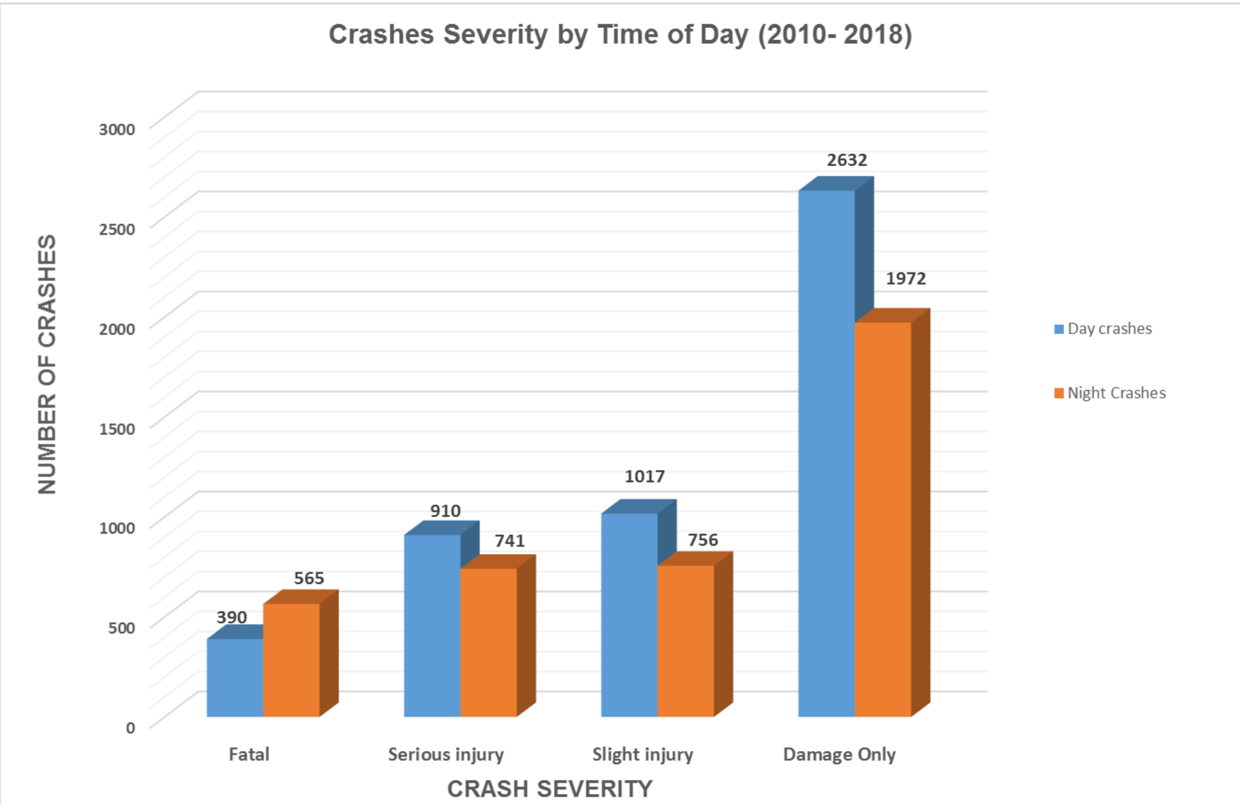


Figure 4-6: Crash Severity by Time of Day (2010-2018) TRAC N4: South African Section

4.3.6 Cause of Crashes

As mentioned under Part 2.4 of this study, AASHTO (2010) reported that "Most crashes cannot be related to a singular causal event; instead, crashes are the result of a convergence of a series of events that are influenced by several contributing factors" (AASHTO, 2010, p.3.8). According to Austroads (2002) the three major contributors to vehicle crashes are "Human factors, Vehicle factors, and the Road environment factors" (Austroads, 2002, p.4).

Figure 4-7 presents a breakdown of the main contributing factors in the crashes that occurred within the South African part of the N4 Toll Road (recorded for the study period, 2010 to 2018). At 72.8%, human factors were found to be the leading cause of RTCs. The primary factors considered as the human factors and reported in this part of the study are; lost control, negligent driving, speed differential, sleeping/fatigue, dangerous overtaking, pedestrian/cyclist, U-turn/reversing vehicles, drugs/alcohol, wrong direction of travel, crashes at intersections, and medical problems. The findings derived from this analysis correlate well with the findings of previous research. Vogel (2004) found that 77.7% of crashes that occurred on the R44 were caused by human factors (refer to Part 2.4 of this report).

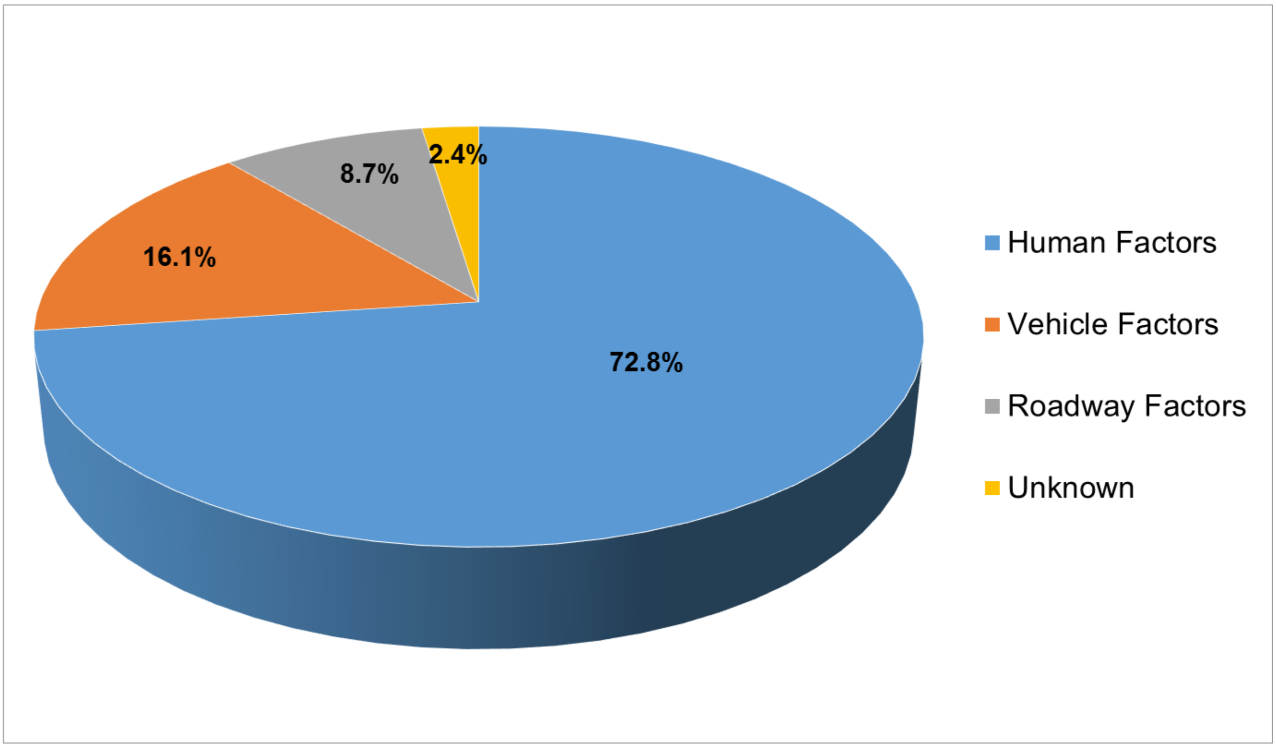


Figure 4-7: Percentage Contributory factors to RTCs, South African part of the N4 Toll Road (2010-2018)

As discussed under Part 2.4 of this report, vehicle factors refer mainly to the condition, maintenance and roadworthiness of the vehicle. The road factors include all aspects of road design and maintenance like geometric design, traffic control devices, surface friction, and construction activities. The environmental factors refer to the weather conditions and problems with visibility due to rain and mist, etc. (Austroads, 2002). Vogel (2004) found 6.4% of the crashes to be caused by vehicle factors on the R44. At 16.1%, vehicle factors were found to play a larger role than the road and environmental factors in the RTCs that occurred within the South African part of the N4 Toll Road. The primary factors considered under the vehicle factors and reported in this part of the study are tyre failure, mechanical failure, brakes failure, trailer failure, towing of vehicles, and vehicle sway. Vogel (2004) found 7.2% of the crashes to be caused by road and environmental factors on the R44. At 8.7%, road and environmental factors were found to play a smaller role than the vehicle factors in the RTCs that occurred within the South African part of the N4 Toll Road. The primary factors considered under the road and environmental factors and reported in this part of the study are construction/maintenance sites, stationary vehicles, visibility, skidding, animal / object in the roadway, edge drop-off / gravel shoulder, previous accident, and public transport stop. At 2.4%, the unknown factors as a cause in the RTCs for the South African part of the N4 Toll Road are far less than the 8.7% reported by Vogel (2004) on the R44.

The noticeable difference in the results obtained by each of the two studies, compared above, can partially be attributed to the quality of data used. Vogel (2004) noted that some problems exist in the data quality, including the limited list of crash factors considered in the crash reports, as well as, the under-reporting of many critical crash details. These factors may affect the number of unknown factors reported as a cause of RTCs. Inadequate South African crash reporting systems have for years prevented the application of quantitative and detailed statistical analyses. The lack of accurate and centralized data relating to crashes is common among the different road authorities. The implementation of a Traffic and Information Data System (TIDS), which is computerized software, developed to capture the information relating to the crashes that occur along the N4, and the standardization of the field crash reporting system, allowed TRAC to capture and centralize all crash data. These systems, combined with proper training of field data capturing personnel, allowed for high-quality crash data to be available for analysis purposes. The vehicle factors as a cause in crashes, obtained from this research, are also markedly higher when compared to the study conducted by Vogel (2004). The reason for this variance can be explained when investigating the high number of un-roadworthy, un-licenced and poorly maintained vehicles travelling on South African roads. A large number of poorly maintained vehicles, travelling from Mozambique to South Africa, are also involved in RTCs on the South African part of the N4 Toll Road.

Table 4-5 gives a comprehensive breakdown of the main contributing factors in the crashes that occurred within the South African part of the N4 Toll Road (recorded for the study period, 2010 to 2018). Concerning Table 4-5, a significant number of crashes were caused by loss of control, negligent driving, speed differential, tyre failure, overtaking and sleeping/fatigue.

Refer to Addendum D for the complete annual breakdown of Crash Causes for 2010 to 2018. The trend of crash causes described above continues through all consecutive years, 2010 to 2018. The number of tyre failures has, however, shown a noticeable decrease from 142 recorded crashes in 2010 to just 62 in 2018. It should also be noted that about 3% of crashes were caused by pedestrians.

Table 4-5: Annual Causes of RTCs (2010-2018)

	Causes of Crashes	TOTAL	Percentage	TOTAL	Percentage
Human Factors	Lost control	2848	22.17%	**9354**	**72.8%**
	Negligent driving	2787	21.69%		
	Speed differential (rear-end)	924	7.19%		
	Sleeping / Fatigue	841	6.55%		
	Dangerous overtaking	548	4.27%		
	Pedestrian / Cyclist	368	2.86%		
	U-Turn / Reversing vehicles	309	2.41%		
	Drugs/Alcohol	213	1.66%		
	Wrong direction of travel	170	1.32%		
	Crash at intersection	292	2.27%		
	Medical problem	54	0.42%		
Vehicle Factors	Tyre failure	921	7.17%	**2071**	**16.1%**
	Trailer failure	376	2.93%		
	Mechanical failure	278	2.16%		
	Brake failure	157	1.22%		
	Towing of vehicles	131	1.02%		
	Vehicle sway	111	0.86%		
	Load loss	97	0.75%		
Roadway Factors	Construction / Maintenance site	239	1.86%	**1113**	**8.7%**
	Stationary vehicles	235	1.83%		
	Poor Visibility	234	1.82%		
	Skidding	162	1.26%		
	Animal in roadway	145	1.13%		
	Object in roadway	60	0.47%		
	Edge drop-off / Gravel shoulder	23	0.18%		
	Previous crash	10	0.08%		
	Public transport stop	5	0.04%		
	Other/Unknown	310	2.41%	**310**	**2.4%**

4.3.7 Weather during Crashes

Weather conditions can contribute to road crashes. As atmospheric conditions changes, so do the possibility of traffic crash occurrence. Muviringi (2012) noted that "Weather conditions like rain and mist reduce visibility, while floods and geomorphic factors such as rock-falls and landslides can also contribute to road crashes" (Muviringi, 2012: 19). Figure 4-8 present the percentages and graphical illustration of road crashes that occurred during the particular weather conditions on the South African part of the N4, and show that most of the RTCs happened in clear weather conditions (about 83%) over the study period (2010-2018). The aforementioned is followed by crashes occurring in rainy and misty conditions; however, only 2% of crashes occurred during misty conditions, and 14% in rainy weather. It would, therefore, appear that adverse weather conditions may not have such a significant effect on the frequency of the crashes recorded in this study, since most of the RTCs happened in clear weather conditions. The latter might be due to drivers appropriately reducing their speed when driving in poor weather conditions, and choosing inappropriate speeds in clear conditions. Refer to Addendum D for the complete annual breakdown of road crashes that occurred during the particular weather conditions on the South African part of the N4.

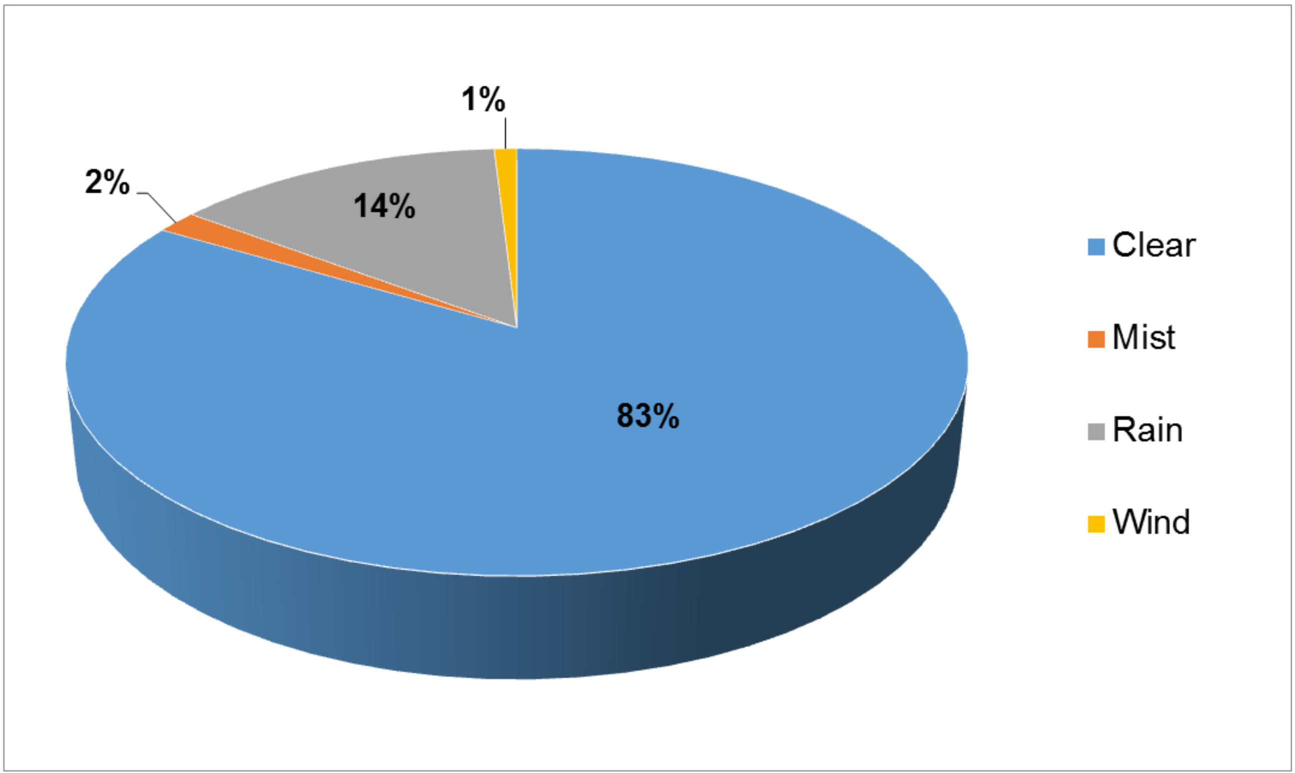


Figure 4-8: Percentage of RTCs per Weather Condition, South African part of the N4 Toll Road (2010-2018)

4.3.8 Vehicle Types involved in Crashes

Different vehicles types are involved in RTCs over the review period (2010-2018). Table 4-6 presents the vehicle types involved in RTCs on the South African part of the N4 Toll Road and indicates that passenger cars and LDVs (about 71% on average) are the vehicle types mostly involved in RTCs, followed by heavy vehicles (about 17% on average). Minibus taxis are also responsible for a considerable number of crashes that occurred throughout the 9-year review period, ranging from 10.3% in 2010, 11.1% in 2011, to about 8% and 9% in 2017 and 2018 respectively. A graphical illustration of the vehicles involved in crashes is presented in Figure 4-9 below.

Table 4-6: Number and Type of vehicles involved in RTCs, South African part of the N4 Toll Road (2010-2018)

	Number of Crashes per vehicle type per Annum										
Vehicle type	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**TOTAL**	**Percentage**
Passenger & LDV	1085	920	974	1260	1065	1171	1098	1202	1241	10016	71.71%
Heavy & Tanker	260	238	217	325	281	242	252	309	315	2439	17.46%
Minibus	158	148	119	138	130	132	142	128	151	1246	8.92%
Bus	17	16	16	15	21	11	15	15	13	139	1.00%
Motorcycle	9	6	6	10	6	13	7	8	6	71	0.51%
Other	4	3	2	5	5	4	20	3	10	56	0.40%

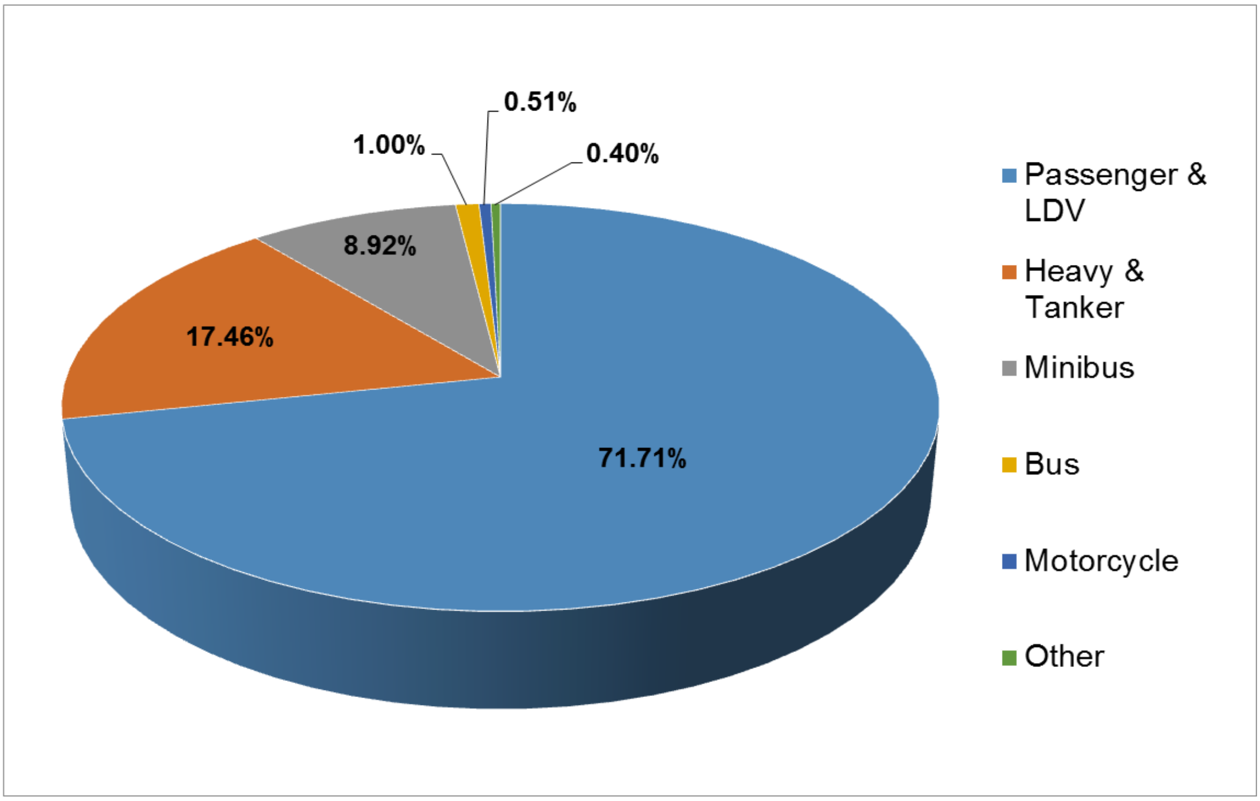


Figure 4-9: Types of vehicles involved in RTCs (2010-2018) TRAC N4: South African Section

4.3.9 Types of Crashes

Table 4-7 presents the number and percentage of RTCs per crash type that occurred within the South African part of the N4 over the study period (2010-2018) and indicates that Single vehicle type of crashes predominantly occurred (about 54%), followed by head-tail crashes (19%), head-side (10%), side-swipe (7%), multiple pile-ups (6%) and head-on crashes (3%). A graphical illustration is presented in Figure 4-10 below. Refer to Addendum D for the complete annual breakdown of the different types of crashes that occurred within the South African part of the N4.

Table 4-7: Number and Percentage of RTCs per Crash Type (2010-2018) TRAC N4: South African Section

Number of Crashes per Crash type (2010 -2018)		
Accident type	**Total**	**Percentage**
Single vehicle	4795	53.59%
Head-tail	1710	19.11%
Head-side	881	9.85%
Side-swipe	570	6.37%
Multiple pile-up	555	6.20%
Head-on	277	3.10%
Unknown/other	106	1.18%
Hit and Run	53	0.59%

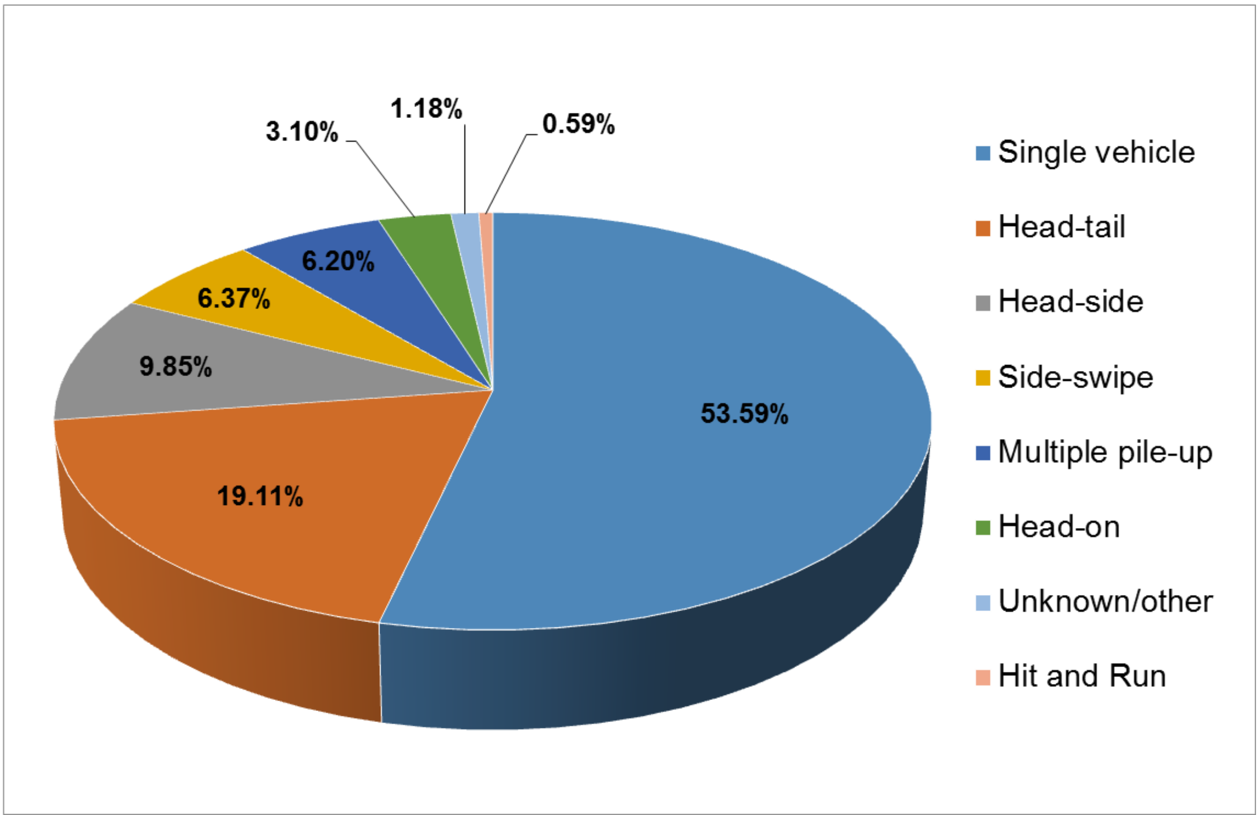


Figure 4-10: Percentage of RTCs per Crash Type (2010-2018) TRAC N4: South African Section

4.3.10 Crash details per road section

As previously stated, the number of crashes that occur within a road section is generally used to determine how safe the section of road is. However, only taking the number of crashes into account and disregarding the number of vehicles that travel along the section of road, can lead to an erroneous interpretation of the number of crashes. For this reason, using the crash rate of the road section is recommended. This recommendation takes into account the vehicle kilometres travelled by calculating the crash rate per million vehicle kilometres.

According to the World Health Organisation (WHO), Australia has one of the lowest road crash fatality rates in the world and is, therefore, considered one of the world leaders in road safety (WHO, 2018). In Australia a crash rate of 1 per mvkm is deemed sufficiently safe, therefore, a crash rate of 1 per mvkm is set as the acceptable target rate to work towards. Previously all the road sections in the South African section of the N4 were deemed sufficiently safe, due to the crash rates always being less than 1. However, in 2013, several 'high-risk' areas developed, mainly as a result of the major construction works along various sections of the N4. TRAC decided to identify sections that can be improved and, therefore, for an analysis criterion uses a crash rate of more than 0.6 per million vehicle kilometres for the sections in South Africa. This crash rate is used to identify high-risk areas in South Africa. A complete analysis of the high-risk sections follows in Part 4.4 of this report.

The N4 route is subdivided into different sections on the basis of measurable traffic volumes and similar geometric elements and properties. To effectively evaluate the comparative number of crashes that occurred on each of the road sections with different traffic volumes, it was necessary to calculate the crash rate for each section. To assess the most current situation regarding the road safety of each of the different sections, recent crash rates were evaluated and compared with previous years' statistics to note trends, determine high-risk areas and find solutions to reduce crashes and improve on crash severity.

Table 4-8 provides a breakdown of the annual crash rates for the different road sections within the South African part of the N4 over the review period (2010-2018). Figure 4-10 presents a graphical illustration of the average crash rates for these different road sections. Refer to Addendum D for the complete breakdown of the Annual crash rates for the different road sections within the South African part of the N4 over the review period (2010-2018).

Table 4-8: Annual Crash rates for the different road sections N4: South Africa (2010-2018)

Region		Road Section and Description	Crash rate per Annum									Average
			2010	2011	2012	2013	2014	2015	2016	2017	2018	2010 to 2018
Gauteng	1g	N4-1 km 21.3 - km 25.59 Solomon Mahlangu - end N4/1	0.1	0.06	0.15	0.1	0.03	0.06	0.09	0.09	0.24	0.101
	2a	N4/2 km 0.00 to N4/2 km 2.90 Start N4/2 to Boschkop / Donkerhoek interchange	0.05	0.09	0.3	0.33	0.19	0.09	0.53	0.18	0.27	0.224
	2b	N4/2 km 2.90 to N4/2 km 21.98 Boschkop interchange to Witfontein / Valtaki interchange	0.36	0.22	0.32	0.51	0.35	0.36	0.2	0.24	0.2	0.305
	2c	N4/2 km 21.98 to N4/2 km 30.08 Witfontein interchange to Ekandustria / Bronkhorstspruit interchange	0.41	0.42	0.24	0.44	0.34	0.36	0.22	0.2	0.2	0.316
	2d	N4/2 km 30.08 to N4/2 km 35.40 Bronkhorstspruit interchange to Delmas interchange	0.30	0.48	0.28	0.55	0.3	0.47	0.41	0.22	0.26	0.364
	2e	N4/2 km 35.40 to N4/2 km 47.0 Delmas interchange to Bossemanskraal interchange	0.58	0.43	0.46	0.46	0.36	0.35	0.34	0.3	0.31	0.399
	2f	N4/2 km47.0 to N4/2 km 55.0 Bossemanskraal interchange to Gauteng / Mpumalanga border	0.33	0.28	0.4	0.34	0.4	0.28	0.36	0.28	0.34	0.333
Highveld	1	N4/3 km 0.0 to N4/3 km 19.6 Spitskop – Clew er	0.32	0.22	0.24	0.22	0.24	0.17	0.18	0.18	0.20	0.219
	2	N4/3 km 14.5 to N4/3 km 30.2 Clew er to Start of Concrete section	0.3	0.27	0.3	0.24	0.45	0.39	0.14	0.38	0.39	0.317
	3	N4/3 km 30.2 to km 41.76 to N4/4 km 6.60 Concrete section to Van Dyksdrift	0.34	0.24	0.17	0.17	0.36	0.35	0.3	0.51	0.54	0.330
	4a	N4/4 km 6.60 to N4/4 km 9.60 Van Dyksdrift to km 9.60	0.32	0.24	0.48	0.48	0.36	0.59	0.51	0.48	0.54	0.442
	4b	N4/4 km 9.6 to N4/4 km 19.50 km 9.60 to Rockdale N11	0.43	0.47	0.34	0.34	0.31	0.41	0.35	0.45	0.4	0.387
	4c	N4/4 km 19.50 to N4/4 km 34.0 N11 to Lemoenfontein	0.53	0.46	0.48	0.48	**0.62**	0.57	0.53	0.26	0.34	0.472
	4d	N4/4 km 34.0 to km 47.55 to N4/5 km 9.90 Lemoenfontein to Wonderfontein	0.5	0.46	0.35	0.35	0.57	0.59	0.45	0.35	0.42	0.451
	5a	N4/5 km 9.90 to N4/5X km 29.4 Wonderfontein to Belfast	0.37	0.33	0.32	0.32	0.39	0.46	0.48	0.45	0.36	0.385
	5b	N4/5X km 29.4 to km 56.8 to N4/6X km 2.70 Belfast to Crossroads	**0.72**	**0.61**	**0.86**	**0.86**	0.48	**0.71**	**0.71**	**0.75**	**0.85**	**0.730**
Lowveld	6E	N4/6X km 2.70 to km 43.32 to N4/7X km 22.70 Crossroads via Elandspoort to Montrose	0.39	0.49	0.4	0.4	**0.7**	**0.62**	**0.83**	**1.07**	**0.78**	**0.630**
	6N	N4/6Y km 0.0 to km N4/6Y km 63.72 Schoemanskloof Road (Crossroads to Montrose)	0.53	0.44	0.33	0.33	0.52	0.52	**0.73**	**0.84**	**0.82**	0.563
	7a	N4/7X km 22.70 to N4/7X km 36.50 Montrose to Alkmaar	0.45	0.54	**0.71**	**0.60**	**0.63**	0.49	0.39	0.54	0.53	0.542
	7b i	N4/7X km 36.50 to N4/7X km 46 Alkmaar to Ring Road start	0.41	0.33	0.26	**0.71**	**0.81**	**0.83**	0.59	**0.68**	0.42	0.559
	8f ii	N4/7X km 64.8 to N4/7X km 65.60 Ring Road end to Karino	0.5	0.51	0.48	**1.23**	**0.74**	0.17	**1.15**	**0.86**	**0.62**	**0.694**
	8BP	N4/7 km 46.0 to N4/7 km 64.8 Nelspruit Ring Road	**1.18**	0.54	0.27	0.30	0.21	0.46	0.60	0.24	0.41	0.467
	9	N4/7X km 65.60 to N4/7X km 74.1 Karino to Mara	0.37	0.40	0.41	0.6	**0.81**	**0.77**	**0.62**	**0.78**	**0.73**	**0.609**
	10	N4/7X km 74.1 to N4/7X km 90.05 Mara to Crocodile River	**0.89**	0.54	0.57	**1.2**	**0.76**	**0.60**	0.43	0.57	0.46	**0.668**
	11	N4/8X km 0.0 to N4/8X km 4.90 Crocodile River to Kaapmuiden	0.37	0.51	0.30	0.48	**0.63**	**0.67**	**0.65**	**1.25**	**1.57**	**0.714**
	12	N4/8X km 4.90 to N4/8X km 14.60 Kaapmuiden to Strathmore	0.41	0.24	0.32	0.57	0.44	0.39	0.49	0.40	0.56	0.424
	13	N4/8X km 14.60 to N4/8X km 26.90 Strathmore to Malelane gate/ Jeppe's Reef Int	**0.63**	**0.70**	0.47	0.41	0.31	0.36	0.41	0.47	**0.66**	0.492
	14	N4/8X km 26.9 to N4/8X km 39.10 Malelane gate/Jeppe's Reef Int to Hectorspruit	0.43	0.36	0.31	**0.70**	0.47	0.46	0.57	0.70	0.42	0.491
	15a	N4/8X km 39.10 to N4/8X km 69.10 Hectorspruit to Border gate	0.53	**0.63**	0.37	0.56	0.46	0.56	0.57	**1.33**	**0.62**	**0.626**
	15b	N4/8X km 69.10 to N4/8X km 70.63 Border post	0.00	0.32	**1.21**	**1.10**	0.30	**0.65**	0.00	0.34	**0.72**	0.515

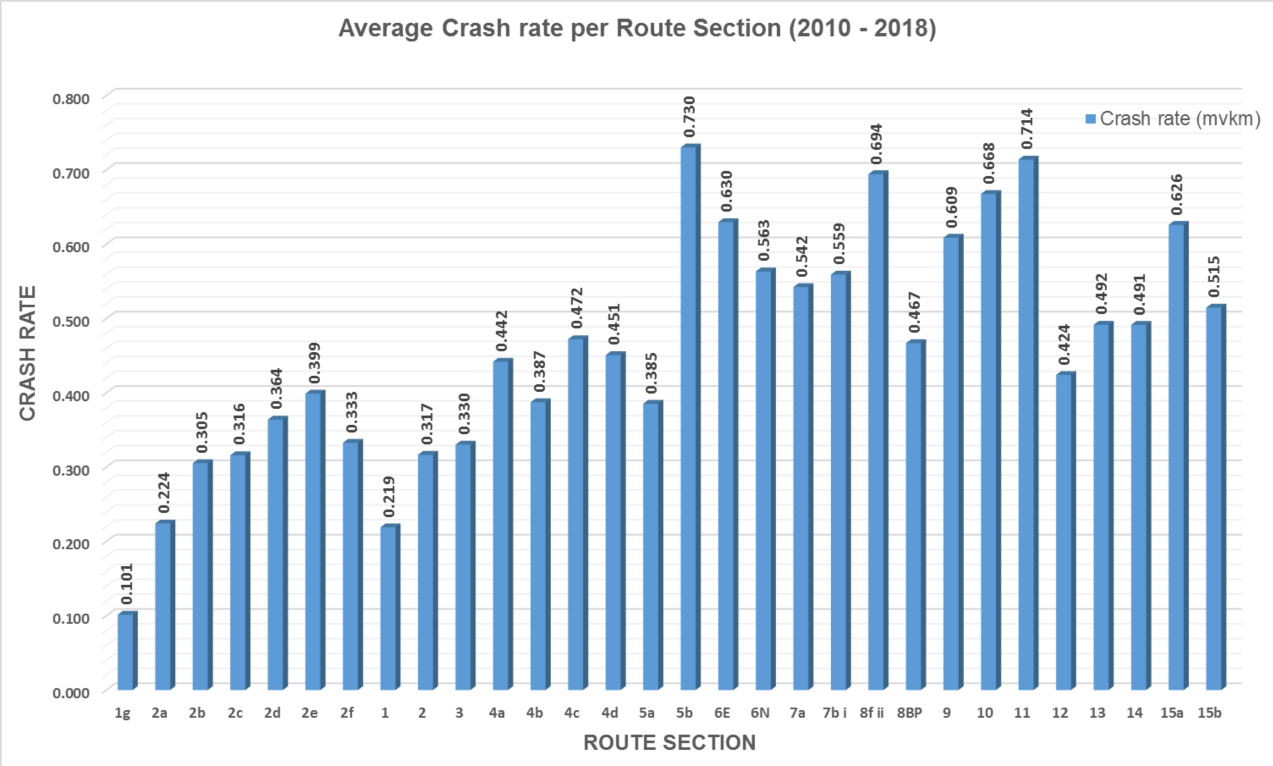


Figure 4-11: Average Crash rates for the different road sections N4: South Africa (2010-2018)

4.4 High-Risk Area Analysis

The South African Section of the N4 Toll Route is divided into three topographical regions, namely Gauteng, the Highveld (Nkangala) and the Lowveld (Ehlanzeni). Each region is sub-divided into different road sections based on measurable traffic and geometric segments with similar properties (refer to Table 4-8). Table 4-8 provides a breakdown of the annual crash rates for the different road sections over the study period (2010-2018) and indicates various sections as having a crash rate above the target criterion of 0.6 per million vehicle kilometres. For this part of the study, each road section was independently evaluated. To find the possible association between the high crash rate, and the human factors involved, areas with the highest crash rate were identified for further study.

As mentioned under Part 2.4 of this study, AASHTO (2010) reported that “Most crashes cannot be related to a singular causal event; instead, crashes are the result of a convergence of a series of events that are influenced by several contributing factors” (AASHTO, 2010: 3.8). Results from this study found the human factors alone to have caused 72.8% of RTCs, while 8.7% of RTCs were due to the road environment factors. Refer to Figure 4-7.

The South African Road Safety Manual (Volume 1) articulates as follows: “Road safety engineering plays a vital role in influencing driver behaviour as engineering measures, for example, traffic control rely heavily upon the driver to see, interpret, respond to and obey the measure. In this sequence, the road environment should assist the driver in making a series of correct decisions and, if not correct, provide a forgiving road environment to reduce the severity of the accident. Road safety engineering can create such an environment by, controlling the rate of decision-making to a level that a driver is able to accommodate, and by providing information to the driver in such a manner that it facilitates quick and correct decisions” (COLTO, 1999a:B2). The high-risk areas identified in this study were evaluated, with the abovementioned serving as the assessment criteria.

4.4.1 High-Risk Sections: Design Elements and Crash Analysis

The identification of the high-risk areas allows for hazardous sections to be improved through methods like the provision of traffic-calming measures, high visibility road signs and stock fences etc. The road design data shown in Table 4-9, was correlated with the crash data collected from TRAC for each of the identified high-risk areas; refer to Table 4-10. This has been done to explore the possible underlying relation between the different road design elements and the RTCs caused by human factors.

According to AASHTO (2010) “The goal [with studying the] human factors is to reduce the probability and consequences of human error within systems, and the associated injuries and fatalities, by designing for human characteristics and limitations” (AASHTO, 2010, p.2.1). To assess the most current situation regarding the safety of each of the different sections, recent crash rates were evaluated and compared with previous years’ statistics to note trends, determine high-risk areas and find solutions to reduce crashes and improve on crash severity.

The following sections were classified as high-risk areas on the TRAC N4 Toll Route, with average rates of over 0.6 crashes per million vehicle kilometres travelled (mvkm), recorded over the assessment period shown in brackets;

- Section 5B - 0.730 crashes per mvkm (2010-2018)
- Section 6E - 0.797 crashes per mvkm (2014-2018)
- Section 6N - 0.799 crashes per mvkm (2016-2018)
- Section 8f ii - 0.694 crashes per mvkm (2010-2018)

- Section 9 - 0.609 crashes per mvkm (2010-2018)
- Section 10 - 0.668 crashes per mvkm (2010-2018)
- Section 11 - 0.714 crashes per mvkm (2010-2018)
- Section 15A - 0.626 crashes per mvkm (2010-2018)

Table 4-9: High-Risk sections: Design details N4: South Africa

Route section	Region	Length (km)	Posted Speed (km/h)	No. of lanes (per direction)	Lane width (m)	Shoulder width (m)	Median width (m)	Access -point density	Auxiliary lanes	Terrain
2	Gauteng	59.29	120	2	3.7	1.8	9	Low	N/A	Level
5B	Highveld	30.10	120	1	3.7	0.6 & 1.8	-	Low	Limited	Rolling
6E	Highveld	63.32	120	1	3.7	0.6 & 1.8	-	Low	Alternating	Rolling
6N	Lowveld	63.72	120	1	3.7	0.6 & 1.8	-	Low	Limited	Rolling
8f ii	Lowveld	19.60	120	1	3.7	0.6 & 1.8	-	High	Limited	Rolling
9	Lowveld	8.50	120	1	3.7	0.6 & 1.8	-	Low	Limited	Rolling
10	Lowveld	15.95	120	1	3.7	0.6 & 1.8	-	Low	Limited	Rolling
11	Lowveld	4.90	120	1	3.7	0.6 & 1.8	-	High	Limited	Rolling
15A	Lowveld	30.00	120	1	3.7	0.6 & 1.8	-	High	Limited	Rolling

Table 4-10: High-Risk sections: Crash details N4: South Africa

Route section	Average Crash rate	Length (km)	Injury Count			Gender of Driver		Crash cause		
			Fatal	Serious	Slight	Male	Female	Human	Vehicle	Road
2	0.292	59.29	120	263	2884	542	108	72.4%	18.9%	8.7%
5B	0.730	30.10	105	255	366	307	37	66.9%	19.1%	14.0%
6E	0.797	63.32	108	282	541	352	38	66.3%	23.4%	10.2%
6N	0.799	63.72	58	210	335	269	52	72.3%	17.4%	10.3%
8f ii	0.694	19.60	21	61	104	72	11	77.2%	18.4%	4.4%
9	0.609	8.50	41	105	115	84	12	76.8%	16.9%	6.2%
10	0.668	15.95	54	185	250	174	32	76.0%	13.1%	10.9%
11	0.714	4.90	7	36	55	47	11	69.4%	24.1%	6.5%
15A	0.626	30.00	72	181	294	126	18	60.8%	18.4%	20.9%

4.4.1.1 Gauteng Region of the South African N4 Section

None of the sections located in the Gauteng region was found to have problematical crash rates, with all road sections having lower than 0.6 crashes per million vehicle kilometres travelled (mvkm). A key map indicating the Gauteng region showing the various sections is presented in Figure 4-12 below.

Figure 4-12: Gauteng Region of the N4 South African Section

A total of 888 RTCs were reported over the review period (2010-2018) for the Gauteng region, resulting in an average crash rate of less than 0.3 crashes per mvkm. Table 4-11 presents a breakdown of the main contributing factors in the crashes that occurred within the Gauteng region of the N4 Toll Road (2010 to 2018). At 72.4%, human factors were found to be the leading cause of RTCs.

At 20.1% the majority of crashes were caused by driver fatigue, resulting in single vehicle crashes. At 13.4%, many of the crashes were also caused by either, vehicles travelling at speeds above the posted speed limit, or vehicles following inappropriate speed-differentials, resulting in head-tail crashes. Table 4-11 further presents the number and percentage of crashes per crash type that occurred within the Gauteng region of the N4 over the study period (2010-2018) and indicates that single vehicle type of crashes predominantly occurred (about 64.4%), followed by head-tail crashes (21.2%), and head-side (5.9%).

Table 4-11: Types and Causes of Crashes Gauteng region (2010-2018)

Type of Crash	TOTAL	Percentage	TOTAL
Single vehicle	572	64.4%	888
Head-tail	188	21.2%	
Sideswipe	32	3.6%	
Head-on	7	0.8%	
Head-side	52	5.9%	
Multiple pile-up	37	4.2%	

Cause of Crash	TOTAL	Percentage	TOTAL	Percentage
Lost control	136	15.7%	628	72.4%
Negligent driving	84	9.7%		
Speed differential (rear-end)	116	13.4%		
Speeding	4	0.5%		
Sleeping	174	20.1%		
Overtaking	14	1.6%		
Pedestrian/Cyclist	28	3.2%		
U-Turn / Reversing vehicles	23	2.7%		
Drugs/Alcohol	26	3.0%		
Wrong direction of travel	5	0.6%		
Crash at Intersection	6	0.7%		
Medical problem	12	1.4%		
Tyre failure	86	9.9%	164	18.9%
Trailer failure	24	2.8%		
Mechanical failure	20	2.3%		
Brake failure	9	1.0%		
Towing of vehicles	15	1.7%		
Vehicle sway	4	0.5%		
Load loss	6	0.7%		
Construction site	10	1.2%	75	8.7%
Stationary vehicles	10	1.2%		
Poor Visibility	14	1.6%		
Skidding	10	1.2%		
Animal in roadway	24	2.8%		
Object on road	5	0.6%		
Edge drop-off/Gravel shoulder	0	0.0%		
Previous crash	2	0.2%		
Public transport stop	0	0.0%		

The highest crash rates for the Gauteng region were calculated for the following sections:

- Section 2d between Bronkhorstspruit West / Ekandustria Interchange and Bronkhorstspruit East/Delmas Interchange with an average rate of 0.364 crashes per mvkm for 2010-2018.
- Section 2e between Delmas / Bronkhorstspruit East Interchange and Bossemanskraal Interchange with an average rate of 0.399 crashes per mvkm travelled for 2010-2018.
- Section 2f between Bossemanskraal and the Gauteng/Mpumalanga Provincial Boundary with an average rate of 0.333 crashes per mvkm travelled for 2010-2018.

The overall lower crash rates found within the Gauteng regional sections can be largely attributed to the cross-section design, level terrain and absence of challenging horizontal curvature. Figure 4-13 presents a photograph indicating the general cross-section design for the region. The cross-section consists of a divided dual carriageway with a well-designed median. The median acts as a clear zone for errant vehicles and reduces the incidence of opposite direction collisions. Crash rate and severity decrease with an increase in median width. A wide median should, therefore, be provided as far as possible as it reduces the likelihood of head-on crashes between vehicles travelling in the opposite direction. A wide median further reduces same-direction accidents as it provides a recovery area. The construction of the UTFC Asphalt overlay on Section 2e during 2013, contributed to the increase in the crash rate over this period (0.276 to 0.553), especially at night time when permanent road markings and studs were not yet in place. After the construction was completed, the crash rate decreased to rates of 0.220 and 0.263 for 2017 and 2018 respectively.

Figure 4-13: N4 Section 2f between Bossemanskraal and the Gauteng/Mpumalanga Provincial Boundary (Source: Google Street view)

4.4.1.2 Highveld Region of the South African N4 section

Only one section in the Highveld region has an average crash rate above 0.6 crashes per million vehicle kilometres travelled (mvkm) recorded over the 9-year period from 2010 to 2018. A key map indicating the Highveld region showing the various sections is presented in Figure 4-14 below.

Figure 4-14: Highveld Region of the N4 South African Section

The highest crash rates were calculated for the following section:

- Section 5B between Belfast and Machadodorp experienced an average rate of 0.730 crashes per mvkm for 2010-2018.

Section 5B between Belfast and Machadodorp

A total of 608 RTCs were reported over the review period (2010-2018) for Section 5B, resulting in an average crash rate of 0.730 crashes per mvkm. Table 4-12 presents a breakdown of the main contributing factors in the crashes that occurred within Section 5B of the N4 Toll Road (2010 to 2018). At 66.9%, human factors were found to be the leading cause of RTCs. At 17.3% the majority of crashes were caused by 'Lost Control', resulting predominantly in single vehicle crashes. At 14%, many of the crashes were also caused by negligent driving, and vehicles following inappropriate speed-differentials, resulting in head-tail crashes. Table 4-12 further presents the number and percentage of crashes per crash type that occurred within Section 5B of the N4 over the study period (2010-2018) and indicates that Single vehicle type of crashes predominantly occurred (51.5%), followed by head-tail crashes (17.8%), and head-side (12.3%).

Table 4-12: Types and Causes of Crashes Section 5B (2010-2018)

Type of Crash	TOTAL	Percentage	TOTAL
Single vehicle	313	51.5%	**608**
Head-tail	108	17.8%	
Sideswipe	29	4.8%	
Head-on	30	4.9%	
Head-side	75	12.3%	
Multiple pile-up	53	8.7%	

Cause of Crash	TOTAL	Percentage	TOTAL	Percentage
Lost control	105	17.3%	**406**	**66.9%**
Negligent driving	85	14.0%		
Speed differential (rear-end)	63	10.4%		
Speeding	2	0.3%		
Sleeping	34	5.6%		
Overtaking	39	6.4%		
Pedestrian/Cyclist	9	1.5%		
U-Turn / Reversing vehicles	19	3.1%		
Drugs/Alcohol	15	2.5%		
Wrong direction of travel	3	0.5%		
Crash at Intersection	29	4.8%		
Medical problem	3	0.5%		
Tyre failure	32	5.3%	**116**	**19.1%**
Trailer failure	26	4.3%		
Mechanical failure	26	4.3%		
Brake failure	7	1.2%		
Towing of vehicles	18	3.0%		
Vehicle sway	2	0.3%		
Load loss	5	0.8%		
Construction site	3	0.5%	**85**	**14.0%**
Stationary vehicles	23	3.8%		
Poor Visibility	32	5.3%		
Skidding	18	3.0%		
Animal in roadway	5	0.8%		
Object on road	4	0.7%		
Edge drop-off/Gravel shoulder	0	0.0%		
Previous crash	0	0.0%		
Public transport stop	0	0.0%		

The high crash rate, found on Section 5B, can mainly be attributed to the existing cross-section design, the rolling terrain and some challenging horizontal curvature. Figure 4-15 presents a photograph indicating the general cross-section design along the section. The existing cross-section consists of an undivided single carriageway, 3.7m wide lanes in both directions, with paved outside shoulders. Auxiliary lanes have been provided at certain segments along the section to meet the specified Level of Service D requirement for the N4 Toll Route. Speed profile analyses are also regularly conducted along the N4 Toll Route to establish where climbing lanes are required to alleviate congestion on the steep gradient sections. Slow-moving vehicles and trucks crawling on steep up and downgrades remain a major concern. This, combined with limited passing opportunities has caused frustration and reckless driving. Negligent drivers become frustrated and overtake over barrier lines. The section has since been earmarked for upgrading to a four-lane road.

Figure 4-15: N4 Section 5B between Belfast and Machadodorp (Source: Google Street view)

4.4.1.3 Lowveld Region of the South African N4 section

Seven sections located in the Lowveld region with average crash rates of more than 0.6 crashes per mvkm, recorded over the 9-years from 2010 to 2018, were analysed. A key map indicating the Lowveld region showing the various sections is presented in Figure 4-16 below.

The highest crash rates were calculated for the following sections:

- Section 6E, Elands Valley Road to Montrose, experienced an average rate of 0.630 crashes per mvkm for 2010-2018.
- Section 6N, Schoemanskloof Road (Crossroads to Montrose), experienced an average rate of 0.688 crashes per mvkm for 2014-2018
- Section 8f ii in the Karino area (east of Nelspruit) experienced an average rate of 0.694 crashes per mvkm for 2010-2018.
- Section 9 between Karino and Mara experienced an average rate of 0.609 crashes per mvkm for 2010-2018.
- Section 10 between Mara and the Crocodile River experienced an average rate of 0.760 crashes per mvkm for 2010-2015.
- Section 11 from Crocodile River (Matsulu) to Kaapmuiden Region experienced an average rate of 0.714 crashes per mvkm for 2010-2018.
- Section 15A between Hectorspruit and Komatipoort experienced an average rate of 0.626 crashes per mvkm for 2010-2018.

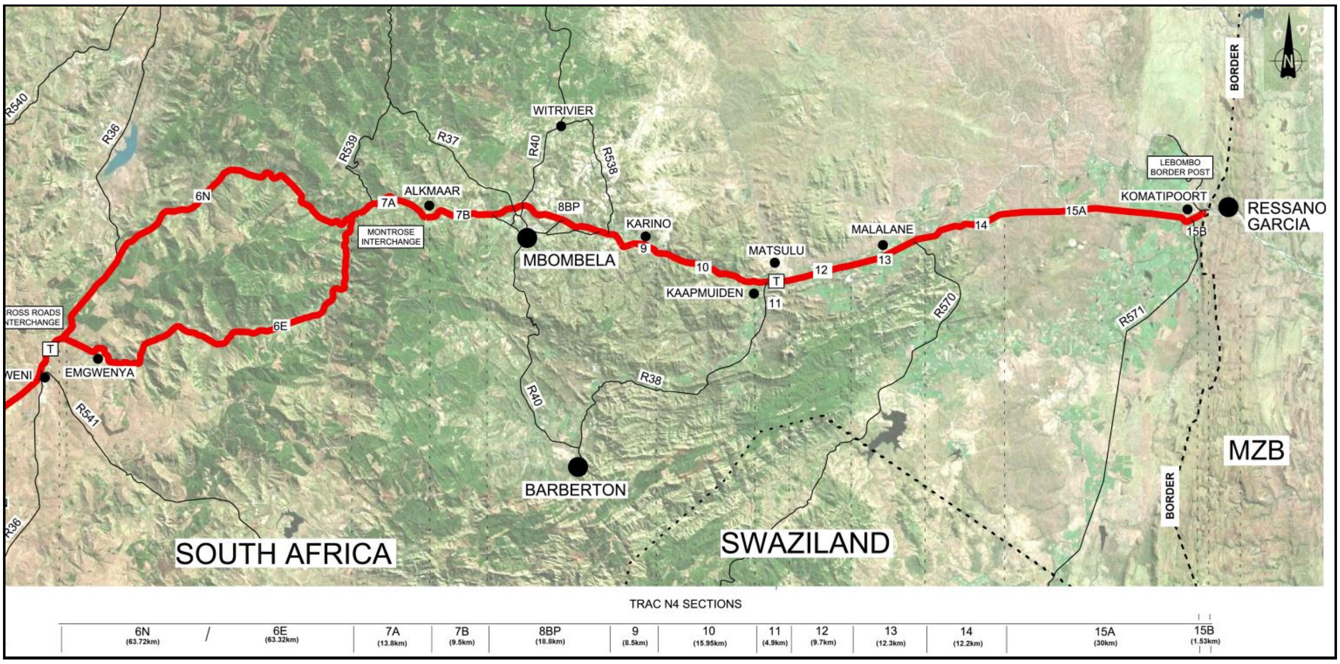


Figure 4-16: Lowveld Region of the N4 South African Section

Section 6E, Elands Valley Road to Montrose

A total of 683 RTCs were reported over the review period (2010-2018) for Section 6E, resulting in an average crash rate of 0.630 crashes per mvkm. Table 4-13 presents a breakdown of the main contributing factors in the crashes that occurred within Section 6E of the N4 Toll Road (2010 to 2018). At 66.3%, human factors were found to be the leading cause of RTCs. At 12.9% the majority of crashes were caused by 'Lost Control', resulting predominantly in single-vehicle crashes. At 11.1%, many of the crashes were also caused by negligent driving, and vehicles following inappropriate speed-differentials (9.2%), resulting in head-tail crashes. Table 4-13 further presents the number and percentage of crashes per crash type that occurred within Section 6E of the N4 over the study period (2010-2018) and indicates that Single-vehicle type of crashes predominantly occurred (51.5%), followed by head-tail crashes (17.3%), and head-side (11.3%).

Table 4-13: Types and Causes of Crashes Section 6E (2010-2018)

Type of Crash	TOTAL	Percentage	TOTAL
Single vehicle	349	51.1%	683
Head-tail	118	17.3%	
Sideswipe	63	9.2%	
Head-on	24	3.5%	
Head-side	77	11.3%	
Multiple pile-up	52	7.6%	

Cause of Crash	TOTAL	Percentage	TOTAL	Percentage
Lost control	88	12.9%	453	66.3%
Negligent driving	76	11.1%		
Speed differential (rear-end)	63	9.2%		
Speeding	1	0.1%		
Sleeping	73	10.7%		
Overtaking	74	10.8%		
Pedestrian/Cyclist	7	1.0%		
U-Turn / Reversing vehicles	23	3.4%		
Drugs/Alcohol	23	3.4%		
Wrong direction of travel	13	1.9%		
Crash at Intersection	11	1.6%		
Medical problem	1	0.1%		
Tyre failure	47	6.9%	160	23.4%
Trailer failure	15	2.2%		
Mechanical failure	54	7.9%		
Brake failure	16	2.3%		
Towing of vehicles	15	2.2%		
Vehicle sway	1	0.1%		
Load loss	12	1.8%		
Construction site	5	0.7%	70	10.2%
Stationary vehicles	30	4.4%		
Poor Visibility	6	0.9%		
Skidding	6	0.9%		
Animal in roadway	14	2.0%		
Object on road	7	1.0%		
Edge drop-off/Gravel shoulder	0	0.0%		
Previous crash	0	0.0%		
Public transport stop	2	0.3%		

The high crash rate, found on Section 6E, can mainly be attributed to the existing cross-section design, the rolling terrain and construction activities along the section. Figure 4-17 presents a photograph indicating the general cross-section design along the section. The existing cross-section consists of an undivided single carriageway, 3.7m wide lanes in both directions, with paved outside shoulders.

Section 6E, Elands Valley Road to Montrose, experienced an average rate of 0.630 crashes per mvkm for 2010-2018. The rate for 2017 was 1.070 increasing from 0.826 in the previous year. The section has been under major rehabilitation with Stop/Go's traffic accommodation in place. The rehabilitation and expansions were completed in October 2018. The completion of the construction and added passing opportunities should have a positive impact on traffic safety and reduce the number of RTCs in future years.

Figure 4-17: N4 Section 6E, Elands Valley Road to Montrose (Source: Google Street view)

Section 6N, Schoemanskloof Road (Crossroads to Montrose)

A total of 528 RTCs were reported over the review period (2010-2018) for Section 6N, resulting in an average crash rate of 0.688 crashes per mvkm. Table 4-14 presents a breakdown of the main contributing factors in the crashes that occurred within Section 6N of the N4 Toll Road (2010 to 2018). At 72.3%, human factors were found to be the leading cause of RTCs. At 20.4% the majority of crashes were caused by ‘Negligent driving’ resulting predominantly in single-vehicle crashes. At 18.3%, many of the crashes were also caused by ‘Lost control’, and vehicles following inappropriate speed-differentials (8%), resulting in head-tail crashes. Table 4-14 further presents the number and percentage of crashes per crash type that occurred within Section 6N of the N4 over the study period (2010-2018) and indicates that Single-vehicle type of crashes predominantly occurred (58.5%), followed by head-tail crashes (12.9%), and head-side (6.8%).

Table 4-14: Types and Causes of Crashes Section 6N (2010-2018)

Type of Crash	TOTAL	Percentage	TOTAL
Single vehicle	309	58.5%	528
Head-tail	68	12.9%	
Sideswipe	45	8.5%	
Head-on	27	5.1%	
Head-side	36	6.8%	
Multiple pile-up	43	8.1%	

Cause of Crash	TOTAL	Percentage	TOTAL	Percentage
Lost control	96	18.3%	379	72.3%
Negligent driving	107	20.4%		
Speed differential (rear-end)	42	8.0%		
Speeding	0	0.0%		
Sleeping	35	6.7%		
Overtaking	53	10.1%		
Pedestrian/Cyclist	6	1.1%		
U-Turn / Reversing vehicles	9	1.7%		
Drugs/Alcohol	10	1.9%		
Wrong direction of travel	11	2.1%		
Crash at Intersection	5	1.0%		
Medical problem	5	1.0%		
Tyre failure	22	4.2%	91	17.4%
Trailer failure	13	2.5%		
Mechanical failure	25	4.8%		
Brake failure	13	2.5%		
Towing of vehicles	14	2.7%		
Vehicle sway	0	0.0%		
Load loss	4	0.8%		
Construction site	3	0.6%	54	10.3%
Stationary vehicles	9	1.7%		
Poor Visibility	7	1.3%		
Skidding	10	1.9%		
Animal in roadway	22	4.2%		
Object on road	3	0.6%		
Edge drop-off/Gravel shoulder	0	0.0%		
Previous crash	0	0.0%		
Public transport stop	0	0.0%		

The high crash rate, found on Section 6N, can mainly be attributed to the existing cross-section design, the rolling terrain and the construction activities along Section 6E. Figure 4-18 presents a photograph indicating the general cross-section design along the section. The existing cross-section consists of an undivided single carriageway, 3.7m wide lanes in both directions, with paved outside shoulders. Auxiliary lanes have been provided at certain segments along the section to meet the specified Level of Service D requirement for the N4 Toll Route. Crashes on Section 6N have increased dramatically from 50 in 2015 to 127 in 2016, 140 in 2017 and 127 in 2018. The crash rate also increased from 0.520 in 2015 to 0.734 in 2016, 0.734 in 2017 and 0.823 in 2018.

Due to delays during the rehabilitation and construction of passing lanes on Section 6E, traffic has decreased substantially on Section 6E and diverted to the Schoemanskloof Road to avoid Stop/Go delays. The diversion of trucks onto Schoemanskloof crawling on steep up and downgrades and limited passing opportunities has caused frustration and reckless driving. Negligent drivers become frustrated and overtake over barrier lines. To improve safety during the rehabilitation of Section 6E, the Provincial Traffic department has introduced aggressive law enforcement of speed and moving violations on this section.

Figure 4-18: N4 Section 6N, Schoemanskloof Road (Crossroads to Montrose)
(Source: Google Street view)

Section 8f ii in the Karino area (east of Nelspruit)

A total of 159 RTCs were reported over the review period (2010-2018) for Section 8f ii, resulting in an average crash rate of 0.694 crashes per mvkm. Table 4-15 presents a breakdown of the main contributing factors in the crashes that occurred within Section 8f ii of the N4 Toll Road (2010 to 2018). At 77.2%, human factors were found to be the leading cause of RTCs. At 21.5% the majority of crashes were caused by 'Negligent driving' resulting predominantly in single-vehicle crashes. At 10.1%, many of the crashes were also caused by 'Lost control', and vehicles following inappropriate speed-differentials (7%), resulting in head-tail crashes. Table 4-15 further presents the number and percentage of crashes per crash type that occurred within Section 8 of the N4 over the study period (2010-2018) and indicates that Single-vehicle type of crashes predominantly occurred (45.3%), followed by head-tail crashes (17.0%), and head-side (17.0%).

Table 4-15: Types and Causes of Crashes Section 8f ii (2010-2018)

Type of Crash	TOTAL	Percentage	TOTAL
Single vehicle	72	45.3%	159
Head-tail	27	17.0%	
Sideswipe	15	9.4%	
Head-on	6	3.8%	
Head-side	27	17.0%	
Multiple pile-up	12	7.5%	

Cause of Crash	TOTAL	Percentage	TOTAL	Percentage
Lost control	16	10.1%	122	77.2%
Negligent driving	34	21.5%		
Speed differential (rear-end)	11	7.0%		
Speeding	0	0.0%		
Sleeping	9	5.7%		
Overtaking	15	9.5%		
Pedestrian/Cyclist	4	2.5%		
U-Turn / Reversing vehicles	17	10.8%		
Drugs/Alcohol	4	2.5%		
Wrong direction of travel	5	3.2%		
Crash at Intersection	5	3.2%		
Medical problem	2	1.3%		
Tyre failure	11	7.0%	29	18.4%
Trailer failure	1	0.6%		
Mechanical failure	9	5.7%		
Brake failure	1	0.6%		
Towing of vehicles	3	1.9%		
Vehicle sway	0	0.0%		
Load loss	4	2.5%		
Construction site	1	0.6%	7	4.4%
Stationary vehicles	4	2.5%		
Poor Visibility	0	0.0%		
Skidding	0	0.0%		
Animal in roadway	1	0.6%		
Object on road	1	0.6%		
Edge drop-off/Gravel shoulder	0	0.0%		
Previous crash	0	0.0%		
Public transport stop	0	0.0%		

The high crash rate, found on Section 8f ii, can mainly be attributed to the existing cross-section design, the rolling terrain and access point density. Figure 4-19 presents a photograph indicating the general cross-section design along the section. The existing cross-section consists of an undivided single carriageway, 3.7m wide lanes in both directions, with paved outside shoulders. Auxiliary and turning lanes have been provided at certain segments along the section to meet the specified Level of Service D requirement for the N4 Toll Route. Access Roads D636 and D2296 along the section created traffic flow complications, resulting in 27 head-side crashes over the study period. A traffic signal has since been installed at the intersection of Road D636 and Road D2296, which has improved traffic flow dramatically and eliminated queues on to the N4. Vehicles on the southbound approach of Road D636 still have difficulty in entering the N4.

The construction of the Karino Interchange planned for implementation in the near future should, however, address this problematic section. Point duty is done during morning peak times by Mpumalanga Provincial Traffic officers to alleviate congestion during the morning peak periods.

Figure 4-19: N4 Section 8f ii, Karino area (east of Nelspruit) (Source: Google Street view)

Section 9 between Karino and Mara

A total of 177 RTCs were reported over the review period (2010-2018) for Section 9, resulting in an average crash rate of 0.609 crashes per mvkm. Table 4-16 presents a breakdown of the main contributing factors in the crashes that occurred within Section 9 of the N4 Toll Road (2010 to 2018). At 76.8%, human factors were found to be the leading cause of RTCs. At 25.4% the majority of crashes were caused by 'Negligent driving' resulting predominantly in single-vehicle crashes. At 14.7%, many of the crashes were also caused by 'Lost control', and vehicles following inappropriate speed-differentials (6.8%), resulting in head-tail crashes. Table 4-16 further presents the number and percentage of crashes per crash type that occurred within Section 9 of the N4 over the study period (2010-2018) and indicates that Single-vehicle type of crashes predominantly occurred (45.2%), followed by head-tail crashes (22.0%), and sideswipe (13.0%).

Table 4-16: Types and Causes of Crashes Section 9 (2010-2018)

Type of Crash	TOTAL	Percentage	TOTAL
Single vehicle	80	45.2%	177
Head-tail	39	22.0%	
Sideswipe	23	13.0%	
Head-on	11	6.2%	
Head-side	17	9.6%	
Multiple pile-up	7	4.0%	

Cause of Crash	TOTAL	Percentage	TOTAL	Percentage
Lost control	26	14.7%	136	76.8%
Negligent driving	45	25.4%		
Speed differential (rear-end)	12	6.8%		
Speeding	0	0.0%		
Sleeping	7	4.0%		
Overtaking	18	10.2%		
Pedestrian/Cyclist	5	2.8%		
U-Turn / Reversing vehicles	11	6.2%		
Drugs/Alcohol	4	2.3%		
Wrong direction of travel	4	2.3%		
Crash at Intersection	4	2.3%		
Medical problem	0	0.0%		
Tyre failure	5	2.8%	30	16.9%
Trailer failure	2	1.1%		
Mechanical failure	15	8.5%		
Brake failure	4	2.3%		
Towing of vehicles	3	1.7%		
Vehicle sway	0	0.0%		
Load loss	1	0.6%		
Construction site	3	1.7%	11	6.2%
Stationary vehicles	0	0.0%		
Poor Visibility	0	0.0%		
Skidding	1	0.6%		
Animal in roadway	6	3.4%		
Object on road	1	0.6%		
Edge drop-off/Gravel shoulder	0	0.0%		
Previous crash	0	0.0%		
Public transport stop	0	0.0%		

The high crash rate, found on Section 9, can mainly be attributed to the existing cross-section design, the rolling terrain, steep downgrades and the sharp horizontal curves. Figure 4-20 presents a photograph indicating the general cross-section design along the section. The existing cross-section consists of an undivided single carriageway, 3.7m wide lanes in both directions, with paved outside shoulders. Auxiliary and turning lanes have been provided at certain segments along the section to meet the specified Level of Service D requirement for the N4 Toll Route. 30 Crashes occurred on this 8.5km section in 2018. The average crash rate over the past five years was even higher, calculated as 0.741. The section is currently earmarked for upgrading, with SANRAL's long-term strategy for realignment under development. The trucks crawling on steep up and downgrades and limited passing opportunities have caused frustration and reckless driving. Negligent drivers become frustrated and overtake over barrier lines.

Figure 4-20: N4 Section 9, between Karino and Mara (Source: Google Street view)

Section 10 between Mara and the Crocodile River (Matsulu)

A total of 376 RTCs were reported over the review period (2010-2018) for Section 10, resulting in an average crash rate of less than 0.668 crashes per mvkm. Table 4-17 presents a breakdown of the main contributing factors in the crashes that occurred within Section 10 of the N4 Toll Road (2010 to 2018). At 76.0%, human factors were found to be the leading cause of RTCs. At 24.8% the majority of crashes were caused by 'Negligent driving' resulting predominantly in single-vehicle and head-tail crashes. At 16.3%, many of the crashes were also caused by 'Overtaking', and 'Lost control' (10.4%). Table 4-17 further presents the number and percentage of crashes per crash type that occurred within Section 10 of the N4 over the study period (2010-2018) and indicates that Single-vehicle type of crashes predominantly occurred (39.9%), followed by head-tail crashes (22.9%), sideswipe (13.6%) and multiple pile-up (9.0%).

Table 4-17: Types and Causes of Crashes Section 10 (2010-2018)

Type of Crash	TOTAL	Percentage	TOTAL
Single vehicle	150	39.9%	**376**
Head-tail	86	22.9%	
Sideswipe	51	13.6%	
Head-on	22	5.9%	
Head-side	33	8.8%	
Multiple pile-up	34	9.0%	

Cause of Crash	TOTAL	Percentage	TOTAL	Percentage
Lost control	39	10.4%	**285**	**76.0%**
Negligent driving	93	24.8%		
Speed differential (rear-end)	19	5.1%		
Speeding	1	0.3%		
Sleeping	24	6.4%		
Overtaking	61	16.3%		
Pedestrian/Cyclist	4	1.1%		
U-Turn / Reversing vehicles	15	4.0%		
Drugs/Alcohol	7	1.9%		
Wrong direction of travel	11	2.9%		
Crash at Intersection	7	1.9%		
Medical problem	4	1.1%		
Tyre failure	20	5.3%	**49**	**13.1%**
Trailer failure	3	0.8%		
Mechanical failure	12	3.2%		
Brake failure	7	1.9%		
Towing of vehicles	4	1.1%		
Vehicle sway	1	0.3%		
Load loss	2	0.5%		
Construction site	18	4.8%	**41**	**10.9%**
Stationary vehicles	6	1.6%		
Poor Visibility	2	0.5%		
Skidding	1	0.3%		
Animal in roadway	12	3.2%		
Object on road	2	0.5%		
Edge drop-off/Gravel shoulder	0	0.0%		
Previous crash	0	0.0%		
Public transport stop	0	0.0%		

The high crash rate of 0.89 crashes per mvkm for 2010, found on Section 10, can mainly be attributed to the topography, cross-section design, traffic congestion and the lack of passing opportunities. Figure 4-21 presents a photograph indicating the general cross-section design along Section 10 in 2010. Section 10 spans the gorge between Mara and the Crocodile River (Matsulu). The topography consists mainly of rolling terrain, creating limited sight distance and passing opportunities due to the high number of horizontal and vertical curves. The 2010 cross-section consisted of an undivided single carriageway, 3.7m wide lanes in both directions, with paved outside shoulders and limited auxiliary lanes. The section had high levels of peak traffic flow, which regularly resulted in congestion and limited passing opportunities, and in turn resulted in predominantly head-tail, head-side, and by multiple pile-up crashes. To address the high crash rate, Section 10 was included in the Gorge Expansion Program, designed to increase capacity and passing opportunities by the construction of additional passing lanes along this section. Construction on Section 10 commenced in early 2013. The high accident rates continued throughout the construction period, with the construction activities being the main contributory factor for the increased crash rates along the section (1.20 and 0.760 crashes per mvkm for 2013 and 2014 respectively). The various lane closures and temporary traffic accommodation procedures affected the natural flow of traffic and resulted in delays and frustrations, as well as, the platooning of vehicles. Construction work on Section 10 was completed in April 2015. The provision of additional overtaking lanes successfully addressed the road safety issues. This is evident in the decrease in the crash rates along the section, 0.430, 0.570 and 0.460 crashes per mvkm for 2016, 2017 and 2018 respectively.

Figure 4-21: N4 Section 10, Mara to Crocodile River (Matsulu) (Source: Google Street view)

Section 11 from Crocodile River (Matsulu) to Kaapmuiden Region

A total of 110 RTCs were reported over the review period (2010-2018) for Section 11, resulting in an average crash rate of 0.714 crashes per mvkm. Table 4-18 presents a breakdown of the main contributing factors in the crashes that occurred within Section 11 of the N4 Toll Road (2010 to 2018). At 69.4%, human factors were found to be the leading cause of RTCs. At 23.1% the majority of crashes were caused by 'Lost Control', resulting predominantly in single-vehicle crashes. At 10.2%, many of the crashes were also caused by negligent driving, and vehicles following inappropriate speed-differentials (10.2%), resulting in head-tail crashes. Table 4-18 further presents the number and percentage of crashes per crash type that occurred within Section 11 of the N4 over the study period (2010-2018) and indicates that Single-vehicle type of crashes predominantly occurred (52.7%), followed by head-tail crashes (26.4%), and head-side (10.9%).

Table 4-18: Types and Causes of Crashes Section 11 (2010-2018)

Type of Crash	TOTAL	Percentage	TOTAL
Single vehicle	58	52.7%	110
Head-tail	29	26.4%	
Sideswipe	4	3.6%	
Head-on	3	2.7%	
Head-side	12	10.9%	
Multiple pile-up	4	3.6%	

Cause of Crash	TOTAL	Percentage	TOTAL	Percentage
Lost control	25	23.1%	75	69.4%
Negligent driving	11	10.2%		
Speed differential (rear-end)	11	10.2%		
Speeding	0	0.0%		
Sleeping	2	1.9%		
Overtaking	6	5.6%		
Pedestrian/Cyclist	4	3.7%		
U-Turn / Reversing vehicles	9	8.3%		
Drugs/Alcohol	1	0.9%		
Wrong direction of travel	3	2.8%		
Crash at Intersection	2	1.9%		
Medical problem	1	0.9%		
Tyre failure	3	2.8%	26	24.1%
Trailer failure	1	0.9%		
Mechanical failure	7	6.5%		
Brake failure	14	13.0%		
Towing of vehicles	1	0.9%		
Vehicle sway	0	0.0%		
Load loss	0	0.0%		
Construction site	1	0.9%	7	6.5%
Stationary vehicles	4	3.7%		
Poor Visibility	1	0.9%		
Skidding	0	0.0%		
Animal in roadway	0	0.0%		
Object on road	1	0.9%		
Edge drop-off/Gravel shoulder	0	0.0%		
Previous crash	0	0.0%		
Public transport stop	0	0.0%		

The high crash rate, found on Section 11, can mainly be attributed to the existing cross-section design, traffic congestion, the proximity to the Toll plaza, and access point density. Figure 4-22 presents a photograph indicating the general cross-section design along the section. The existing cross-section consists of an undivided single carriageway, 3.7m wide lanes in both directions, with paved outside shoulders. Auxiliary and turning lanes have been provided at certain segments along the section to meet the specified Level of Service D requirement for the N4 Toll Route. This section currently has high traffic volumes and peak traffic volumes resulting in congestion and limited passing opportunities. It is earmarked for a future upgrade to a 4-lane undivided highway. Several crashes occurred at the Nkomazi Toll Plaza. Speed reduction and Toll Plaza warnings signs have since been put in place to warn motorists of the Toll Plaza ahead.

Figure 4-22: N4 Section 11, Crocodile River (Matsulu) to Kaapmuiden Region (Source: Google Street view)

Section 15A between Hectorspruit and Komatipoort

A total of 316 RTCs were reported over the review period (2010-2018) for Section 15A, resulting in an average crash rate of 0.626 crashes per mvkm. Table 4-19 presents a breakdown of the main contributing factors in the crashes that occurred within Section 15A of the N4 Toll Road (2010 to 2018). At 60.8%, human factors were found to be the leading cause of RTCs. At 16.1% the majority of crashes were caused by 'Lost Control', resulting predominantly in single-vehicle crashes. At 8.9%, many of the crashes were also caused by negligent driving, and vehicles following inappropriate speed-differentials (6.6%), resulting in head-tail crashes. Table 4-19 further presents the number and percentage of crashes per crash type that occurred within Section 15A of the N4 over the study period (2010-2018) and indicates that Single-vehicle type of crashes predominantly occurred (49.1%), followed by head-tail crashes (12.7%), and head-side (17.4%).

Table 4-19: Types and Causes of Crashes Section 15A (2010-2018)

Type of Crash	TOTAL	Percentage	TOTAL
Single vehicle	155	49.1%	316
Head-tail	40	12.7%	
Sideswipe	29	9.2%	
Head-on	14	4.4%	
Head-side	55	17.4%	
Multiple pile-up	23	7.3%	

Cause of Crash	TOTAL	Percentage	TOTAL	Percentage
Lost control	51	16.1%	192	60.8%
Negligent driving	28	8.9%		
Speed differential (rear-end)	21	6.6%		
Speeding	0	0.0%		
Sleeping	15	4.7%		
Overtaking	29	9.2%		
Pedestrian/Cyclist	11	3.5%		
U-Turn / Reversing vehicles	7	2.2%		
Drugs/Alcohol	1	0.3%		
Wrong direction of travel	4	1.3%		
Crash at Intersection	24	7.6%		
Medical problem	1	0.3%		
Tyre failure	19	6.0%	58	18.4%
Trailer failure	4	1.3%		
Mechanical failure	19	6.0%		
Brake failure	8	2.5%		
Towing of vehicles	1	0.3%		
Vehicle sway	0	0.0%		
Load loss	7	2.2%		
Construction site	49	15.5%	66	20.9%
Stationary vehicles	3	0.9%		
Poor Visibility	9	2.8%		
Skidding	0	0.0%		
Animal in roadway	2	0.6%		
Object on road	3	0.9%		
Edge drop-off/Gravel shoulder	0	0.0%		
Previous crash	0	0.0%		
Public transport stop	0	0.0%		

The high crash rate, found on Section 15A, can mainly be attributed to the existing cross-section design, traffic congestion, the rolling terrain and access point density. Figure 4-23 presents a photograph indicating the general cross-section design along the section. The existing cross-section consists of an undivided single carriageway, 3.7m wide lanes in both directions, with paved outside shoulders. Auxiliary and turning lanes have been provided at certain segments along the section to meet the specified Level of Service D requirement for the N4 Toll Route. The crash rate on Section 15A has reduced from 1.329 in 2017 to 0.623 in 2018. Construction, as part of the widening and rehabilitation of this section, was completed in February 2018. Crashes reduced from 77 in 2017, to 34 in 2018. Although TRAC has aimed to upgrade and consolidate accesses into formalized upgraded intersections, there are still some accesses which have not successfully been closed off, resulting in safety problems and a total of 55 head-side crashes over the study period.

Figure 4-23: N4 Section 15A Hectorspruit to Komatipoort (Source: Google Street view)

4.5 Association Rule Analysis

Association Rule Analysis was used to determine the relationship between the crash severity and the human factors involved in these crashes. Association Rule data mining technique was used to detect relationships between specific values of categorical variables in the data set. This technique aided in extracting and refining of valuable knowledge from the dataset to uncover patterns which cannot be found from simple inspection of frequency tables. Before the association rule analysis results can be interpreted and discussed, it is necessary to again define the rule extraction terminology used.

***Rule Extraction* –** "A formal presentation of the rule and parameters of confidence, support, and lift which quantify a rule is given below. The general form of the rule is as follows: 'IF event X occurs THEN event Y occurs as well, in M% of times, and this pattern occurs in N% of all events in the dataset'. Where, M is the Confidence, and N is the Support. Support represents the probability that both events X and Y occurred simultaneously in the dataset. Confidence presents the probability that event Y will occur while event X has already occurred. Confidence is the conditional probability of event Y, while event X has already occurred, the Lift value is the ratio of the probability that Y will occur" (Bigham, 2014, p.444).

The Association Rule methodology will be explained in terms of how it was applied in this research study. Different subsets of data were used for analysis using this technique, each obtained from queries performed in the crash database. The methodology for each set of association rules (as compiled for this study) will be discussed under the relevant subheadings and a discussion and interpretation of the results will follow. The values for support, confidence, and lift are presented in respective Tables under each subheading.

As discussed under Part 3.6 of this report, different algorithms can be employed to find associated rules for extracting useful information from the data. According to Li *et al*. (2017) "A classical association rule mining method is the Apriori algorithm who's main task is to find frequent itemsets" (Li *et al*., 2017, p.363). The algorithm employed shall determine the association rules without the need for any user input to specify the number of different categories present in the data, or have any preceding knowledge of the complexity of the major associations.

Large datasets often generate a large number of association rules that do not necessarily have any significance. To avoid this, the user can specify limits on output statistics so that only the association rules are retained which have a confidence, support and correlation value greater than a user-defined minimum value. It must, however, be noted that the user should not set the minimum limits too high, as this may cause meaningful associations to be detected. Additionally, in order to avoid complexity of the analysis, the user can also specify the maximum number of items in the Body and Head of the association rules.

Statistica software package was used in the data analysis. Microsoft Excel software was used to verify the results obtained through the Statistica software analysis. Before commencing with the Association Rule extraction, the crash data first had to be prepared and categorised, according to the specific variables required for the analysis. Once the datasheet was appropriately prepared, it was imported into the statistical software package for analysis. The pre-defined minimum output values were chosen and are indicated in Figure 4-24 below.

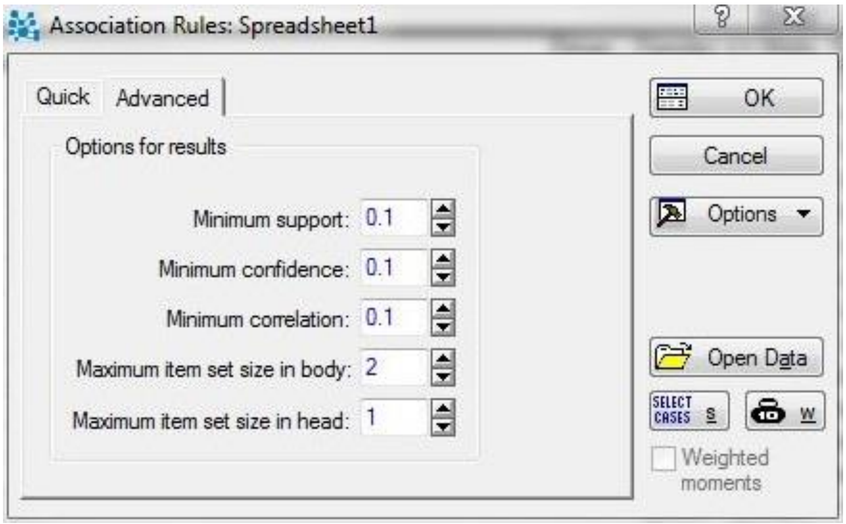


Figure 4-24: Statistica - Pre-defined min values – Output statistics

The Association Rule extraction returned nearly 2900 association rules, many of which did not have any significance to the research study. The Association Rule dataset was therefore first reduced to those rules that reflected relationships that had statistical value. The dataset was further reduced to reflect the relationship between the severity of the RTCs and the various human factors involved in the crashes. Refer to Table 4-20: Association Rule extraction – Injury Severity vs Unknown Variables and Table 4-21: Association Rule extraction – Crash cause vs Unknown Variables for the reduced association rule datasets. The dataset after the first reduction can be viewed in Addendum E: Association Rules – Statistica.

Interpretation and Understanding of Association Rules

The major statistical outputs for the association rules are Support, Confidence, Correlation (not used in this study) and Lift. These statistical values are given in the spreadsheets, as indicated in Table 4-20 and Table 4-21. The values for support and confidence are expressed in percentages. Looking at Table 4-20, the first rule has only one item in the Body, namely "Injury Fatal count = Yes" and one item in the Head, namely "Accident Type = Head-on." This can be interpreted as: "if a fatality occurred, it is likely that the crash type was a head-on collision in 14.69% of times, and this pattern occurs in 1.73% of all events in the dataset." The Lift value is = 8.503 > 1, indicating that this rule can most likely be used for prediction rather than only a random guess.

a) Injury Severity vs. Unknown Variables

The different injury severities were cross-tabulated against the various unknown crash variables. This was done for all the crashes that occurred within the study section (recorded for the study period, 2010 to 2018). The objective was to find any co-occurrences between the severities of the crashes that occurred and the unknown factors that may shed light on the crash causation. The objective was to find the confidence with which the severity of a crash could be predicted, in terms of the co-occurrence with other factors that may be regarded as a hidden cause of the crash.

The major findings:

IF event "Injury - Fatal count = YES occurs then Accident Type = Single vehicle occurs as well, in 43.28% of the times, and this pattern occurs in 5.09% of all events in the dataset". The Lift value is 8.503, which gives an indication that this rule can most likely be used for prediction rather than only a random guess.

IF event "Injury - Fatal count = YES occurs then Pedestrian/Cyclist occurs as well, in 23.13% of the times, and this pattern occurs in 2.72% of all events in the dataset". The Lift value is 8.503, which gives an indication that this rule can most likely be used for prediction rather than only a random guess.

IF event "Injury - Serious count = YES occurs then Negligent driving occurs as well, in 22.54% of the times, and this pattern occurs in 5.64% of all events in the dataset". The Lift value is 3.996, which gives an indication that this rule can most likely be used for prediction rather than only a random guess.

Table 4-20: Association Rule extraction – Injury Severity vs Unknown Variables

Rule	Body	==>	Head	Support (%)	Confidence (%)	Lift
152	Injury - Fatal count == YES	==>	Accident Type == Head-on	1.73	14.69	8.503
153	Injury - Fatal count == YES	==>	Accident Type == Head-Side	1.86	15.78	8.503
154	Injury - Fatal count == YES	==>	Accident Type == Head-tail	1.30	11.09	8.503
155	Injury - Fatal count == YES	==>	Accident Type == Multiple pile-up	1.19	10.16	8.503
156	Injury - Fatal count == YES	==>	Accident Type == Single vehicle	5.09	43.28	8.503
164	Injury - Fatal count == YES	==>	Lost control	1.98	16.88	8.503
165	Injury - Fatal count == YES	==>	Negligent driving	1.91	16.25	8.503
166	Injury - Fatal count == YES	==>	Overtaking	1.19	10.16	8.503
167	Injury - Fatal count == YES	==>	Pedestrian/Cyclist	2.72	23.13	8.503
168	Injury - Fatal count == YES	==>	Sleeping	1.23	10.47	8.503
216	Injury - Serious count == YES	==>	Accident Type == Head-on	2.32	9.25	3.996
217	Injury - Serious count == YES	==>	Accident Type == Head-Side	4.36	17.40	3.996
218	Injury - Serious count == YES	==>	Accident Type == Head-tail	4.37	17.47	3.996
219	Injury - Serious count == YES	==>	Accident Type == Multiple pile-up	2.59	10.35	3.996
220	Injury - Serious count == YES	==>	Accident Type == Sideswipe	2.43	9.69	3.996
221	Injury - Serious count == YES	==>	Accident Type == Single vehicle	8.97	35.83	3.996
227	Injury - Serious count == YES	==>	Accident - Road Section Detail == 6E	2.02	8.08	3.996
228	Injury - Serious count == YES	==>	Accident - Road Section Detail == 5B	1.58	6.31	3.996
229	Injury - Serious count == YES	==>	Accident - Road Section Detail == 15A	1.19	4.77	3.996
232	Injury - Serious count == YES	==>	Accident - Road Section Detail == 6N	1.76	7.05	3.996
234	Injury - Serious count == YES	==>	Accident - Road Section Detail == 10	1.47	5.87	3.996
239	Injury - Serious count == YES	==>	Crash at Intersection	1.23	4.92	3.996
240	Injury - Serious count == YES	==>	Lost control	4.89	19.53	3.996
241	Injury - Serious count == YES	==>	Negligent driving	5.64	22.54	3.996
242	Injury - Serious count == YES	==>	Overtaking	3.31	13.22	3.996
243	Injury - Serious count == YES	==>	Sleeping	2.92	11.67	3.996
244	Injury - Serious count == YES	==>	Speed differential (rear-end)	2.81	11.23	3.996
245	Injury - Serious count == YES	==>	U-Turn / Reversing vehicles	1.56	6.24	3.996
246	Injury - Slight count == YES	==>	Accident Type == Head-on	1.75	5.29	3.030
247	Injury - Slight count == YES	==>	Accident Type == Head-Side	5.16	15.65	3.030
248	Injury - Slight count == YES	==>	Accident Type == Head-tail	6.96	21.10	3.030
249	Injury - Slight count == YES	==>	Accident Type == Multiple pile-up	3.20	9.69	3.030
250	Injury - Slight count == YES	==>	Accident Type == Sideswipe	2.81	8.52	3.030
251	Injury - Slight count == YES	==>	Accident Type == Single vehicle	13.10	39.70	3.030
258	Injury - Slight count == YES	==>	Accident - Road Section Detail == 6E	2.52	7.63	3.030
259	Injury - Slight count == YES	==>	Accident - Road Section Detail == 5B	2.19	6.63	3.030
260	Injury - Slight count == YES	==>	Accident - Road Section Detail == 15A	1.29	3.90	3.030
265	Injury - Slight count == YES	==>	Accident - Road Section Detail == 6N	2.57	7.80	3.030
267	Injury - Slight count == YES	==>	Accident - Road Section Detail == 10	1.71	5.18	3.030
274	Injury - Slight count == YES	==>	Crash at Intersection	1.41	4.29	3.030
275	Injury - Slight count == YES	==>	Drugs/Alcohol	1.16	3.51	3.030
276	Injury - Slight count == YES	==>	Lost control	6.95	21.05	3.030
277	Injury - Slight count == YES	==>	Negligent driving	7.68	23.27	3.030
278	Injury - Slight count == YES	==>	Overtaking	3.18	9.63	3.030
279	Injury - Slight count == YES	==>	Sleeping	4.52	13.70	3.030
280	Injury - Slight count == YES	==>	Speed differential (rear-end)	4.63	14.03	3.030
281	Injury - Slight count == YES	==>	U-Turn / Reversing vehicles	1.71	5.18	3.030
1738	Injury - Fatal count == YES, Injury - Serious count == NO	==>	Accident Type == Single vehicle	3.80	57.18	15.033
1743	Injury - Fatal count == YES, Injury - Serious count == NO	==>	Pedestrian/Cyclist	2.57	38.67	15.033
1744	Injury - Fatal count == YES, Injury - Serious count == YES	==>	Accident Type == Head-on	1.10	21.58	19.575
1745	Injury - Fatal count == YES, Injury - Serious count == YES	==>	Accident Type == Single vehicle	1.29	25.18	19.576
1750	Injury - Fatal count == YES, Injury - Serious count == YES	==>	Lost control	1.23	24.10	19.575
1751	Injury - Fatal count == YES, Injury - Slight count == YES	==>	Accident Type == Single vehicle	1.07	27.36	25.670
1755	Injury - Fatal count == YES, Injury - Slight count == NO	==>	Accident Type == Head-on	1.12	14.25	12.715
1756	Injury - Fatal count == YES, Injury - Slight count == NO	==>	Accident Type == Head-Side	1.08	13.79	12.715
1757	Injury - Fatal count == YES, Injury - Slight count == NO	==>	Accident Type == Single vehicle	4.02	51.17	12.715
1762	Injury - Fatal count == YES, Injury - Slight count == NO	==>	Lost control	1.19	15.19	12.715
1763	Injury - Fatal count == YES, Injury - Slight count == NO	==>	Negligent driving	1.21	15.42	12.715
1764	Injury - Fatal count == YES, Injury - Slight count == NO	==>	Pedestrian/Cyclist	2.50	31.78	12.715
1779	Injury - Fatal count == YES, Lost control	==>	Accident Type == Single vehicle	1.03	51.85	50.389
1785	Injury - Fatal count == YES, Pedestrian/Cyclist	==>	Accident Type == Single vehicle	2.54	93.24	36.770
2114	Injury - Serious count == YES, Injury - Slight count == YES	==>	Accident Type == Head-on	1.21	10.31	8.503
2115	Injury - Serious count == YES, Injury - Slight count == YES	==>	Accident Type == Head-Side	2.28	19.38	8.503
2116	Injury - Serious count == YES, Injury - Slight count == YES	==>	Accident Type == Head-tail	2.09	17.81	8.503
2117	Injury - Serious count == YES, Injury - Slight count == YES	==>	Accident Type == Multiple pile-up	1.60	13.59	8.503
2118	Injury - Serious count == YES, Injury - Slight count == YES	==>	Accident Type == Sideswipe	1.29	10.94	8.503
2119	Injury - Serious count == YES, Injury - Slight count == YES	==>	Accident Type == Single vehicle	3.29	27.97	8.503
2122	Injury - Serious count == YES, Injury - Slight count == YES	==>	Accident - Road Section Detail == 6E	1.07	9.06	8.503
2125	Injury - Serious count == YES, Injury - Slight count == YES	==>	Lost control	2.21	18.75	8.503
2126	Injury - Serious count == YES, Injury - Slight count == YES	==>	Negligent driving	2.77	23.59	8.503

Table 4-20: Association Rule extraction – Injury Severity vs Unknown Variables (continues)

Rule	Body	==>	Head	Support (%)	Confidence (%)	Lift
2127	Injury - Serious count == YES, Injury - Slight count == YES	==>	Overtaking	1.65	14.06	8.503
2128	Injury - Serious count == YES, Injury - Slight count == YES	==>	Sleeping	1.23	10.47	8.503
2129	Injury - Serious count == YES, Injury - Slight count == YES	==>	Speed differential (rear-end)	1.54	13.13	8.503
2130	Injury - Serious count == YES, Injury - Slight count == NO	==>	Accident Type == Head-on	1.10	8.31	7.537
2131	Injury - Serious count == YES, Injury - Slight count == NO	==>	Accident Type == Head-Side	2.08	15.65	7.537
2132	Injury - Serious count == YES, Injury - Slight count == NO	==>	Accident Type == Head-tail	2.28	17.17	7.537
2133	Injury - Serious count == YES, Injury - Slight count == NO	==>	Accident Type == Sideswipe	1.14	8.59	7.537
2134	Injury - Serious count == YES, Injury - Slight count == NO	==>	Accident Type == Single vehicle	5.68	42.80	7.537
2140	Injury - Serious count == YES, Injury - Slight count == NO	==>	Lost control	2.68	20.22	7.537
2141	Injury - Serious count == YES, Injury - Slight count == NO	==>	Negligent driving	2.87	21.61	7.537
2142	Injury - Serious count == YES, Injury - Slight count == NO	==>	Overtaking	1.65	12.47	7.537
2143	Injury - Serious count == YES, Injury - Slight count == NO	==>	Sleeping	1.69	12.74	7.537
2144	Injury - Serious count == YES, Injury - Slight count == NO	==>	Speed differential (rear-end)	1.27	9.56	7.537
2190	Injury - Serious count == YES, Lost control	==>	Accident Type == Single vehicle	3.49	71.43	20.459
2197	Injury - Serious count == YES, Negligent driving	==>	Accident Type == Head-Side	1.12	19.87	17.726
2198	Injury - Serious count == YES, Negligent driving	==>	Accident Type == Head-tail	1.36	24.10	17.726
2199	Injury - Serious count == YES, Negligent driving	==>	Accident Type == Single vehicle	1.36	24.10	17.726
2210	Injury - Serious count == YES, Sleeping	==>	Accident Type == Single vehicle	1.64	55.97	34.226
2216	Injury - Serious count == YES, Speed differential (rear-end)	==>	Accident Type == Head-tail	1.71	60.78	35.569

Table 4-20 indicates the statistical values as previously discussed under the *Interpretation and Understanding of Association Rules* paragraph. The values for support and confidence are expressed as percentages. The most significant variables, influencing the occurrence of fatalities during a crash, are illustrated in Figure 4-25 below. The graph can be interpreted as: if a fatality occurred, the specific variable was likely to be involved in the crash at the given percentage (%) of times.

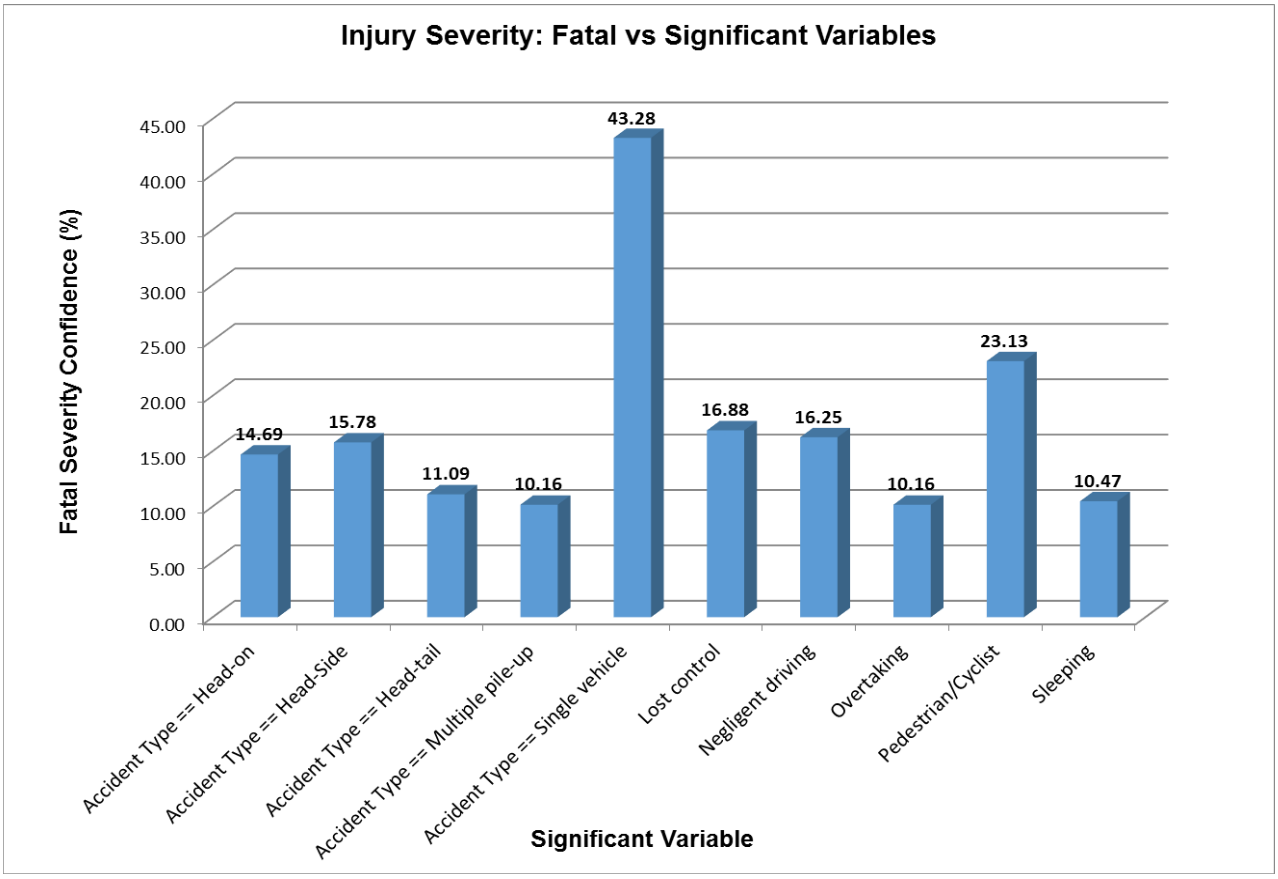


Figure 4-25: Injury Severity: Fatal vs Significant Variables

The most significant variables, influencing the occurrence of serious injuries during a crash, are illustrated in Figure 4-26 below. The graph can be interpreted as follows: if a serious injury occurred, the specific variable was likely to be involved in the crash at the given percentage (%) of times.

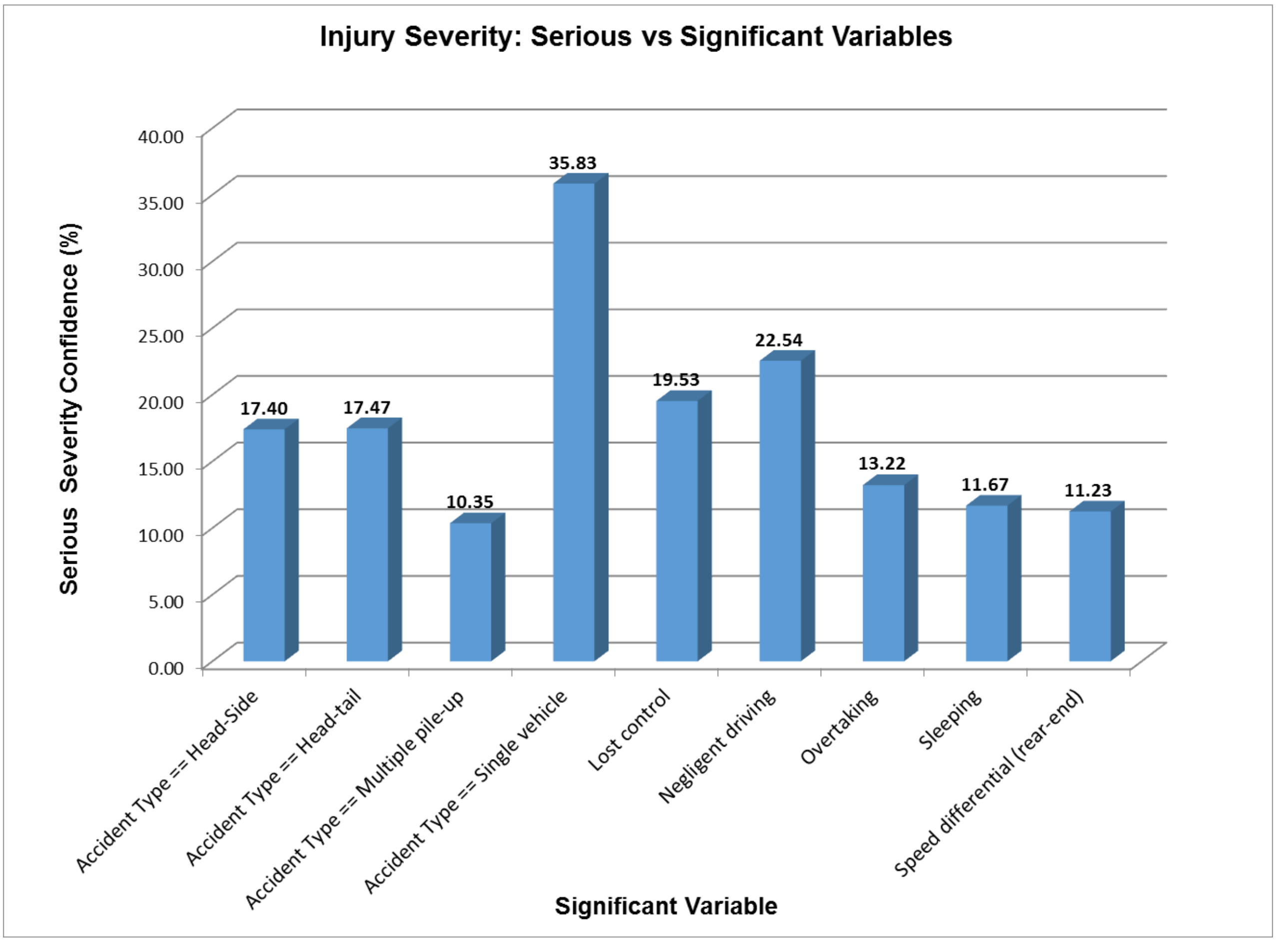


Figure 4-26: Injury Severity: Serious vs Significant Variables

b) Crash cause vs Unknown Variables

The different crash causes were cross-tabulated against the various unknown crash variables. This was done for all the crashes that occurred within the study section (recorded for the study period, 2010 to 2018). The objective was to find any co-occurrences between the cause of crashes and the unknown factors that may shed light on the crash severity. The objective was to find the degree of confidence with which the severity of a crash could be predicted, in terms of the co-occurrence with other factors that may be regarded as a hidden cause of the crash.

The major findings:

IF event "Pedestrian/Cyclist occurs then Injury - Fatal count = YES occurs as well, in 71.50% of the times, and this pattern occurs in 2.72% of all events in the dataset". The Lift value is 26.29, which gives an indication that this rule can most likely be used for prediction rather than only a random guess.

IF event "Overtaking occurs then Injury - Serious count = YES occurs as well, in 36.81% of the times, and this pattern occurs in 3.31% of all events in the dataset". The Lift value is 11.129, which gives an indication that this rule can most likely be used for prediction rather than only a random guess.

Table 4-21: Association Rule extraction – Crash cause vs Unknown Variables

Rule	Body	==>	Head	Support (%)	Confidence (%)	Lift
605	Crash at Intersection	==>	Accident Type == Head-Side	2.57	52.83	20.536
606	Crash at Intersection	==>	Accident Type == Single vehicle	1.01	20.75	20.536
607	Crash at Intersection	==>	Injury - Fatal count == NO	4.58	93.96	20.536
608	Crash at Intersection	==>	Injury - Serious count == NO	3.64	74.72	20.536
609	Crash at Intersection	==>	Injury - Serious count == YES	1.23	25.28	20.536
610	Crash at Intersection	==>	Injury - Slight count == YES	1.41	29.06	20.536
611	Crash at Intersection	==>	Injury - Slight count == NO	3.45	70.94	20.536
614	Drugs/Alcohol	==>	Accident Type == Single vehicle	1.80	55.68	30.920
615	Drugs/Alcohol	==>	Injury - Fatal count == NO	2.87	88.64	30.921
616	Drugs/Alcohol	==>	Injury - Serious count == NO	2.46	76.14	30.920
617	Drugs/Alcohol	==>	Injury - Slight count == YES	1.16	35.80	30.921
618	Drugs/Alcohol	==>	Injury - Slight count == NO	2.08	64.20	30.920
621	Lost control	==>	Accident Type == Single vehicle	18.82	82.58	4.389
622	Lost control	==>	Injury - Fatal count == NO	20.80	91.29	4.389
623	Lost control	==>	Injury - Fatal count == YES	1.98	8.71	4.389
624	Lost control	==>	Injury - Serious count == NO	17.90	78.55	4.389
625	Lost control	==>	Injury - Serious count == YES	4.89	21.45	4.389
626	Lost control	==>	Injury - Slight count == YES	6.95	30.48	4.389
627	Lost control	==>	Injury - Slight count == NO	15.84	69.52	4.389
629	Lost control	==>	Accident - Road Section Detail == 6E	1.62	7.10	4.389
630	Lost control	==>	Accident - Road Section Detail == 5B	1.93	8.47	4.389
633	Lost control	==>	Accident - Road Section Detail == 6N	1.76	7.74	4.389
639	Negligent driving	==>	Accident Type == Head-Side	3.71	15.88	4.278
640	Negligent driving	==>	Accident Type == Head-tail	6.50	27.83	4.278
641	Negligent driving	==>	Accident Type == Multiple pile-up	2.08	8.88	4.278
642	Negligent driving	==>	Accident Type == Sideswipe	2.65	11.32	4.278
643	Negligent driving	==>	Accident Type == Single vehicle	7.66	32.78	4.278
644	Negligent driving	==>	Injury - Fatal count == NO	21.46	91.82	4.278
645	Negligent driving	==>	Injury - Fatal count == YES	1.91	8.18	4.278
646	Negligent driving	==>	Injury - Serious count == NO	17.73	75.86	4.278
647	Negligent driving	==>	Injury - Serious count == YES	5.64	24.14	4.278
648	Negligent driving	==>	Injury - Slight count == YES	7.68	32.86	4.278
649	Negligent driving	==>	Injury - Slight count == NO	15.69	67.14	4.278
651	Negligent driving	==>	Accident - Road Section Detail == 6E	1.40	5.97	4.278
653	Negligent driving	==>	Accident - Road Section Detail == 5B	1.56	6.68	4.278
656	Negligent driving	==>	Accident - Road Section Detail == 6N	1.97	8.41	4.278
658	Negligent driving	==>	Accident - Road Section Detail == 10	1.71	7.31	4.278
663	Overtaking	==>	Accident Type == Head-on	1.05	11.66	11.129
664	Overtaking	==>	Accident Type == Head-Side	1.38	15.34	11.129
665	Overtaking	==>	Accident Type == Sideswipe	2.63	29.24	11.129
666	Overtaking	==>	Accident Type == Single vehicle	2.00	22.29	11.129
667	Overtaking	==>	Injury - Fatal count == NO	7.79	86.71	11.129
668	Overtaking	==>	Injury - Fatal count == YES	1.19	13.29	11.129
669	Overtaking	==>	Injury - Serious count == NO	5.68	63.19	11.129
670	Overtaking	==>	Injury - Serious count == YES	3.31	36.81	11.129
671	Overtaking	==>	Injury - Slight count == YES	3.18	35.38	11.129
672	Overtaking	==>	Injury - Slight count == NO	5.81	64.62	11.129
673	Overtaking	==>	Accident - Road Section Detail == 6E	1.36	15.13	11.129
674	Overtaking	==>	Accident - Road Section Detail == 10	1.12	12.47	11.129
677	Pedestrian/Cyclist	==>	Accident Type == Single vehicle	3.53	92.75	26.290
678	Pedestrian/Cyclist	==>	Injury - Fatal count == NO	1.08	28.50	26.290
679	Pedestrian/Cyclist	==>	Injury - Fatal count == YES	2.72	71.50	26.290
680	Pedestrian/Cyclist	==>	Injury - Serious count == NO	2.96	77.78	26.290
681	Pedestrian/Cyclist	==>	Injury - Slight count == NO	3.33	87.44	26.290

Table 4-21: Association Rule extraction – Crash cause vs Unknown Variables (continues)

Rule	Body	==>	Head	Support (%)	Confidence (%)	Lift
684	Sleeping	==>	Accident Type == Head-tail	1.40	12.42	8.892
685	Sleeping	==>	Accident Type == Single vehicle	8.25	73.37	8.892
686	Sleeping	==>	Injury - Fatal count == NO	10.01	89.05	8.892
687	Sleeping	==>	Injury - Fatal count == YES	1.23	10.95	8.892
688	Sleeping	==>	Injury - Serious count == NO	8.32	74.02	8.892
689	Sleeping	==>	Injury - Serious count == YES	2.92	25.98	8.892
690	Sleeping	==>	Injury - Slight count == YES	4.52	40.20	8.892
691	Sleeping	==>	Injury - Slight count == NO	6.73	59.80	8.892
692	Sleeping	==>	Accident - Road Section Detail == 6E	1.34	11.93	8.892
695	Speed differential (rear-end)	==>	Accident Type == Head-tail	9.17	69.02	7.527
696	Speed differential (rear-end)	==>	Accident Type == Multiple pile-up	1.69	12.72	7.527
697	Speed differential (rear-end)	==>	Accident Type == Single vehicle	1.47	11.07	7.527
698	Speed differential (rear-end)	==>	Injury - Fatal count == NO	12.42	93.50	7.527
699	Speed differential (rear-end)	==>	Injury - Serious count == NO	10.47	78.84	7.527
700	Speed differential (rear-end)	==>	Injury - Serious count == YES	2.81	21.16	7.527
701	Speed differential (rear-end)	==>	Injury - Slight count == YES	4.63	34.85	7.527
702	Speed differential (rear-end)	==>	Injury - Slight count == NO	8.65	65.15	7.527
703	Speed differential (rear-end)	==>	Accident - Road Section Detail == 6E	1.16	8.71	7.527
704	Speed differential (rear-end)	==>	Accident - Road Section Detail == 5B	1.16	8.71	7.527
709	U-Turn / Reversing vehicles	==>	Accident Type == Head-Side	2.59	51.65	19.934
710	U-Turn / Reversing vehicles	==>	Injury - Fatal count == NO	4.43	88.28	19.934
711	U-Turn / Reversing vehicles	==>	Injury - Serious count == NO	3.45	68.86	19.934
712	U-Turn / Reversing vehicles	==>	Injury - Serious count == YES	1.56	31.14	19.934
713	U-Turn / Reversing vehicles	==>	Injury - Slight count == YES	1.71	34.07	19.934
714	U-Turn / Reversing vehicles	==>	Injury - Slight count == NO	3.31	65.93	19.934
717	Wrong direction of travel	==>	Injury - Fatal count == NO	1.73	76.42	44.244
718	Wrong direction of travel	==>	Injury - Serious count == NO	1.47	65.04	44.244

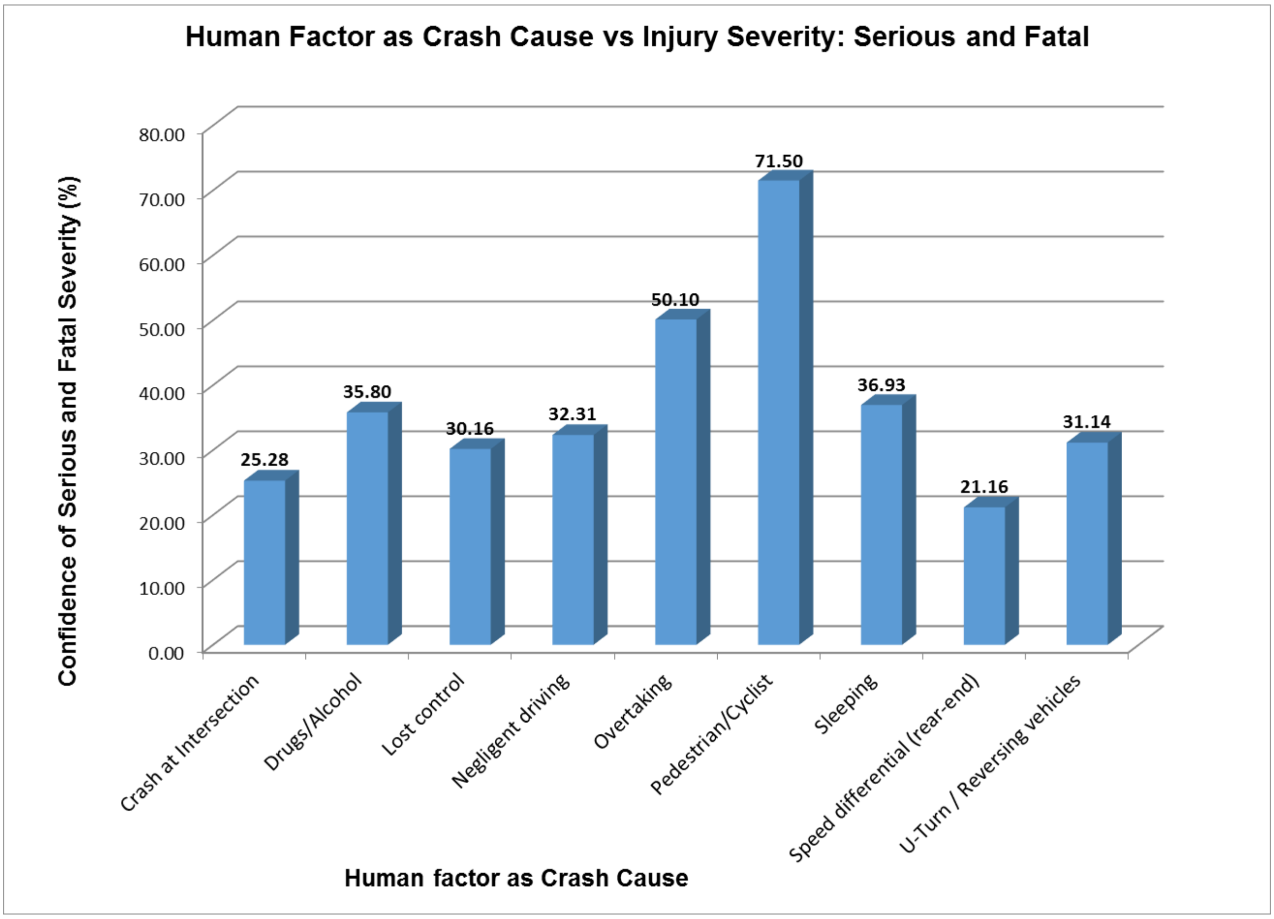


Figure 4-27: Human Factor as Crash Cause vs Injury Severity: Serious and Fatal

Table 4-27 above indicates the statistical values as previously discussed under the *Interpretation and Understanding of Association Rules* paragraph. The values for support and confidence are expressed as percentages. The most significant Human factor variables, which influence the occurrence of serious injuries and fatalities during a crash, are illustrated in Figure 4-26 above. The graph can be interpreted as follows: if a serious injury or fatality occurred, the specific human factor variable was likely to be involved in the crash at the given percentage (%) of times.

Verification of Results

Microsoft Excel software was used to verify the results obtained through the Statistica analysis. The known Association Rules obtained through the Statistica analysis were entered as a formula in an Excel spreadsheet in order to verify the results obtained. The Excel Association Rule results confirmed the findings obtained from the Statistica analysis. The Excel Association Rule Analysis can be seen in Table 4-22 below. One of the results and findings can be interpreted as follows:

IF event "Pedestrian/Cyclist occurs then Injury - Fatal count = YES occurs as well, in 71.50% of the times, and this pattern occurs in 2.72% of all events in the dataset". The Lift value is 26.21, which gives an indication that this rule can most likely be used for prediction rather than only a random guess.

Table 4-22: Association Rule Analysis – Fatal crashes and Human factors – Excel verification

Relationship of Fatal crashes and Human Factors					
Rule	**Count**	**Support**	**Confidence**	**Lift**	**Test**
Lost control	1240				
Lost control =>Fatal	108	0.01990	0.0871	4.3766	1
Lost control =>Not fatal	1132	0.20859	0.9129	4.3766	
Negligent driving	1272				
Negligent driving=>Fatal	104	0.01916	0.0818	4.2665	1
Negligent driving=>Not fatal	1168	0.21522	0.9182	4.2665	
Speed differential (rear-end)	723				
Speed differential (rear-end)=>Fatal	47	0.00866	0.0650	7.5062	1
Speed differential (rear-end)=>Not fatal	676	0.12456	0.9350	7.5062	
Sleeping	612				
Sleeping =>Fatal	67	0.01235	0.1095	8.8676	1
Sleeping =>Not fatal	545	0.10042	0.8905	8.8676	
Overtaking	489				
Overtaking=>Fatal	65	0.01198	0.1329	11.0982	1
Overtaking =>Not fatal	424	0.07813	0.8671	11.0982	
Pedestrian/Cyclist	207				
Pedestrian/Cyclist =>Fatal	148	0.02727	0.7150	26.2174	1
Pedestrian/Cyclist=>Not fatal	59	0.01087	0.2850	26.2174	

4.6 Analysis of Road User Survey

This section focuses on the prevailing road conditions, and details road user behaviour and driver perceptions towards road safety. The results from the road user survey were accessed to help evaluate and identify road user behaviour that could contribute to RTCs. Part 4.6 presents the results and findings from the road user behaviour and driver perceptions survey used in this study. The findings of the survey led to the provision of a detailed account of driving behaviour. Furthermore, the survey offers further clarification into the findings produced by the crash data. The survey questionnaire can be viewed in Addendum C.

4.6.1 Data Collection: Road User Survey

Besides, the crash data, an electronic survey was distributed to collect information about the perception that drivers have on the possible relationship between RTCs and the human factors involved in these crashes. In addition, the survey gathered information on the behaviour of drivers when driving on a highway under South African conditions.

Data on the following specific topics were collected from the survey questionnaire;

1. Demographic details and driving experience.
2. Drivers' perceptions of road safety.
3. Drivers' perceptions of the significance of human factors in the contribution towards RTCs.
4. Frequency of irregular driving behaviour.
5. Risk perception of specific factors like the use of seat-belts, prescribed medication and communication devices while driving.

4.6.2 Limitations

Limitations experienced during the distribution of the survey include:

- Considering South Africa's national state of disaster due to the COVID-19 pandemic, some critical safety measures were required to maintain a healthy research environment for all participants.

- Due to the threat of exposure to the Corona virus, the survey was distributed in electronic format only. Potential respondents were asked to complete an online questionnaire. This allowed for no physical contact, and no individuals being in close proximity to each other.
- The drawbacks to the electronic data collection method include the potential for selection bias and a lower response rate. It also limits the potential respondents to those who have access to an active e-mail account.

The information gathered from the electronic survey remains significant and valuable for evaluating driver behaviour and driver perceptions towards safety. However, when interpreting the results of the survey the abovementioned limitations should be kept in mind.

4.6.3 Survey Responses

A total number of 119 survey records were received at the conclusion of the survey analysis period. However, the data analysis revealed that approximately 28 of the survey responses were either spoiled or incomplete, leaving a total of 91 usable data records to be assessed. Although the response number was far from the target value of 350 participants, the researcher decided to continue with an analysis of the collected data. The smaller sample size, however, meant that the margin of error increased from 5% to 10% at a 95% confidence level.

The results of the online survey used in the research study are discussed in this segment. The figures and statistics in the following sections include the response data from the survey participants and the results for the different survey questions. Surveys provide a reliable source of real-world data, which can easily be analysed and illustrated using descriptive statistical methods. Surveys also provide invaluable data, like, personal views and experiences of drivers, which cannot be obtained from any crash database.

The survey has been divided into the following two sections:

Section 1- focused on the demographic information of the respondent, their driving history and general perceptions regarding road traffic safety.

Section 2 – focused on the personal driving behaviour of the respondent, their frequency of irregular driving behaviour, and their risk perception and tendency to risk exposure.

Section 1: Driving History and General Perceptions

1.1 Are you male or female?

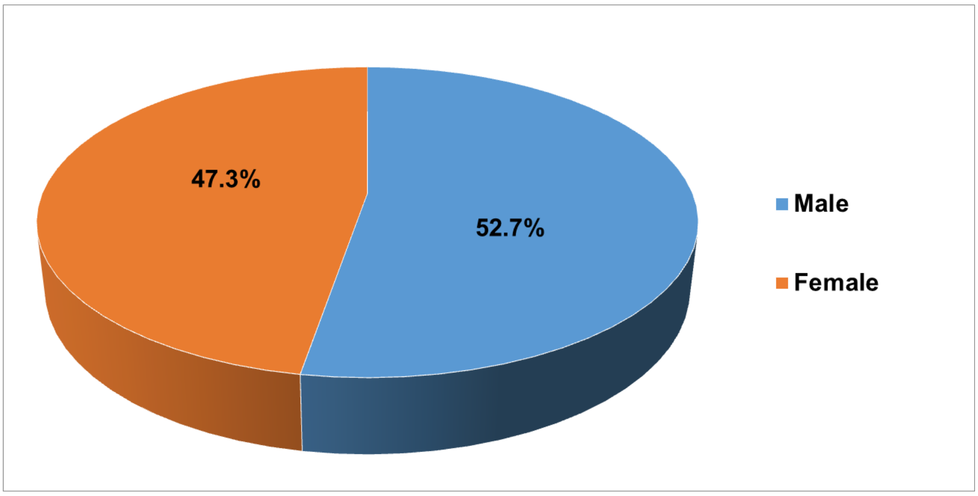


Figure 4-28: Gender of drivers

Figure 4-28 depicts the gender distribution of survey participants. The 52.7% share of male respondents was significantly higher than the 47.3% share of female respondents. The survey respondents provide a good representation of both male and female participants.

1.2 How old are you?

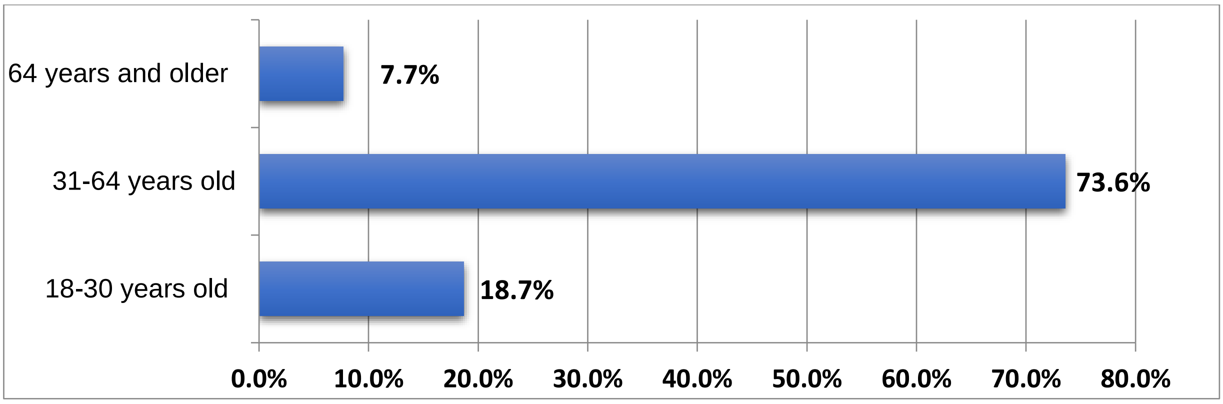


Figure 4-29: Age of drivers

Figure 4-29 depicts the age of the survey participants, shows 31 to 64-year-old drivers (73.6%) to be the highest representation of survey respondents followed by 18 to 30-year-old drivers (18.7%) and elderly drivers (7.7%). The age distribution also provides an accurate reflection of the crash record age distribution, where the majority of drivers involved in crashes are middle-aged.

1.3 How long have you held a driver's license?

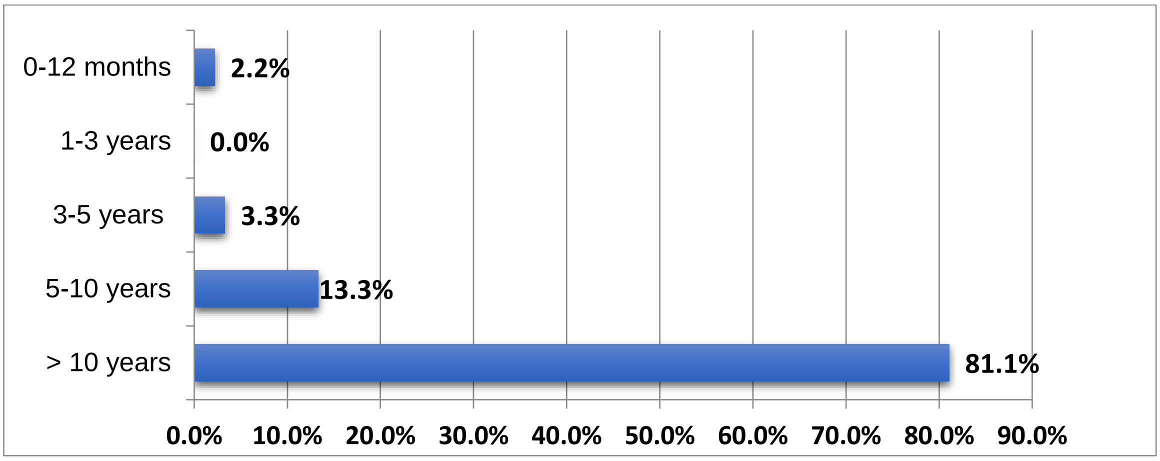


Figure 4-30: Driving experience

Survey participants were assessed according to their driving experience. Participants were classified as follows, in accordance to years of driving experience; beginner drivers (0-12 months), novice drivers (1 to 3 years, 3 to 5 years and 5 to 10 years) and experienced drivers (more than 10 years). Figure 4-30 indicates that most of the respondents have been driving for more than 10-years. Beginner and novice drivers represent 18.9% of survey participants, while experienced drivers represent 81.1% of survey respondents.

1.4 Approximately how many kilometres do you drive per year?

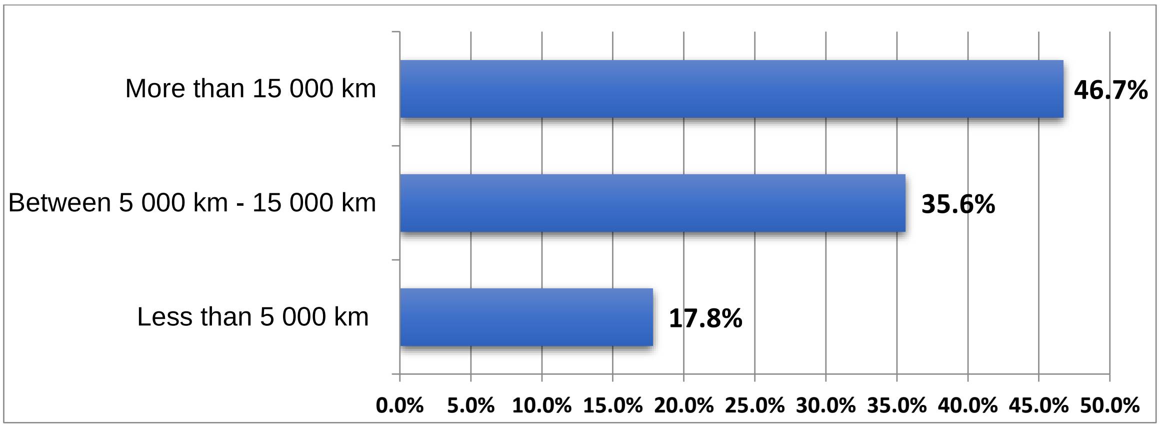


Figure 4-31: Driving experience in terms of km per annum

Similar to the driving experience, which was classified in terms of years of driving experience, Figure 4-31 indicates that most survey participants are driving more than 15000 km per annum (46.7%), followed by between 5000 km and 15000 km per annum (35.6%), and less than 5000 km per annum (17.8%). The majority of respondents are, therefore, considered novice to experienced drivers in terms of driving distance.

1.5 Have you ever been involved in a vehicle crash?

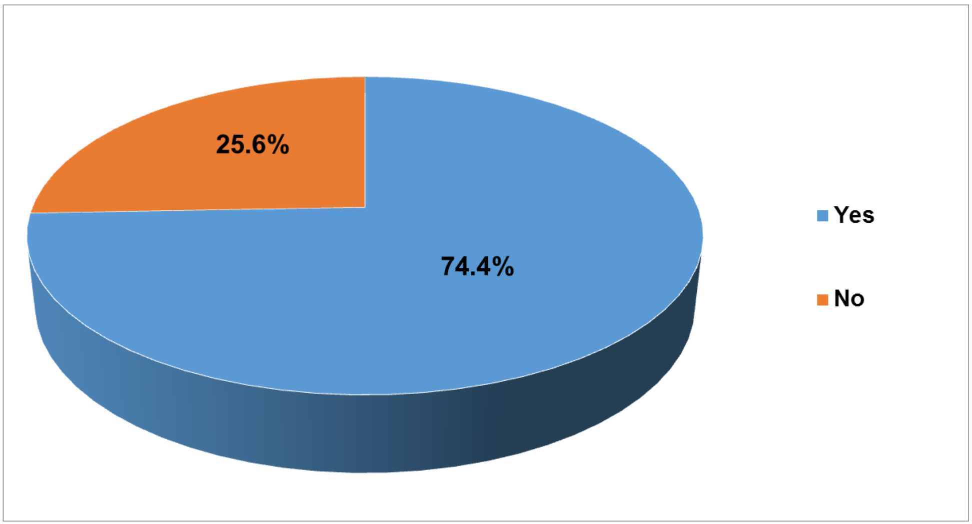


Figure 4-32: Crash involvement

Figure 4-32 indicates the distribution of survey participants according to their involvement in a road traffic crash. The majority of respondents (74.4%) have been involved in an RTC. Only 25.6% of the respondents have not been involved in a crash. The mentioned statistics only highlights the extent of the problem and emphasises the need to address road safety.

1.6 In your opinion, what was the main cause of the crash?

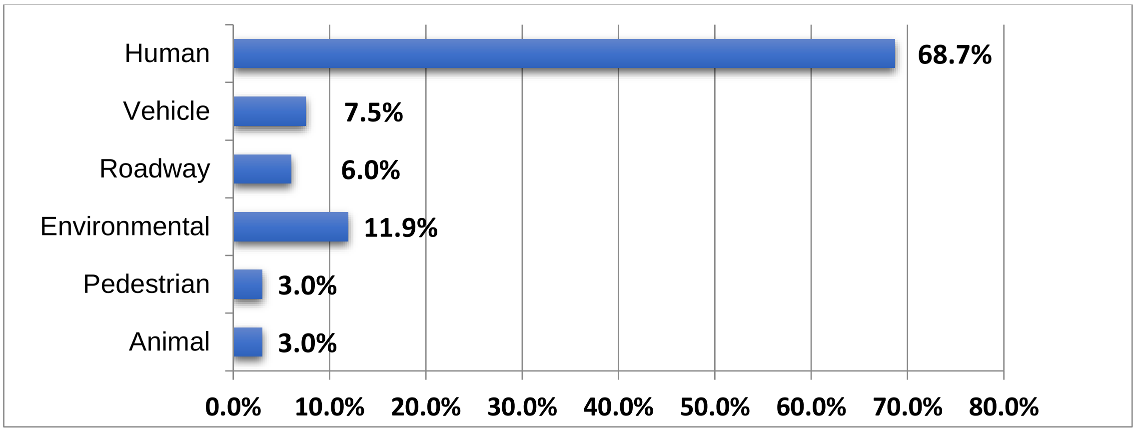


Figure 4-33: Cause of the crash

Figure 4-33 indicates that most respondents have cited Human factors as the cause of the crash referred to in the previous question. Grouped with the pedestrian factor, the human & pedestrian factors total 71.7%. The Roadway, Environmental and Animal factors were found to be the cause of 20.9% of crashes, followed by the Vehicle factors at 7.5%. These results compare very well with the analysis of the crash data, which have listed Human factors at 72.8%, Vehicle factors at 16.1% and Environmental factors at 8.7%.

1.7 How would you rate your driving ability?

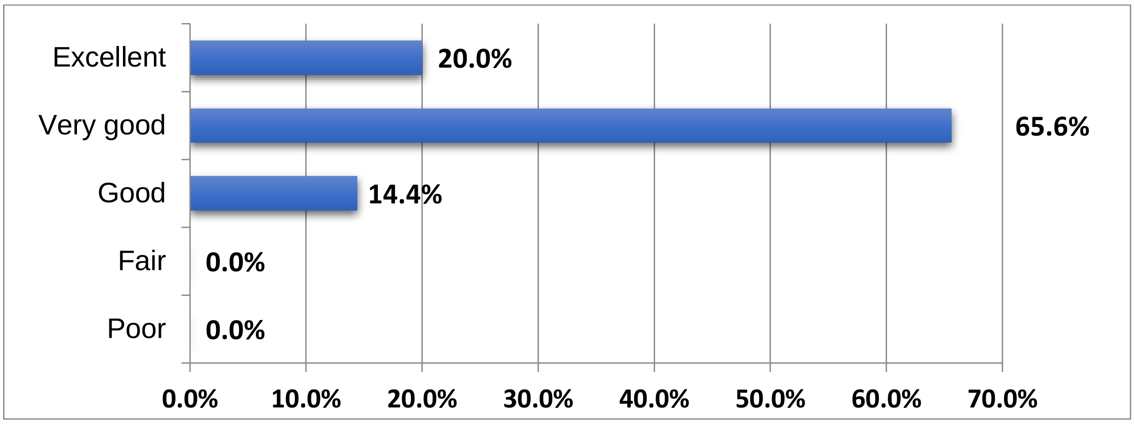


Figure 4-34: Driving ability

Figure 4-34 indicates that most of the participants have rated their driving ability as either 'very good' or 'excellent' (85.6%). Considering, that most of the respondents have been involved in a crash, and have listed human factors as the main cause of these crashes, it can be said, that many drivers either, overestimate their driving ability, or they have a misconception about the physical capabilities of a driver.

1.8 What is the biggest attribute that a good driver should possess?

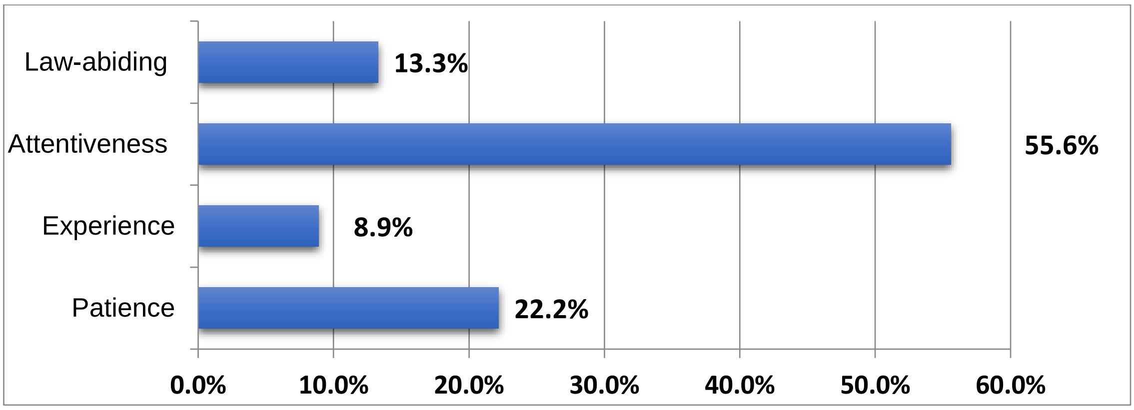


Figure 4-35: Attributes of a good driver

Figure 4-35 indicates that most respondents have considered "Attentiveness" as the biggest attribute that a good driver should possess (55.6%), followed by patience (22.2%). Only 13.3% of respondents thought being 'law-abiding' as the biggest attribute that a good driver should have. It is interesting to note that 'Driver experience' as the biggest attribute only received 8.9% of the replies.

1.9 How often do you drive on the following roads?

Table 4-23: Type of Road Usage

	Never	Rarely	Sometimes	Often	Always
Highways / Freeways	0.0%	3.3%	26.7%	46.7%	23.3%
Rural	4.4%	40.0%	24.4%	22.2%	8.9%
Urban / Residential	1.1%	0.0%	2.3%	36.4%	60.2%

It was important to establish how often the respondents to the survey make use of different types of roads. Table 4-23 above presents a breakdown of the driver usage of the various road networks and indicates that 70% of the respondents, often and always, travel on highways and freeways. Drivers rarely make use of rural roads, and as can be expected, almost 97% of drivers make use of urban and residential road networks. It can, therefore, be said that most of the survey respondents have acquired adequate highway driving experience to confidently provide meaningful answers to the survey questions relating to driving on a highway.

1.10 How often do you drive at night on a highway/freeway?

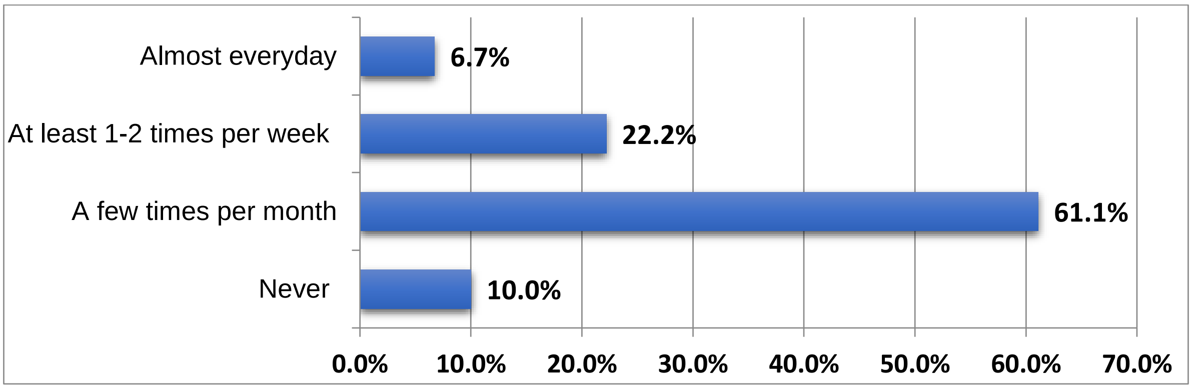


Figure 4-36: Driving at night on a highway/freeway

Figure 4-36 above furthermore indicates that most respondents have experience of driving on a highway at night, 61.1% reported driving at night at least a few times per month, and nearly 29% indicated driving at night almost every day or at least once or twice weekly.

1.11 In your opinion, what contributes the most towards road safety?

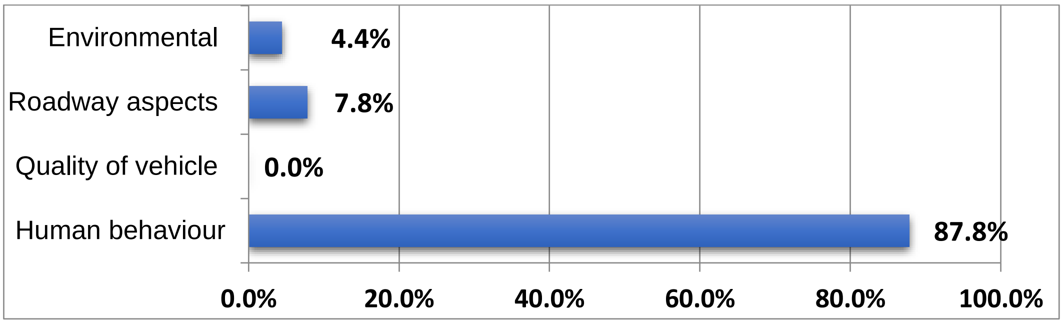


Figure 4-37: Contribution towards road safety

1.12 In your opinion, what contributes the most towards an unsafe road?

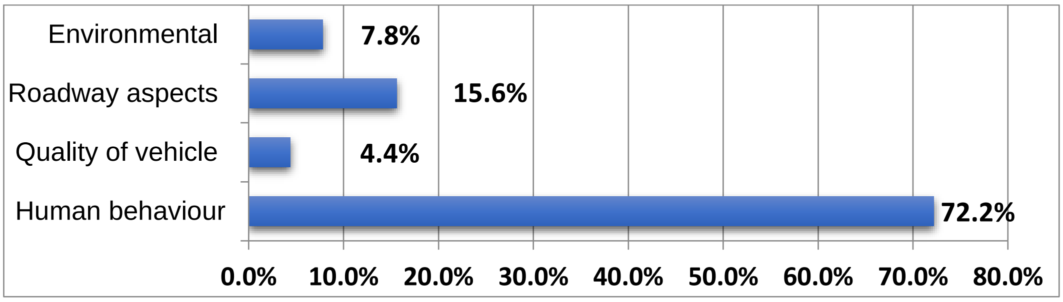


Figure 4-38: Contribution towards an unsafe road

1.13 What kind of risky behaviour have you observed being made by other highway/freeway drivers?

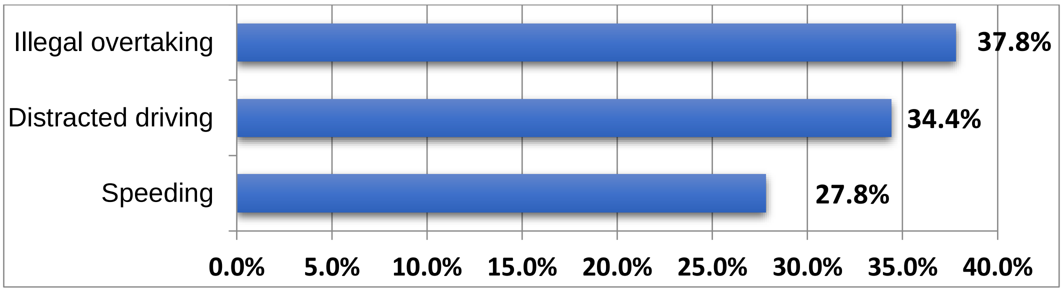


Figure 4-39: Risky behaviour by highway drivers

Figure 4-37, Figure 4-38, and Figure 4-39 report on driver's perceptions towards road safety and their observations when driving on a highway. Having to indicate what contributes the most towards road safety, and what contributes the most towards an unsafe road, most participants listed 'Human behaviour' as the primary factor that leads to a road being deemed safe or unsafe. Most respondents indicated 'illegal overtaking' (37.8%), and 'distracted driving' (34.4%) as the risky driving behaviour mostly being made by other drivers when driving on a highway.

Section 2: Personal Driving Behaviour

2.1 Do you ever drive above the speed limit?

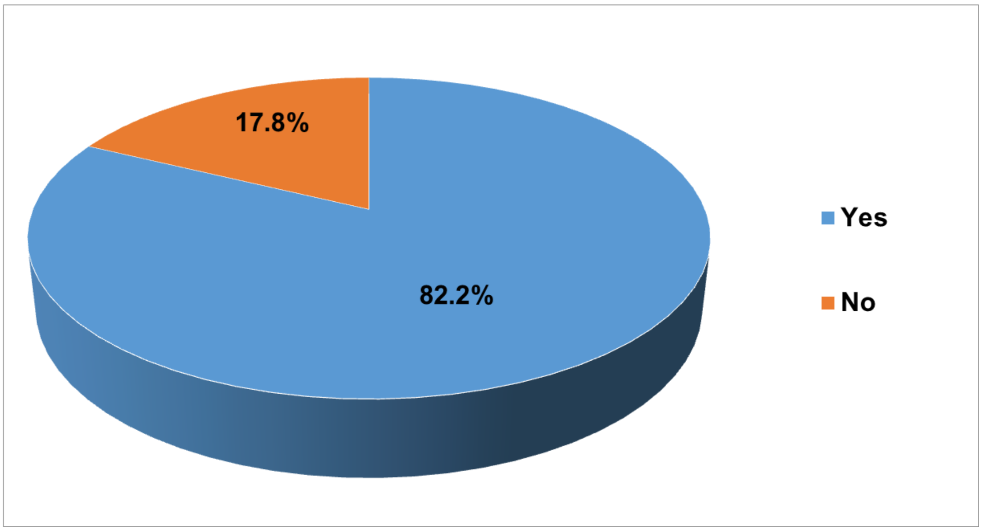


Figure 4-40: Driving above the speed limit

2.2 When you do find yourself speeding, how likely is it due to the following reasons?

Table 4-24: Reasons for speeding

	Very unlikely	Unlikely	Likely	Very likely
You don't know what the speed limit is	24.7%	33.7%	34.8%	6.7%
You are unaware of your speed	20.0%	26.7%	37.8%	15.6%
You enjoy speed	22.2%	31.1%	35.6%	11.1%
You know your own safe speed, which is higher than the speed limit	12.2%	20.0%	37.8%	30.0%
You are in a hurry	8.9%	16.7%	47.8%	26.7%
You believe that the speed you have chosen is appropriate for the driving conditions	4.5%	13.5%	47.2%	34.8%
You are confident in your ability to stop in time for unexpected conditions	2.2%	13.3%	57.8%	26.7%
You believe that there is no danger in exceeding the speed limit, especially when there is less traffic on the road	11.1%	26.7%	41.1%	21.1%
You don't think you will be detected by a speed camera	17.8%	30.0%	40.0%	12.2%
You don't think there are any police/traffic officers on the road	20.0%	27.8%	41.1%	11.1%

Figure 4-40 shows that 82.2% of the respondents admitted to, when diving on a highway, they do sometimes drive above the posted speed limit. Only 17.8% indicated that they always adhere to the speed limit. Considering that 85.6% of the respondents regard themselves as 'very good' or 'excellent' drivers, and 87.7% acknowledges 'Human behaviour' as the leading factor in road safety, it can be said that most drivers, either do not regard driving above the speed as dangerous or they do not consider driving above the legal speed limit as a negative reflection towards their driving ability.

To understand the motivations behind speeding, respondents were asked to show the degree to which the factors set out in Table 4-24 would affect their judgement or influence their decision to exceed the posted speed limit. Survey responses were measured on a four-point scale, but, to simplify the data analysis process, the responses were grouped into either a negative or positive reply, where negative responses were the "very unlikely and unlikely" replies, and the positive responses were the "very likely and likely" replies.

According to the results, the primary motivation for driving above the speed limit was the belief of drivers that they would be able to stop in time for unexpected conditions (84.5%). 82% of respondents indicated that they would drive above the posted speed limit when they feel that their choice of travel speed was acceptable for the driving conditions. 74.5% of the survey participants indicated that they would be more likely to drive above the posted speed limit when they were in a hurry.

Another big motivation for driving above the posted speed limit is the low perceived risk associated with speeding. 62.2% of respondents indicated that they believe that there is no additional risk in exceeding the posted speed limit, especially when the volume of traffic is low. 52.2% of the survey participants admitted to driving above the posted speed limit when feeling certain that they would not be caught by law enforcement officers. More than 50% of respondents confessed to driving above the posted speed limit if they believed that there are no cameras regulating speed along the route. 53.4% of the respondents pointed to the fact that they might be unaware of the speed that they are travelling.

2.3 How often do you do each of the following on a freeway / highway?

Table 4-25: Driving behaviour on a highway

	Never	Rarely	Sometimes	Often	Always
I choose a speed lower than the speed limit	16.9%	28.1%	31.5%	20.2%	3.4%
I choose a speed higher than the speed limit	7.8%	24.4%	33.3%	31.1%	3.3%
I make a call while driving, using my mobile phone, without a hands-free device	43.3%	35.6%	15.6%	5.6%	0.0%
I make a call while driving, using my mobile phone, with a hands-free device	20.0%	20.1%	23.3%	24.4%	12.2%
I send a text message while driving, using my mobile phone	49.4%	23.6%	23.6%	2.2%	1.1%
I keep to a safe following distance	0.0%	0.0%	6.7%	44.4%	48.9%
I would overtake a vehicle against a no-overtaking/barrier line, when I consider it to be safe	41.6%	29.2%	18.0%	6.7%	4.5%
I do a vehicle inspection before the trip	24.4%	34.4%	24.4%	11.1%	5.6%
I overtake slow moving vehicles travelling-in or making-way in the emergency lane (yellow-line)	25.6%	6.7%	16.7%	33.3%	17.8%
I make use of the emergency lane (yellow-line) to allow other fast moving vehicles to overtake me	20.5%	18.2%	25.0%	22.7%	13.6%
I would make use of the emergency lane (yellow-line) to change a flat tyre or in case of a vehicle breakdown	14.4%	23.3%	24.4%	21.1%	16.7%
I use my seat-belt and child-restraint	0.0%	0.0%	1.1%	12.4%	86.5%
I eat or drink while driving	9.0%	20.2%	33.7%	36.0%	1.1%
I drive when I have consumed alcoholic beverages, but only when I think that I might still be within the legal blood-alcohol limit	33.3%	26.7%	31.1%	7.8%	1.1%
I drive when I have consumed alcoholic beverages, even though I think that I might be just over the legal blood-alcohol limit	53.9%	30.3%	13.5%	2.2%	0.0%

To understand the behaviour of drivers, when it comes to driving on a highway, the most common behavioural traits were listed in Table 4-25. Survey responses were measured on a five-point scale, but, to simplify the data analysis process, the responses were grouped into either a negative or positive reply, where negative responses were the "never and rarely" replies, and the positive responses were the "sometimes, often and always" replies. According to the results, 58.8% of drivers do not undertake a vehicle inspection before the trip. 70.8% of respondents eat or drink while driving. 40.6% of the respondents have admitted to driving when they have consumed alcoholic beverages, but only when they believe that their blood-alcohol level is within the legal limit. 15.7% admitted to having driven a vehicle when they have consumed alcoholic beverages, even though they thought that their blood-alcohol level might be above the legal limit. 26.9 % of the survey participants admitted to sending a text message, using their mobile phones, while operating a vehicle on a highway.

29.2% of the respondents said that they would overtake a vehicle against a no-overtaking/barrier line when they consider it to be safe. A large percentage of respondents, 67.5%, said that they do overtake slow-moving vehicles travelling-in, or making-way in the emergency lane (yellow-line/shoulder), and 61.3% said that they make use of the emergency lane (yellow-line/shoulder) to allow other fast-moving vehicles to overtake them. At the same time, 62.2% of respondents conceded that they would make use of the emergency lane (yellow-line) to change a flat tyre or in the case of a vehicle breakdown. Considering the fact that over the study period (2010-2018), 235 crashes occurred as a result of stationary vehicles on the South African part of the N4, the practice of using the emergency lane for overtaking may prove to be extremely dangerous (refer to Part 4.3.9).

2.4 The following questions deal with your experience of feeling tired when driving on a highway / freeway. How often do you?

Table 4-26: Fatigue when driving on a highway

	Never	Rarely	Sometimes	Often
Drive while you are tired	11.2%	34.8%	47.2%	6.7%
Have fallen asleep or nodded off (even for a brief moment)	64.0%	23.6%	12.4%	0.0%
Realise you have no clear recollection of the road along which you have just been travelling	42.7%	29.2%	20.2%	7.9%
Have lapses of concentration or struggle to focus	31.8%	43.2%	21.6%	3.4%
Struggle to keep your eyes open or to stay awake	46.1%	36.0%	16.9%	1.1%

2.5 What do you do when you get tired?

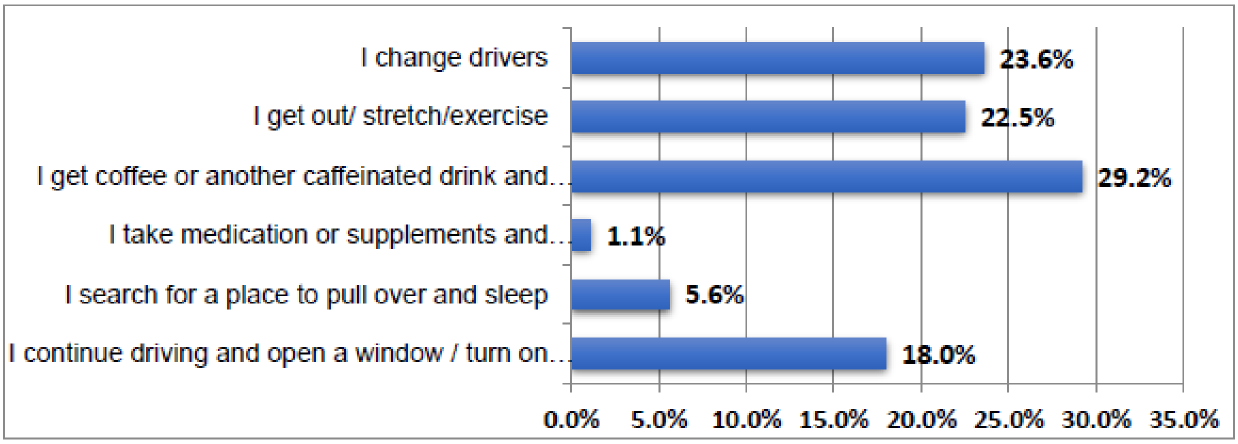


Figure 4-41: Driver fatigue countermeasures

In order to understand the respondents' perceptions of feeling exhausted while driving on the highway, participants were asked to specify to what degree they encountered the signs of exhaustion mentioned in Table 4-26 above. Survey responses were measured on a four-point scale, but, to simplify the data analysis process, the responses were grouped into either a negative or positive reply, where negative responses were the "never and rarely" replies, and the positive responses were the "sometimes and often" replies. More than 50% of respondents admitted to having driven when they felt tired (53.9%). A smaller percentage of respondents (27.9%) also admitted to having had an incident where they cannot recollect the road along which they were travelling.

The participants were, furthermore, asked about the actions they take to counteract exhaustion and tiredness during driving. Figure 4-41 indicate the responses obtained from all the participants. Most participants prefer to “get a caffeinated drink and continue driving” (29.2%) in order to counteract the feelings of fatigue when driving on a highway, followed by “changing drivers” (23.6%). The fatigue countermeasures least adopted by drivers is to ‘search for a place to sleep’ (5.6%), and ‘take medication or supplements and continue driving’ (1.1%).

2.6 The following questions deal with your experience with taking medication when driving on a highway / freeway. How often do you?

Table 4-27: Taking medication when driving

	Never	Rarely	Sometimes	Often	Always
I drive when I have taken some prescribed medication	27.0%	29.2%	23.6%	11.2%	9.0%
I drive when I have taken some over-the-counter medication	19.1%	16.9%	40.4%	15.7%	7.9%
I always read the side-effects of the medication when I know I am going to drive	29.2%	25.8%	15.7%	13.5%	15.7%
I drive when I believe the medication would not cause drowsiness, without reading the side-effects	19.1%	14.6%	27.0%	20.2%	19.1%
I believe prescription medication or over-the-counter medication would not have an effect on my driving ability	27.0%	20.2%	24.7%	16.9%	11.2%

To understand the views that survey participants have about the use of prescription and over-the-counter drugs, the most common assumptions regarding the issue were described in Table 4-27. Survey responses were measured on a five-point scale, but, to simplify the data analysis process, the responses were grouped into either a negative or positive reply, where negative responses were the "never and rarely" replies, and the positive responses were the "sometimes, often and always" replies. According to the results, when it comes to taking medication while driving, the majority of the respondents (64%) drive when they have taken some over-the-counter medication. Furthermore, an even larger percentage of the respondents (66%) drive when they believe the medication would not cause drowsiness, without first studying the side-effects. 55% of the respondents admit that they do not read the side-effects of the medication, even when they know that they will be driving. Likewise, 52.8% of the respondents believe that neither prescription medication nor over-the-counter medication would affect their driving ability.

4.7 Discussion of Findings

The following section provides a discussion of the most significant findings and results, obtained through the analysis of the crash data and the driver behaviour survey, in order to outline the relationship that exists between the severity of the RTCs and the human factors involved in these crashes.

Based on the findings of the Analysis of Crash data it is evident that:

- Road traffic crashes and fatalities are on the rise in South Africa.
- The number of crashes increases over the festive season and school holiday periods.
- Road traffic crashes on a highway are mostly caused by human factors, of which “Lost control” and “negligent driving” are the major factors.
- Inadequate South African crash reporting has for years prevented the application of quantitative and detailed statistical analyses. Incorrect crash classification and reporting errors, like incomplete report forms, are a concern. The Accident and Incident Field Form does not provide adequate information to clearly explain the specifics concerning “Lost Control” and “Other” crashes.
- Negligent driving and speeding are problematic and leads to loss of control and subsequent crashes.
- Single-vehicle and Head-tail crashes are jointly responsible for 72.7% of crashes.

- Drivers do not adhere to safe following distances which can lead to head-tail crashes.
- Most fatal crashes occurred during the night. The majority of serious-, slight injury and damage-only crashes occur during the day. This is significant considering that the majority of traffic flow occurs during the daytime.
- Most crashes occurred during clear weather conditions, this might be due to the fact that drivers tend to drive at lower speeds in bad weather conditions.
- Vehicle roadworthiness is a major concern, especially the condition of tyres. Many tyre failures result in crashes, especially when driving at high speeds.
- Platooning of vehicles, driver frustration and lack of adherence to the traffic laws and regulations are a real concern. These types of actions lead to negligent driving like illegal overtaking, resulting in subsequent crashes.
- Construction zones, in general, have a negative effect on the crash rates, while improved roads have a positive effect on road safety.
- The majority of fatalities are pedestrian-related, emphasizing the need to protect and educate the most vulnerable road users.
- Pedestrians crossing the road at grade or walking alongside the road on the shoulder pose a serious risk.
- Public transport activities such as dropping off and picking up passengers alongside the road pose a serious risk.
- Stray animals are a major concern, resulting in serious crashes.
- Current laws do not adequately address overloading of children travelling in minibus and taxis.
- Driver distraction is a cause for concern. Distraction is caused by drivers paying attention to billboard signs, mobile phone usage or text messaging etc.
- Failure to perform routine maintenance on vehicles may lead to the deterioration of the various mechanical parts. Drivers also fail to conduct regular vehicle safety and mechanical inspections, meaning mechanical problems are not timeously addressed.

Based on the findings of the Association Rule Analysis it is evident that:

- Association Rule Analysis can be effectively used to find any co-occurrences between the severities of the crashes and the unknown factors that may shed light on the crash occurrence.
- Association Rule analysis can successfully be done using software packages like Excel.
- There exists a relationship between the severity of road traffic crashes that occur on a highway and specific human factors involved in these crashes.
- Single vehicles tend to be in more fatal crashes.

- Pedestrian/cyclist-vehicle crashes are mostly fatal.
- Drugs/Alcohol and Sleeping/Fatigue tend to lead to more serious crashes.
- Negligent driving, U-turn/reversing and overtaking vehicles tend to be the most dangerous illegal behaviour and tend to lead to more serious crashes.
- Head-side and Head-on crashes tend to be more serious.

Based on the findings of the Road User Survey it is evident that:

- Most people have been involved in a road traffic crash.
- Many drivers either overestimate their driving ability, or they have a misconception about the physical capabilities of a driver.
- Most respondents recognise human factors as the biggest contributor to road safety.
- Most drivers consider themselves to be good drivers.
- Most drivers admitted to driving above the speed limit at some stage.
- Most drivers do not read the side effects of the medication before taking medication and operating a vehicle.
- Most drivers do not carry out a vehicle inspection before a trip on a highway.
- Most drivers admitted that law-enforcement along the route would deter them from driving above the speed limit.

4.8 Recommendations of Countermeasures

The following section discusses the solutions and recommends the countermeasures that can be put in place to address RTCs, and the human factors involved in the RTCs on highways in South Africa.

According to the National Road Safety Strategy, 2016-2030 (2017), a safe road design should focus on providing an environment intended to protect its users. This approach recognizes that people can make mistakes, and as a result, the design of the road needs to protect the user from the human errors that result in crashes or severe injury as much as possible. To achieve this, forgiving and intelligent road design elements must be incorporated (RTMC, 2017).

The following countermeasures are recommended:

- Road Safety Education must be made part of the school curriculum in order to teach kids about road and pedestrian safety from an early age.
- Raised pedestrian crossings/speed humps, the installation of additional street lighting and the consolidation/formalization of accesses must be considered and prioritized in the urban areas where high pedestrian fatalities are experienced.
- Accident reporting officials should receive accredited training. Reporting officials should be able to investigate the crash site to properly and clearly define the crash type and accurately determine the possible crash cause. The Accident and Incident Field Form should allow for a detailed explanation to the cause of "Lost Control" and "other" crashes.
- The public needs to be educated on road safety issues, such as safe pedestrian road crossing behaviour, especially in rural districts.
- The public needs to be educated about the importance of vehicles and tyres being in a good mechanical and working condition.
- Drivers need to be educated to reduce speed in poor conditions and to keep a safe following distance at all times.
- Road signs and markings are also an important part of a roadway system as they convey a substantial amount of safety information and user services to the driver of the vehicle.
- The road messages should control the rate of decision-making to a level that a driver can accommodate, and provide information to the driver in such a manner that it facilitates quick and correct decisions.
- It is strongly advised to plan resting points before embarking on a long journey. Safe resting places should also be provided by the roads authority.
- It is essential to re-evaluate legislation to protect children from overloading in vehicles.
- Limitations in human information processing can be addressed through the design of roadway environments that is in accordance with driver expectations. When drivers can rely on experience to assist with control, guidance, or navigation, there is less information to process.
- Accident rate and severity decrease with an increase in median width. A wide median should be provided as far as possible as it reduces the likelihood of head-on accidents between vehicles, it further reduces same-direction accidents as it provides a recovery area.
- Reflective measurements and night inspections on road signs must be conducted and missing/defective studs and road signs replaced on an ongoing basis.
- VMS signs must be utilized at construction sections improve communication with road users, and to notifying them of delays, road closures and other dangerous conditions.

- According to Guidelines for Pedestrian and Public Transport Facilities: "Pedestrian access to freeways should be prevented as far as possible, and along rural roads it should be minimised as far as possible" (SANRAL, 2017, p.16).
- According to Guidelines for Pedestrian and Public Transport Facilities: "Minimise conflict points as far as possible by taking due cognisance of the surrounding land use and its need for access" (SANRAL, 2017, p.16).
- According to Guidelines for Pedestrian and Public Transport Facilities: "Identify pedestrian desire lines and assess these routes through the collection of data (p.16). Based on the outcome of this process, the pedestrian desire lines across the network can be determined, as well as the reasons for it. The extent of the risk can be assessed. Hereafter, the possible interventions to improve the road safety conditions of the section of road under investigation can be determined" (SANRAL, 2017, p.17).
- Street lighting is required along urban sections to improve visibility of pedestrians.
- Construction of additional passing/climbing lanes must be prioritized.
- Law enforcement remains the most effective way to reduce speeds and enforce regulations. Regular speed prosecution is required by law enforcement agencies.
- Rumble strips to be added at identified areas where motorists tend to fall asleep.
- Warning signs to be added at hot spot areas to advise motorists to reduce speed.
- Proper enforcement on road worthiness of vehicles is done, including the tyre treads.
- Further analyses and investigations are done to determine possible solutions to improve the safety at hazardous sections identified.
- According to Guidelines for Pedestrian and Public Transport Facilities: "Public transport services operating along the national road network to be in accordance with the Operating License Strategy of the Local Authority or District Authority" (SANRAL, 2017, p.9).
- According to Guidelines for Pedestrian and Public Transport Facilities: "Public Transport should not be provided along undivided freeways where the two carriageways cannot be separated by a fence" (SANRAL, 2017, p.10).

5. Conclusions

This chapter presents the conclusions drawn from the research study. The main purpose of this research was to analyse the relationship between the severity of road traffic crashes, which occurred on the N4 Toll Route in South Africa, and the interaction of the human factors involved in these crashes. Association Rule Analysis was the primary analysis method used to determine if a relationship exists between the crash severity and the human factors involved in these crashes. Besides, the crash data, an electronic survey was distributed to collect information about the perception that drivers have on the possible relationship between RTCs and the human factors involved in these crashes. The survey was, furthermore, used to collect information about driver behaviour when driving on a highway.

Results obtained from this research study confirmed that the human factor plays a critical role in road traffic crashes. Out of the nearly 9000 crashes analysed, 72.8% were caused by human factors, 16.1% by vehicle factors, 8.7% by road and environmental factors and 4.4% by unknown factors.

The study established that there exists a relationship between the various human factors and crash severity. Among the human factors, crashes that occurred as a result of negligent driving, illegal overtaking and travelling in the wrong direction proofed to pose the highest risk for fatalities or serious injury. Vehicle- pedestrian crashes proofed to be the most dangerous, leading to a fatality in 71.5% of these types of crashes.

As discussed under Part 2.3.2 of this report, "Haddon (1980) created a matrix that defines crash risk factors for each stage - before, during and after - of the crash, concerning the driver, the vehicle and the environment... Each phase – pre-crash, crash and post-crash – can be analysed systematically for the human, vehicle, road and environmental factors" (Peden et al., 2004, p.12). The road designer/roads authority can influence each one of these phases to ensure that the impact of a crash is reduced. There are, accordingly, several possible actions that can be implemented for each stage to minimise the impact of the crash or to prevent the crash from occurring in the first place. The designer, along with the road authority, may attempt to influence the road (design, maintenance), the vehicle (travel speed, vehicle condition with the assistance of law enforcement) or the driver (road user behaviour through road safety campaigns and road safety signs and messages). Table 5.1 on the following page provides a summary of the major Findings and Recommendations derived from this research study in relation to each of these different phases.

Table 5-1: Summary of major Findings and Recommendations

PHASE GOALS	FINDINGS	RECOMMENDATIONS
PRE-CRASH	• Many drivers either overestimate their driving ability, or they have a misconception about the physical capabilities of a driver. • Most drivers admitted to driving above the speed limit at some stage. • Most drivers do not read the side effects of the medication before taking it and then operate a vehicle. • Most drivers do not do a vehicle inspection before going on a trip on a highw ay. • Law -enforcement along the route w ould deter drivers from driving above the speed limit. • Drivers do not adhere to safe follow ing distances w hich can lead to head-tail crashes. • Current law s do not adequately address overloading of children travelling in minibus and taxis.	• Educate people about the physical capabilities of a driver, like driver reaction time. • Educate people about the dangers of speeding. • Educate people about the dangers of driving w hen tired, and the effects of taking medication. • Educate people about safe follow ing distances. • Make vehicle services and inspections compulsory.Vehicles should be tested for roadw orthiness at least every 3 years for models older than 10 years. • Law -enforcement should be made more visible along all major highw ays. • Current law s should be revised to adequately address overloading of children travelling in minibus and taxis.
CRASH	• Association Rule Analysis can be effectively used to find any co-occurrences betw een the severities of the crashes and the unknow n factors that may shed light on the crash occurrence. • There is a relationship betw een the severity of road traffic crashes that occur on a highw ay and certain human factors involved in these crashes. • Negligent driving tent to lead to more serious crashes. • Illegal overtaking tent to lead to more serious crashes. • Pedestrian-vehicle crashes are mostly fatal. • Head-side crashes tent to be more serious. • Road traffic crashes and fatalities are on the rise in South Africa. • The number of crashes increases over the festive season and school holiday periods. • Driver distraction is a cause for concern. Distraction is caused by drivers paying attention to billboard signs, mobile phone usage or text messaging etc.	• Inadequate South African crash reporting systems have for years prevented the application of quantitative and detailed statistical analyses. A national reporting system must be implemented. • More statistical analysis should be done on the available South African crash data. • The public needs to be educated on road safety issues, such as safe pedestrian road crossing behaviour, especially in rural districts. • Road should provide enough passing oppurtunities to reduce illegal overtaking. • Illegal signs or any obstacle that lead to driver distraction should be removed • More coordinated law -enforcement campaigns required over holiday periods. • Minimise conflict points as far as possible by taking due cognisance of the surrounding land use and its need for access.
POST CRASH	• Road traffic crashes on a highw ay are mostly caused by human factors, of w hich “Lost control” and “negligent driving” are the major factors. • Negligent driving is problematic and leads to loss of control and subsequent crashes. • Single-vehicle and Head-tail crashes are jointly responsible for 72.7% of crashes. • Most fatal crashes occurred during the night. • Platooning of vehicles, driver frustration and lack of adherence to the traffic law s and regulations are a real concern. • The majority of fatalities are pedestrian-related. • Stray animals are a major concern, resulting in serious crashes. • Pedestrians crossing the road at grade or w alking alongside the road on the shoulder pose a serious risk. • Public transport activities such as dropping off and picking up passengers alongside the road pose a serious risk..	• Raised pedestrian crossings/speed humps and the consolidation/formalization of accesses must be considered and prioritized in the urban areas. • Road signs and markings are also an important part of a roadw ay system as they convey a substantial amount of safety information and user services to the driver of the vehicle. • The road messages should control the rate of decision-making to a level that a driver can accommodate. • Safe resting places should also be provided by the roads authority. • Limitations in human information processing can be addressed through the design of roadw ay environments that is in accordance w ith driver expectations. • Accident rate and severity decrease w ith an increase in median w idth. A w ide median should be provided as far as possible. • Reflective measurements and night inspections on road signs must be conducted and missing/defective studs and road signs replaced on an ongoing basis. • VMS signs must be utilized at construction sections improve communication w ith road users, and to notifying them of delays, road closures and other dangerous conditions. • Street lighting is required along urban sections to improve visibility of pedestrians. • Construction of additional passing/climbing lanes must be prioritized.

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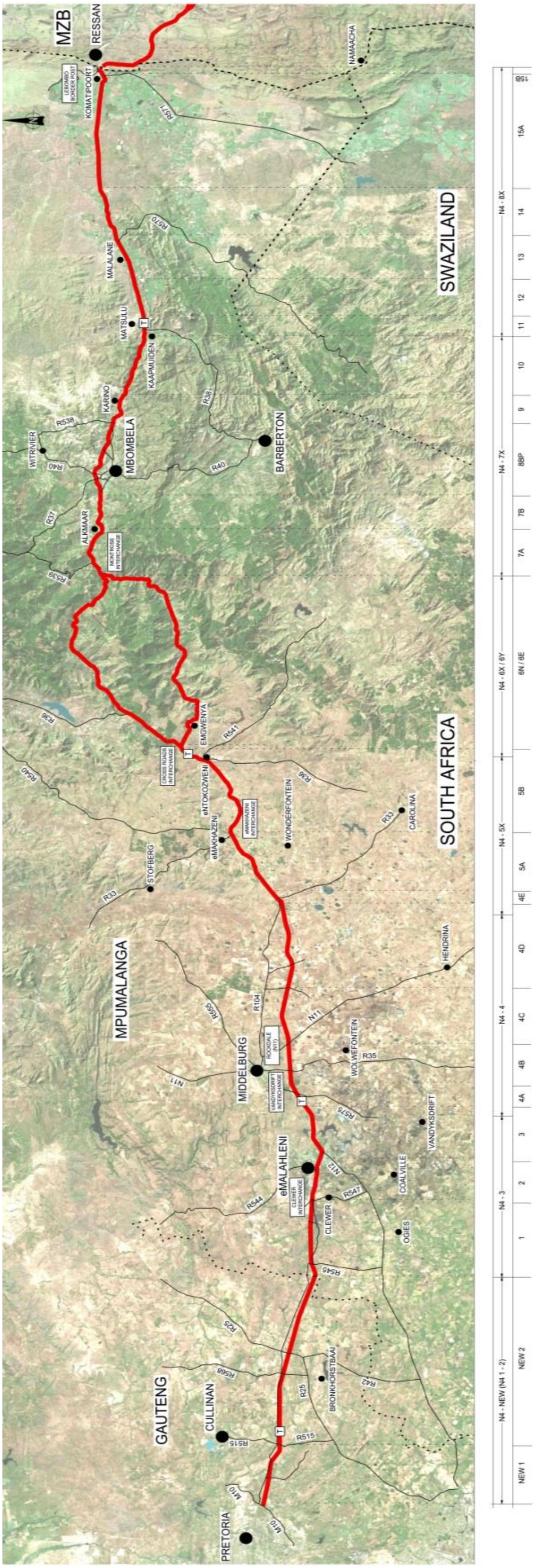
Addenda

Addendum A: Key Plan – N4 South African Section
(Pretoria, Gauteng, to the Lebombo border post, Mpumalanga)


MZB
RESSAN
KOMATIPOORT
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WITRIVIER
BARBERTON
ALKMAAR
EMGWENYA
eNTOKOZWENI
eMAKHAZENI
WONDERFONTEIN
CAROLINA
STOFBERG
SOUTH AFRICA
MPUMALANGA
HENDRINA
MIDDELBURG
WOLWEFONTEIN
VANDYKSDRIFT
eMALAHLENI
COALVILLE
CLEWER
OGIES
BRONKHORSTBAAI
GAUTENG
CULLINAN
PRETORIA

Addendum B: Examples - TRAC Accident Reports

Example - TRAC Traffic and Information Data System (TIDS)

Accident Date	Accident Time	Accident Description	Accident Type	Accident - Chainage	Accident - Visibility	Accident- Weather Type	Injury - Fatal count	Injury - Serious count	Injury - Slight count	Accident - Road Section Detail	Driver - Age	Driver - Gender	Accident Cause
2010/01/02	19:45	Driver was speeding on a wet road. He then lost control and vehicle went off the road.	Single vehicle	52.40	Night	Rain				N4/5X km 29.4 to km 56.8 to N4/6X km 2.70 (Crossroads)	40	Male	Speeding
2010/01/03	11:50	Vehicle had a tyre blow out and cause the vehicle to overturn.	Single vehicle	22.80	Clear Daylight	Clear		2		N4/8X km 14.60 to N4/8X km 26.90 (Malelane gate)	Unkown	Unkown	Tyre burst - Vehicle
2010/01/03	16:00	Toyota Tazz collied head tail with a Chev	Head-tail	28.00	Clear Daylight	Clear			2	N4/3 km 14.5 to N4/3 km 30.2 (start of concrete)	Unkown	Unkown	Speeding
2010/01/04	05:45	Driver lost control of the vehicle due to the problem with the front wheel.	Single vehicle	3.00	Clear Daylight	Clear				N4/6X km 2.70 to km 43.32 to N4/7X km 22.70 (Crossroads via Elandspoort to Montrose)	28	Male	Lost control
2010/01/04	14:56	Datsun vehicle was travelling in the yellow lane and collided head tail with Chrysler which had a breakdown.	Head-tail	38.20	Poor Daylight	Rain		1	3	N4/3 km 30.2 to km 41.76 to N4/4 km 6.60 (Concrete section to Van dyks drift)	41	Male	Negligent driving
2010/01/04	14:56	Datsun vehicle was travelling in the yellow lane and collided head tail with Chrysler which had a breakdown.	Head-tail	38.20	Poor Daylight	Rain		1	3	N4/3 km 30.2 to km 41.76 to N4/4 km 6.60 (Concrete section to Van dyks drift)	38	Male	Negligent driving
2010/01/04	15:45	The trailer of the LDV swinged and driver then lost control and collided with the Run X.	Sideswipe	8.00	Poor Daylight	Rain			2	N4/8X km 4.90 to N4/8X km 14.60 (Strathmore)	37	Male	Tyre burst - Vehicle
2010/01/04	15:45	The trailer of the LDV swinged and driver then lost control and collided with the Run X.	Sideswipe	8.00	Poor Daylight	Rain			2	N4/8X km 4.90 to N4/8X km 14.60 (Strathmore)	33	Male	Tyre burst - Vehicle
2010/01/04	16:15	Driver lost control of the vehicle.	Single vehicle	41.80	Poor Daylight	Rain	0	0	0	N4/4 km 34.0 to km 47.55 to N4/5 km 9.90 (Wonderfontein	58	Male	Lost control
2010/01/04	16:15	VW Golf collided head tail with an LDV	Head-tail	38.40	Poor Daylight	Rain		1	2	N4/4 km 34.0 to km 47.55 to N4/5 km 9.90 (Wonderfontein	Unkown	Unkown	Speeding
2010/01/04	16:20	Renault Megane collided head tail with Proton waiting to pay the toll	Head-tail	14.40	Poor Daylight	Rain		3		N4/2 km 2.90 to N4/2 km 21.98 (Boshoek ich to Witfontein/Valtaki ich)	45	Male	Speeding
2010/01/04	16:20	Renault Megane collided head tail with Proton waiting to pay the toll	Head-tail	14.40	Poor Daylight	Rain		3		N4/2 km 2.90 to N4/2 km 21.98 (Boshoek ich to Witfontein/Valtaki ich)	31	Female	Speeding
2010/01/04	17:00	Run X wanted to change lanes and sideswiped the bus	Sideswipe	24.20	Clear Daylight	Clear			2	N4/3 km 14.5 to N4/3 km 30.2 (start of concrete)	58	Male	Negligent driving
2010/01/04	17:00	Run X wanted to change lanes and sideswiped the bus	Sideswipe	24.20	Clear Daylight	Clear			2	N4/3 km 14.5 to N4/3 km 30.2 (start of concrete)	41	Female	Negligent driving
2010/01/05	06:55	Truck had a tyre blow out. Driver lost control and vehicle went off the road and down the embankment.	Single vehicle	55.00	Clear Daylight	Rain			3	N4/8X km 39.10 to N4/8X km 69.10 (Border gate)	Unkown	Unkown	Tyre burst - Vehicle
2010/01/05	22:20	Sedan vehicle A that was travelling east around a bend, went across the barrier line and collided head on with sedan vehicle B	Head-on	90.00	Night	Rain	3	1	2	N4/7X km 74.1 to N4/7X km 90.05 (Crocodile River)	Unkown	Unkown	Unknown
2010/01/06	05:20	Driver fell asleep and vehicle went off the road.	Single vehicle	3.20	Clear Daylight	Clear				N4/6X km 2.70 to km 43.32 to N4/7X km 22.70 (Crossroads via Elandspoort to Montrose)	Unkown	Unkown	Sleeping
2010/01/06	05:44	Brakes of the truck failed. Driver then lost control and the truck went off the road.	Single vehicle	47.60	Clear Daylight	Clear			2	N4/6Y km 0.0 to km N4/6Y km 63.72 (Schoemanskloof)	35	Male	Mechanical – vehicle

Example - TRAC Accident and Incident Field Report Form

Accident and Major Incident Form

Sector	RSA (N4 Main)	RSA (N4 Schoemanskloof)	RSA (N4 Extension)
	RSA (N4 Ring Road)	Mozambique	Km's Travelled

Accident / Incident Notification

Reported by ☐ Emergency Patrol (T) ☐ Patrol Officer (T) ☐ Patrol Officer (M)

☐ Other Authority [..........]

Name [..........]

Alerted on [dd - mm - yyyy] at [hh : min] On scene [dd - mm - yyyy] at [hh : min]

Action [..........] at [.... : ....]

Call Centre Ref. [..........]

Location and Time of Accident / Incident

Location N4\ [sec] [dir] km [chainage] Date [dd - mm - yyyy] Time [hh : min]

☐ On Ramp ☐ Off Ramp

Nature of Incident

Mark appropriate box(es)

☐ Accident ☐ Fire / Smoke ☐ Breakdown ☐ Lost Load

☐ Secondary Accident ☐ Hazardous Chemicals ☐ Roadside Furniture ☐ [..........]

Type of Accident

Mark one only (if this is an accident)

☐ Single vehicle ☐ Head-tail ☐ Head-on ☐ Head-side

☐ Multiple pile-up ☐ Sideswipe ☐ Unknown

Possible Cause of Accident

Mark appropriate box(es)

	Construction/Maintenance
☐	Construction site
☐	Maintenance site
	Fixed object
☐	Object on road
☐	Previous accident
	Human
☐	Drugs/Alcohol
☐	Loss of control
☐	Medical problem
☐	Negligent driving
☐	Poor Visibility
☐	Sleeping
	Intersection or Access
☐	Stop-controlled approach
☐	Traffic signal controlled approach
☐	Uncontrolled approach to junction

	Load
☐	Animal loss
☐	Load loss
☐	Passenger loss
	Opposing direction
☐	Overtaking
☐	U-Turn
☐	Wrong direction of travel
	Pedestrian/Cyclist/Animals
☐	Animal - Domestic
☐	Animal - Wild
☐	Cyclist
☐	Pedestrian
	Road surface
☐	Edge drop-off
☐	Gravel shoulder
☐	Skidding (water/loose material/smooth surface)

	Speed differentials
☐	Public transport stop
☐	Parked & stationary vehicles
☐	Reversing vehicles
☐	Speed differential (rear-end)
	Tyres
☐	Tyre burst - Trailer
☐	Tyre burst - Vehicle
	Vehicle
☐	Brake failure
☐	Mechanical - trailer
☐	Mechanical - vehicle
☐	Towing of vehicle involved
☐	Trailer sway
☐	Vehicle sway
	Other
☐	Other

Visibility

Mark one only

☐ Clear Daylight ☐ Poor Daylight ☐ Night ☐ Smoke

Weather at time of Accident / Incident

Mark one only

☐ Clear ☐ Rain ☐ Wind ☐ Mist ☐ Special (hail, snow, etc.)

Examples - TRAC Electronic Accident Form

Accident Detail

Accident Number: EK--2018-12-079

TRANS AFRICAN CONCESSIONS

Location, Time and Description of Incident

Location	EN4/2 E km 43.6	**TRAC Assist**	No
Date	17 December 2018 at 10h45	**Cleared**	17 December 2018 at 12h00
Nature	Accident		
Type	Head-tail	**Possible Causes**	Negligent driving,Speed differential (rear-end)
Weather	Clear	**Visibility**	Clear Daylight
Description	Driver of a Toyota Alteza collided head tail into a Toyota Rav4.		

Injuries in Accident

Damage Only Yes

Vehicles in Accident

1	**Sedan**	Toyota Alteza	Black	**Reg. No**	AEU827MC
	Driver	**Name**	[redacted]	**ID No.**	[redacted]
		Address	[redacted]		
		Tel. no.	[redacted]	**Company**	Private
	Condition	**Mechanical**	Good		
		Tyre Name	Goodyear	**Re-Tread**	-
		Tread Depth	5.0	**Ply no.**	0.0
	Insurance	**Company**	Britam Seguros	**Tel. no.**	-
	Notes				

*** Vehicle responsible for damage claims**

2	**SUV**	Toyota Rav4	Gray	**Reg. No**	ACT804MC
	Driver	**Name**	[redacted]	**ID No.**	[redacted]
		Address	[redacted]		
		Tel. no.	[redacted]	**Company**	Private
	Condition	**Mechanical**	Good		
		Tyre Name	Gredtro	**Re-Tread**	-
		Tread Depth	6.0	**Ply no.**	0.0
	Insurance	**Company**	Global Alliance	**Tel. no.**	-
	Notes				

Total 2

Road Closure

Fast Lane was closed from 17 Dec 2018 10:57 to 17 Dec 2018 12:00

No alternative route was used

Photos

Accident Detail

Accident Number: EK--2018-12-099

TRANS AFRICAN CONCESSIONS

Location, Time and Description of Incident

Location	EN4/2 E km 43.8	**TRAC Assist**	No
Date	22 December 2018 at 04h55	**Cleared**	22 December 2018 at 06h10
Nature	Accident		
Type	Head-Side	**Possible Causes**	Drugs/Alcohol
Weather	Mist	**Visibility**	Poor Daylight
Description	Driver of a Toyota Run X did not give way to a Toyota Hiace therefore causing it to collide head side on east side.		

Injuries in Accident

Serious	1
Slight	2

Vehicles in Accident

1	**Heavy**	Toyota ace		Gray	**Reg. No**	AEN099MC
	Driver	**Name**	[redacted]		**ID No.**	[redacted]
		Address	[redacted]			
		Tel. no.	[redacted]		**Company**	Private
	Condition	**Mechanical**	Poor			
		Tyre Name	Mixed		**Re-Tread**	-
		Tread Depth	7.0		**Ply no.**	0.0
	Insurance	**Company**	-		**Tel. no.**	-
	Notes					
2	**Sedan**	Toyota Run X		Gray	**Reg. No**	ADQ663MC
	Driver	**Name**	[redacted]		**ID No.**	[redacted]
		Address	[redacted]			
		Tel. no.	[redacted]		**Company**	Private
	Condition	**Mechanical**	Poor			
		Tyre Name	Mixed		**Re-Tread**	-
		Tread Depth	6.0		**Ply no.**	0.0
	Insurance	**Company**	Indico Seguros		**Tel. no.**	-
	Notes					

*** Vehicle responsible for damage claims**

Total	**2**

Road Closure

Fast Lane was closed from 22 Dec 2018 05:10 to 22 Dec 2018 06:10

No alternative route was used

Photos



Addendum C: Survey Questionnaire

Confidential

ELECTRONIC CONSENT TO PARTICIPATE IN RESEARCH

SURVEY INSTRUCTIONS

1. Please read the following survey consent form.
2. Kindly choose a declaration option and sign the form.
3. Continue to the next page and certify the declaration as correct.
4. Please submit the form and continue to the survey.

THANK YOU!

DECLARATION BY THE PARTICIPANT (Please choose an option in order to continue)

As the participant I hereby select the following option:

○ I accept the invitation to participate in your research project, and if I decide to complete the questionnaire it would automatically mean that I have given consent for my responses to be used confidentially and anonymously.
○ I decline the invitation to participate in your research project.

Note: Confidentiality agreement allows X as a substitute for a signature.

Signature (sign with finger or mouse) ______________________________

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Confidential

DRIVING BEHAVIOUR QUESTIONNAIRE

The purpose of this study is to collect information about the perception that drivers have on road safety and to investigate the relationship between Road Traffic Crashes and the human factors involved.

Please complete the following questionnaire by either ticking one of the boxes or writing in the space provided.

The questionnaire will take approximately 10 minutes to complete.

SECTION 1: DRIVING HISTORY AND GENERAL PERCEPTIONS	
Are you male or female?	◯ Male ◯ Female
How old are you?	◯ 18-30 years old ◯ 31-64 years old ◯ 64 years and older
Do you currently have a valid driver's licence?	◯ Yes ◯ No
How long have you held a driver's license?	◯ 0-12 months ◯ 1-3 years ◯ 3-5 years ◯ 5-10 years ◯ More than 10 years
Approximately how many kilometres do you drive per year?	◯ Less than 5 000 km ◯ Between 5 000 km - 15 000 km ◯ More than 15 000 km
Have you ever been involved in a vehicle accident?	◯ Yes ◯ No
In your opinion, what was the main cause of the accident?	◯ Human (speeding, alcohol, mobile use, fatigue, negligent driving etc.) ◯ Vehicle (tyre burst, headlights, brakes etc.) ◯ Roadway (potholes, skidding, roadmarking, roadsigns etc.) ◯ Environmental (rain, mist, dust, etc.) ◯ Pedestrian ◯ Animal
How would you rate your driving ability?	◯ Poor ◯ Fair ◯ Good ◯ Very good ◯ Excellent
What is the biggest attribute that a good driver should possess?	◯ Patience ◯ Experience ◯ Attentiveness ◯ Law-abiding ◯ Other
Please state any other not listed above:	__________________________

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How often do you drive on the following roads?	Never	Rarely	Sometimes	Often	Always
Highways/Freeways	◯	◯	◯	◯	◯
Rural	◯	◯	◯	◯	◯
Urban/Residential	◯	◯	◯	◯	◯

How often do you drive at night on a highway/freeway?

- ◯ Never
- ◯ A few times per month, but not once a week
- ◯ At least 1-2 times per week
- ◯ Almost everyday

In your opinion, what contributes the most towards road safety?

- ◯ Human behaviour (Adhering to road laws and regulations, attentiveness etc.)
- ◯ Quality of vehicle (New vehicles, maintained vehicles etc.)
- ◯ Roadway aspects (Number of lanes, road markings and signs etc.)
- ◯ Environmental (Visibility, dry roadway etc.)

In your opinion, what contributes the most towards an unsafe road?

- ◯ Human behaviour (Speeding, reckless and negligent driving)
- ◯ Quality of vehicle (Old vehicles, poorly maintained vehicles etc.)
- ◯ Roadway aspects (Number of lanes, road markings and signs etc.)
- ◯ Environmental (Visibility, weather conditions etc.)

What kind of risky behaviour have you observed being made by other highway/freeway drivers?

- ◯ Speeding
- ◯ Distracted driving
- ◯ Illegal overtaking

SECTION 2: PERSONAL DRIVING BEHAVIOUR

Do you ever drive above the speed limit?

- ◯ Yes
- ◯ No

When you do find yourself speeding, how likely is it due to the following reasons? (If you do not speed, please answer the question according to which reasons would be most appealing to you.)

	Very unlikely	Unlikely	Likely	Very Likely
You don't know what the speed limit is	○	○	○	○
You are unaware of your speed	○	○	○	○
You enjoy speed	○	○	○	○
You know your own safe speed, which is higher than the speed limit	○	○	○	○
You are in a hurry	○	○	○	○
You believe that the speed you have chosen is appropriate for the driving conditions	○	○	○	○
You are confident in your ability to stop in time for unexpected conditions	○	○	○	○
You believe that there is no danger in exceeding the speed limit, especially when there is less traffic on the road	○	○	○	○
You don't think you will be detected by a speed camera	○	○	○	○
You don't think there are any police/traffic officers on the road	○	○	○	○

How often do you do each of the following on a freeway/highway?

	Never	Rarely	Sometimes	Often	Always
I choose a speed lower than the speed limit	○	○	○	○	○
I choose a speed higher than the speed limit	○	○	○	○	○
I make a call while driving, using my mobile phone, without a hands-free device	○	○	○	○	○
I make a call while driving, using my mobile phone, with a hands-free device	○	○	○	○	○
I send a text message while driving, using my mobile phone	○	○	○	○	○
I keep to a safe following distance	○	○	○	○	○
I would overtake a vehicle against a no-overtaking/barrier line, when I consider it to be safe	○	○	○	○	○
I do a vehicle inspection before the trip	○	○	○	○	○
I overtake slow moving vehicles travelling-in or making-way in the emergency lane (yellow-line)	○	○	○	○	○
I make use of the emergency lane (yellow-line) to allow other fast moving vehicles to overtake me	○	○	○	○	○
I would make use of the emergency lane (yellow-line) to change a flat tyre or in case of a vehicle breakdown	○	○	○	○	○
I use my seat-belt and child-restraint	○	○	○	○	○
I eat or drink while driving	○	○	○	○	○
I drive when I have consumed alcoholic beverages, but only when I think that I might still be within the legal blood-alcohol limit	○	○	○	○	○
I drive when I have consumed alcoholic beverages, even though I think that I might be just over the legal blood-alcohol limit	○	○	○	○	○

The following questions deal with your experience of feeling tired when driving on a highway/freeway. How often do you?

	Never	Rarely	Sometimes	Often	Always
Drive while you are tired	◯	◯	◯	◯	◯
Have fallen asleep or nodded off (even for a brief moment)	◯	◯	◯	◯	◯
Realise you have no clear recollection of the road along which you have just been travelling	◯	◯	◯	◯	◯
Have lapses of concentration or struggle to focus	◯	◯	◯	◯	◯
Struggle to keep your eyes open or to stay awake	◯	◯	◯	◯	◯

What do you do when you get tired?

◯ I continue driving and open a window / turn on the radio
◯ I search for a place to pull over and sleep
◯ I take medication or supplements and continue driving
◯ I get coffee or another caffeinated drink and continue driving
◯ I get out/ stretch/exercise
◯ I change drivers

The following questions deal with your experience with taking medication when driving on a highway/freeway. How often do you?

	Never	Rarely	Sometimes	Often	Always
I drive when I have taken some prescribed medication	◯	◯	◯	◯	◯
I drive when I have taken some over-the-counter medication	◯	◯	◯	◯	◯
I always read the side-effects of the medication when I know I am going to drive	◯	◯	◯	◯	◯
I drive when I believe the medication would not cause drowsiness, without reading the side-effects	◯	◯	◯	◯	◯
I believe prescription medication or over-the-counter medication would not have an effect on my driving ability	◯	◯	◯	◯	◯

Addendum D: Annual Crash Analysis Tables (2010 – 2018)

TRAFFIC DATA 2017-2018												
Nr	Site	Road Section	TOTAL Traffic data on N4 (2017)					TOTAL Traffic data on N4 (2018)				
	Number		Light	Heavy	Total	30th High	EVU,s	Light	Heavy	Total	30th High	EVU,s
1	9092	Hans Strijdom - Donkerhoek	20433	1017	21450	2468	23484	20303	994	21297	2464	23285
2	Plaza+4251	Donkerhoek - Cullinan	18584	1525	20109	2453	23159	18344	1521	19865	2225	22907
3	4251	Cullinan -Valtaki	14186	1425	15611	1905	18461	14096	1421	15517	1900	18359
4	Plaza+4251	Valtaki - Ekandustria	14400	1453	15853	1934	18759	14142	1427	15569	1909	18423
5	Work out %	Ekandustria - Bronhorsspruit West	12807	1238	14045	2036	16521	12401	1283	13684	1921	16250
6	4265	Bronhorsspruit East - Wilgerivier	15754	1684	17438	2061	20806	15290	1714	17004	1951	20432
7	4265	Wilgerivier - Balmorel	15754	1684	17438	2061	20806	15290	1714	17004	1952	20432
8	4283	Balmorel - Kromdraai	17331	2339	19670	2345	24348	17132	2149	19281	2218	23579
9	Work out %	Highveld - Clever	17331	2339	19670	2346	24348	17652	2556	20208	2484	25320
10	Work out %	Clever - Ferrobank	40881	2462	43343	3832	48267	41682	2691	44373	4059	49755
11	Work out %	Ferrobank - Walter Sisulu(Eadie)	39059	2737	41796	3566	47270	39896	2970	42867	3782	48808
12	Work out %	Walter Sisulu(Eadie) - O.R Tambo(Swartbos)	30040	2087	32127	2994	36301	30580	2272	32852	3182	37397
13	Work out %	O.R Tambo(Swartbos) - N12 Split	15907	1049	16956	1771	19054	16226	1202	17428	1889	19832
15	4252/3040/3041	Mandela Street(President) - Van Dyksdrift	21227	2950	24177	3069	30077	23010	3201	26211	2899	32613
16	9100	Van Dyksdift - Fontein Street	18822	4167	22989	2816	31323	18917	4864	23781	2855	33509
17	4255	Fontein Street - N11 Hendrina	17131	3173	20304	2651	26650	17605	4101	21706	2771	29908
18	Work out %	N11 Hendrina - Woestalleen	15907	2730	18637	2478	24097	15610	3941	19551	2584	27433
19	4284	Woestalleen- Arnot	15907	2730	18637	2478	24097	13641	2607	16248	2396	21462
20	4284	Arnot - Wonderfontein	13596	2575	16171	2156	21321	13641	2607	16248	2397	21462
21	3093	Wonderfontein - Belfast	11347	2354	13701	2018	18409	11700	2210	13910	2127	18330
22	9072	Belfast - Machadodorp	7992	2636	10628	1420	15900	8110	2678	10788	1533	16144
23	4253/3045	Machadodorp - Cross Roads	8137	2373	10510	1482	15256	8713	1906	10619	1518	14431
24	9022	Cross Roads - Lydenburg R36	5874	728	6602	990	8058	5353	516	5869	998	6901
25	4258	Lydenburg R36 - Montrose	5973	1408	7381	1039	10197	5490	1349	6839	1103	9537
26	9022/3049	Cross Roads - Sappi	2526	1329	3855	539	6513	3360	1390	4750	612	7530
27	Work out %	Sappi - Montrose	2804	1635	4439	551	7709	3462	1580	5042	622	8202
28	4277	Montrose - Nelspruit West Split	11740	2635	14375	1609	19645	11784	2722	14506	1652	19950
29	9101	Nelspruit West Split - R37 Sabie Int	4834	1692	6526	752	9910	4533	1904	6437	693	10245
30	9086	R37 Sabie Int -Valencia Int	3062	1887	4949	505	8723	2897	1866	4763	532	8495
31	9075	Valencia Int - Karino	10158	3107	13265	1568	19479	11256	3568	14824	1514	21960
32	3054	Karino - Matsulu	10147	2273	12420	1263	16966	10736	2486	13222	1330	18194
33	4254	Matsulu - Malelane	8382	2350	10732	1123	15432	8512	2499	11011	1135	16009
34	Work out %	Malelane - TSB Intersection	13304	2748	16052	2022	21548	13400	3050	16450	2056	22550
35	Work out %	TSB Intersection - Hectorspruit	5258	2175	7433	594	11783	5417	2095	7512	623	11702
36	3147	Hectorspruit - Komatipoort	3348	1713	5061	400	8487	3447	1538	4985	431	8061
37	1981	Komatipoort - Lebombo Border	3649	1641	5290	423	8572	4980	1486	6466	395	9438

Number of crashes per Annum	
Year	**South Africa**
2010	954
2011	878
2012	877
2013	1074
2014	974
2015	1002
2016	955
2017	1106
2018	1138

Monthly Crashes											
Month	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**TOTAL**	**Percentage**
January	83	71	58	87	69	76	64	87	85	**680**	**7.57%**
February	81	71	72	70	79	72	72	91	83	**691**	**7.69%**
March	84	75	91	89	79	71	91	72	125	**777**	**8.65%**
April	107	79	54	102	77	106	73	86	87	**771**	**8.58%**
May	83	45	52	80	63	70	87	92	83	**655**	**7.29%**
June	88	62	73	107	83	86	70	75	97	**741**	**8.25%**
July	55	83	64	68	75	60	72	94	89	**660**	**7.35%**
August	47	61	64	88	83	76	87	75	80	**661**	**7.36%**
September	63	55	78	99	81	67	64	86	102	**695**	**7.74%**
October	77	71	74	76	70	89	80	116	113	**766**	**8.53%**
November	76	72	79	95	84	95	106	96	83	**786**	**8.75%**
December	109	128	118	111	137	131	118	136	113	**1101**	**12.26%**
										TOTAL	**100.00%**

Annual Crash Severity by Time of Day

Severity	2010		2011		2012		2013		2014		2015		2016		2017		2018		TOTAL		Percentage	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Fatal	54	57	42	57	38	59	45	62	42	67	37	61	36	72	57	68	39	62	**390**	**565**	**40.84%**	**59.16%**
Serious injury	131	97	94	66	97	83	105	103	121	105	96	81	75	72	91	70	100	64	**910**	**741**	**55.12%**	**44.88%**
Slight injury	118	85	116	87	99	74	114	88	92	72	121	93	119	85	127	91	111	81	**1017**	**756**	**57.36%**	**42.64%**
Damage Only	241	173	224	178	237	190	312	244	265	216	274	231	319	206	356	255	404	279	**2632**	**1972**	**57.17%**	**42.83%**
TOTAL	**544**	**412**	**476**	**388**	**471**	**406**	**576**	**497**	**520**	**460**	**528**	**466**	**549**	**435**	**631**	**484**	**654**	**486**	**4949**	**4034**	**55.09%**	**44.91%**

	Annual Causes of Crashes (2010-2018)												
	Causes of Crashes	2010	2011	2012	2013	2014	2015	2016	2017	2018	TOTAL	Percentage	TOTAL	Percentage
Human Factors	Lost control	151	176	220	379	400	231	328	511	452	2848	22.17%	9354	72.8%
	Negligent driving	132	214	207	314	276	308	362	430	544	2787	21.69%		
	Sleeping	109	101	93	124	117	105	74	67	51	841	6.55%		
	Speed differential (rear-end)	116	101	69	99	61	131	106	112	129	924	7.19%		
	Overtaking	26	41	65	81	73	67	65	47	83	548	4.27%		
	Pedestrian	21	18	39	40	43	42	44	65	48	360	2.80%		
	U-Turn	27	31	31	35	28	32	39	34	29	286	2.23%		
	Drugs/Alcohol	16	21	25	22	34	24	30	26	15	213	1.66%		
	Wrong direction of travel	6	16	41	17	13	12	21	25	19	170	1.32%		
	Accident on stop-controlled approach	11	17	12	12	6	21	24	31	26	160	1.25%		
	Accident on uncontrolled approach to junction	11	6	12	21	7	3	3	3	3	69	0.54%		
	Accident on traffic signal controlled approach	13	7	9	8	7	5	3	4	7	63	0.49%		
	Medical problem	10	2	3	10	4	9	9	3	4	54	0.42%		
	Reversing vehicles	1	0	2	4	1	2	4	1	8	23	0.18%		
	Cyclist	3	1	2	0	0	1	0	1	0	8	0.06%		
Vehicle Factors	Tyre burst – Vehicle	142	114	125	109	104	100	97	68	62	921	7.17%	2071	16.1%
	Mechanical – vehicle	29	23	38	28	24	32	35	40	29	278	2.16%		
	Brake failure	12	13	13	22	20	17	11	27	22	157	1.22%		
	Trailer sway	10	9	9	13	14	27	18	21	20	141	1.10%		
	Towing of vehicles involved	14	17	16	22	9	21	6	7	19	131	1.02%		
	Mechanical – trailer	10	6	17	20	11	14	16	16	14	124	0.97%		
	Vehicle sway	7	10	11	6	8	12	22	20	15	111	0.86%		
	Tyre burst – Trailer	14	16	9	18	17	13	15	5	4	111	0.86%		
	Load loss	11	10	7	9	18	5	8	14	15	97	0.75%		
Roadway Factors	Construction/Maintenance site	2	3	6	24	16	29	65	63	31	239	1.86%	1113	8.7%
	Parked and stationary vehicles	21	18	13	17	25	32	39	37	33	235	1.83%		
	Poor Visibility	9	33	32	48	24	23	22	23	20	234	1.82%		
	Skidding	24	8	12	18	30	15	32	23	0	162	1.26%		
	Animal – Domestic	8	10	3	8	5	14	14	10	16	88	0.68%		
	Object on road	5	7	4	4	6	7	9	9	9	60	0.47%		
	Animal – Wild	3	6	7	5	5	11	7	5	8	57	0.44%		
	Edge drop-off	16	0	0	0	0	0	2	0	1	19	0.15%		
	Previous accident	2	2	1	1	2	0	2	0	0	10	0.08%		
	Public transport stop	2	0	0	0	0	0	1	0	2	5	0.04%		
	Gravel shoulder	3	0	0	0	0	0	1	0	0	4	0.03%		
	Other/Unknown	17	9	17	35	36	44	37	47	68	310	2.41%	310	2.4%

Annual Percentage of Crashes per Weather Condition (2010-2018)										
Weather	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Percentages**
Clear	78%	81%	84%	85%	86%	84%	85%	81%	86%	83%
Mist	3%	2.5%	2%	2%	1%	2%	1%	1%	1%	2%
Rain	18%	15.5%	13%	12%	12%	12%	14%	17%	11%	14%
Special (hail)	0%	0.5%	0%	0%	0%	0%	0%	0%	0.6%	0%
Wind	1%	0.5%	1%	1%	1%	2%	0%	1%	1%	1%
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	

	Number of Crashes per Vehicle type per Annum									
Vehicle type	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**TOTAL**	**Percentage**
Passenger	688	563	605	766	666	705	678	736	772	6179	44.24%
LDV	397	357	369	494	399	466	420	466	469	3837	27.47%
Heavy	260	235	214	318	281	233	251	302	293	2387	17.09%
Minibus	158	148	119	138	130	132	142	128	151	1246	8.92%
Bus	17	16	16	15	21	11	15	15	13	139	1.00%
Motorcycle	9	6	6	10	6	13	7	8	6	71	0.51%
Other	4	3	2	5	5	4	20	3	10	56	0.40%
Tanker	0	3	3	7	0	9	1	7	22	52	0.37%
										TOTAL	**100.00%**

	Number of Crashes per Type per Annum										
Accident type	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**TOTAL**	**Percentage**
Single vehicle	504	480	491	531	504	545	495	621	624	4795	53.59%
Head-tail	198	176	145	239	210	181	177	185	199	1710	19.11%
Head-side	118	101	95	114	95	80	84	97	97	881	9.85%
Sideswipe	53	51	62	70	58	61	71	66	78	570	6.37%
Multiple pile up	48	34	39	59	53	86	72	78	86	555	6.20%
Head-on	28	28	35	39	30	26	32	31	28	277	3.10%
Unknown/other	4	5	9	14	14	16	20	8	16	106	1.18%
Hit and Run	1	1	0	0	10	7	4	20	10	53	0.59%
										TOTAL	**100.00%**

Road Section and Description		Region	Road Length (km)	Crash rate									Average Crash rate
				2010	2011	2012	2013	2014	2015	2016	2017	2018	2010 to 2018
1g	N4-1 km 21.3 - km 25.59	Gauteng	4.29	0.099	0.062	0.145	0.095	0.032	0.060	0.090	0.089	0.240	0.101
2a	N4/2 km 0.00 to N4/2 km 2.90	Gauteng	2.90	0.049	0.091	0.299	0.327	0.190	0.089	0.530	0.176	0.266	0.224
2b	N4/2 km 2.90 to N4/2 km 21.98	Gauteng	19.08	0.360	0.222	0.318	0.506	0.351	0.357	0.203	0.236	0.195	0.305
2c	N4/2 km 21.98 to N4/2 km 30.08	Gauteng	8.10	0.413	0.418	0.243	0.439	0.343	0.360	0.222	0.202	0.204	0.316
2d	N4/2 km 30.08 to N4/2 km 35.40	Gauteng	5.32	0.300	0.483	0.276	0.553	0.301	0.474	0.405	0.220	0.263	0.364
2e	N4/2 km 35.40 to N4/2 km 47.0	Gauteng	11.60	0.577	0.430	0.463	0.460	0.363	0.351	0.342	0.298	0.306	0.399
2f	N4/2 km47.0 to N4/2 km 55.0	Gauteng	8.00	0.326	0.282	0.395	0.337	0.397	0.283	0.357	0.275	0.342	0.333
1	N4/3 km 0.0 to N4/3 km 19.6	Highveld	19.60	0.321	0.224	0.244	0.216	0.237	0.173	0.178	0.178	0.200	0.219
2	N4/3 km 14.5 to N4/3 km 30.2	Highveld	15.70	0.304	0.271	0.303	0.237	0.447	0.385	0.135	0.382	0.385	0.317
3	N4/3 km 30.2 to km 41.76 to N4/4 km 6.60	Highveld	18.16	0.340	0.237	0.169	0.169	0.356	0.350	0.301	0.507	0.544	0.330
4a	N4/4 km 6.60 to N4/4 km 9.60	Highveld	3.00	0.315	0.240	0.478	0.478	0.357	0.586	0.507	0.477	0.538	0.442
4b	N4/4 km 9.6 to N4/4 km 19.50	Highveld	9.90	0.433	0.471	0.336	0.336	0.307	0.407	0.351	0.450	0.395	0.387
4c	N4/4 km 19.50 to N4/4 km 34.0	Highveld	14.50	0.528	0.456	0.478	0.478	**0.616**	0.566	0.527	0.261	0.339	0.472
4d	N4/4 km 34.0 to km 47.55 to N4/5 km 9.90	Highveld	23.45	0.503	0.464	0.348	0.348	0.572	0.593	0.454	0.35	0.424	0.451
5a	N4/5 km 9.90 to N4/5X km 29.4	Highveld	19.50	0.365	0.325	0.319	0.319	0.385	0.455	0.484	0.451	0.364	0.385
5b	N4/5X km 29.4 to km 56.8 to N4/6X km 2.70	Highveld	30.10	**0.724**	**0.613**	**0.861**	**0.861**	0.483	**0.711**	**0.713**	**0.754**	**0.852**	**0.730**
6E	N4/6X km 2.70 to km 43.32 to N4/7X km 22.70	Lowveld	63.32	0.388	0.485	0.404	0.404	**0.698**	**0.615**	**0.826**	**1.07**	**0.776**	**0.630**
6N	N4/6Y km 0.0 to km N4/6Y km 63.72	Lowveld	63.72	0.533	0.443	0.327	0.327	0.523	0.520	**0.734**	**0.840**	**0.823**	0.563
7a	N4/7X km 22.70 to N4/7X km 36.50	Lowveld	13.80	0.448	0.535	**0.714**	**0.600**	**0.633**	0.485	0.392	0.539	0.534	0.542
7b i	N4/7X km 36.50 to N4/7X km 46	Lowveld	9.50	0.412	0.333	0.259	**0.705**	**0.808**	**0.825**	0.590	**0.682**	0.417	0.559
8f ii	N4/7X km 64.8 to N4/7X km 65.60	Lowveld	0.80	0.501	0.509	0.479	**1.226**	**0.737**	0.166	**1.153**	**0.861**	**0.616**	**0.694**
8BP	N4/7 km 46.0 to N4/7 km 64.8	Lowveld	18.80	**1.178**	0.538	0.266	0.300	0.209	0.462	0.597	0.241	0.410	0.467
9	N4/7X km 65.60 to N4/7X km 74.1	Lowveld	8.50	0.371	0.399	0.406	0.595	**0.806**	**0.774**	**0.618**	**0.778**	**0.731**	**0.609**
10	N4/7X km 74.1 to N4/7X km 90.05	Lowveld	15.95	**0.889**	0.537	0.565	**1.202**	**0.762**	**0.603**	0.425	0.570	0.455	**0.668**
11	N4/8X km 0.0 to N4/8X km 4.90	Lowveld	4.90	0.374	0.511	0.302	0.477	**0.625**	**0.665**	**0.646**	**1.250**	**1.574**	**0.714**
12	N4/8X km 4.90 to N4/8X km 14.60	Lowveld	9.70	0.41	0.240	0.322	0.565	0.438	0.392	0.490	0.395	0.564	0.424
13	N4/8X km 14.60 to N4/8X km 26.90	Lowveld	12.30	**0.631**	**0.700**	0.469	0.412	0.309	0.361	0.407	0.472	**0.663**	0.492
14	N4/8X km 26.9 to N4/8X km 39.10	Lowveld	12.20	0.433	0.361	0.311	**0.700**	0.470	0.464	0.570	0.695	0.419	0.491
15a	N4/8X km 39.10 to N4/8X km 69.10	Lowveld	30.00	0.529	**0.626**	0.369	0.562	0.461	0.564	0.570	**1.329**	**0.623**	**0.626**
15b	N4/8X km 69.10 to N4/8X km 70.63	Lowveld	1.53	0.000	0.315	**1.207**	**1.102**	0.301	**0.650**	0.000	0.339	**0.718**	0.515

Addendum E: Association Rules - Statistica

Summary of association rules (Spreadsheet1)
Min. support = 1.0%, Min. confidence = 1.0%, Min. correlation = 1.0%
Max. size of body = 2, Max. size of head = 1

Rule	Body	==>	Head	Support (%)	Confidence (%)	Correlation (%)	Lift
152	Injury - Fatal count == YES	==>	Accident Type == Head-on	1.73	14.69	25.64	8.503
153	Injury - Fatal count == YES	==>	Accident Type == Head-Side	1.86	15.78	14.87	8.503
154	Injury - Fatal count == YES	==>	Accident Type == Head-tail	1.30	11.09	8.22	8.503
155	Injury - Fatal count == YES	==>	Accident Type == Multiple pile-up	1.19	10.16	13.16	8.503
156	Injury - Fatal count == YES	==>	Accident Type == Single vehicle	5.09	43.28	21.86	8.503
164	Injury - Fatal count == YES	==>	Lost control	1.98	16.88	12.12	8.503
165	Injury - Fatal count == YES	==>	Negligent driving	1.91	16.25	11.53	8.503
166	Injury - Fatal count == YES	==>	Overtaking	1.19	10.16	11.62	8.503
167	Injury - Fatal count == YES	==>	Pedestrian/Cyclist	2.72	23.13	40.66	8.503
168	Injury - Fatal count == YES	==>	Sleeping	1.23	10.47	10.71	8.503
216	Injury - Serious count == YES	==>	Accident Type == Head-on	2.32	9.25	23.56	3.996
217	Injury - Serious count == YES	==>	Accident Type == Head-Side	4.36	17.40	23.92	3.996
218	Injury - Serious count == YES	==>	Accident Type == Head-tail	4.37	17.47	18.88	3.996
219	Injury - Serious count == YES	==>	Accident Type == Multiple pile-up	2.59	10.35	19.57	3.996
220	Injury - Serious count == YES	==>	Accident Type == Sideswipe	2.43	9.69	16.84	3.996
221	Injury - Serious count == YES	==>	Accident Type == Single vehicle	8.97	35.83	26.40	3.996
222	Injury - Serious count == YES	==>	Injury - Fatal count == NO	19.92	79.59	42.39	3.996
223	Injury - Serious count == YES	==>	Injury - Fatal count == YES	5.11	20.41	29.78	3.996
224	Injury - Serious count == YES	==>	Injury - Slight count == YES	11.76	46.99	40.92	3.996
225	Injury - Serious count == YES	==>	Injury - Slight count == NO	13.27	53.01	32.40	3.996
227	Injury - Serious count == YES	==>	Accident - Road Section Detail == 6E	2.02	8.08	14.00	3.996
228	Injury - Serious count == YES	==>	Accident - Road Section Detail == 5B	1.58	6.31	11.57	3.996
229	Injury - Serious count == YES	==>	Accident - Road Section Detail == 15A	1.19	4.77	12.71	3.996
232	Injury - Serious count == YES	==>	Accident - Road Section Detail == 6N	1.76	7.05	13.36	3.996
234	Injury - Serious count == YES	==>	Accident - Road Section Detail == 10	1.47	5.87	12.84	3.996
239	Injury - Serious count == YES	==>	Crash at Intersection	1.23	4.92	11.15	3.996
240	Injury - Serious count == YES	==>	Lost control	4.89	19.53	20.47	3.996
241	Injury - Serious count == YES	==>	Negligent driving	5.64	22.54	23.32	3.996
242	Injury - Serious count == YES	==>	Overtaking	3.31	13.22	22.06	3.996
243	Injury - Serious count == YES	==>	Sleeping	2.92	11.67	17.42	3.996
244	Injury - Serious count == YES	==>	Speed differential (rear-end)	2.81	11.23	15.42	3.996
245	Injury - Serious count == YES	==>	U-Turn / Reversing vehicles	1.56	6.24	13.94	3.996
246	Injury - Slight count == YES	==>	Accident Type == Head-on	1.75	5.29	15.47	3.030
247	Injury - Slight count == YES	==>	Accident Type == Head-Side	5.16	15.65	24.69	3.030
248	Injury - Slight count == YES	==>	Accident Type == Head-tail	6.96	21.10	26.18	3.030
249	Injury - Slight count == YES	==>	Accident Type == Multiple pile-up	3.20	9.69	21.03	3.030
250	Injury - Slight count == YES	==>	Accident Type == Sideswipe	2.81	8.52	17.00	3.030
251	Injury - Slight count == YES	==>	Accident Type == Single vehicle	13.10	39.70	33.59	3.030
258	Injury - Slight count == YES	==>	Accident - Road Section Detail == 6E	2.52	7.63	15.19	3.030
259	Injury - Slight count == YES	==>	Accident - Road Section Detail == 5B	2.19	6.63	13.94	3.030
260	Injury - Slight count == YES	==>	Accident - Road Section Detail == 15A	1.29	3.90	11.92	3.030
265	Injury - Slight count == YES	==>	Accident - Road Section Detail == 6N	2.57	7.80	16.97	3.030
267	Injury - Slight count == YES	==>	Accident - Road Section Detail == 10	1.71	5.18	13.00	3.030
274	Injury - Slight count == YES	==>	Crash at Intersection	1.41	4.29	11.16	3.030
275	Injury - Slight count == YES	==>	Drugs/Alcohol	1.16	3.51	11.21	3.030
276	Injury - Slight count == YES	==>	Lost control	6.95	21.05	25.33	3.030
277	Injury - Slight count == YES	==>	Negligent driving	7.68	23.27	27.66	3.030
278	Injury - Slight count == YES	==>	Overtaking	3.18	9.63	18.46	3.030
279	Injury - Slight count == YES	==>	Sleeping	4.52	13.70	23.46	3.030
280	Injury - Slight count == YES	==>	Speed differential (rear-end)	4.63	14.03	22.11	3.030
281	Injury - Slight count == YES	==>	U-Turn / Reversing vehicles	1.71	5.18	13.28	3.030
605	Crash at Intersection	==>	Accident Type == Head-Side	2.57	52.83	32.03	20.536
606	Crash at Intersection	==>	Accident Type == Single vehicle	1.01	20.75	6.75	20.536
607	Crash at Intersection	==>	Injury - Fatal count == NO	4.58	93.96	22.07	20.536
608	Crash at Intersection	==>	Injury - Serious count == NO	3.64	74.72	19.04	20.536
609	Crash at Intersection	==>	Injury - Serious count == YES	1.23	25.28	11.15	20.536
610	Crash at Intersection	==>	Injury - Slight count == YES	1.41	29.06	11.16	20.536
611	Crash at Intersection	==>	Injury - Slight count == NO	3.45	70.94	19.13	20.536
614	Drugs/Alcohol	==>	Accident Type == Single vehicle	1.80	55.68	14.75	30.920
615	Drugs/Alcohol	==>	Injury - Fatal count == NO	2.87	88.64	16.97	30.921
616	Drugs/Alcohol	==>	Injury - Serious count == NO	2.46	76.14	15.81	30.920
617	Drugs/Alcohol	==>	Injury - Slight count == YES	1.16	35.80	11.21	30.921
618	Drugs/Alcohol	==>	Injury - Slight count == NO	2.08	64.20	14.11	30.920
621	Lost control	==>	Accident Type == Single vehicle	18.82	82.58	58.05	4.389
622	Lost control	==>	Injury - Fatal count == NO	20.80	91.29	46.39	4.389
623	Lost control	==>	Injury - Fatal count == YES	1.98	8.71	12.12	4.389
624	Lost control	==>	Injury - Serious count == NO	17.90	78.55	43.30	4.389
625	Lost control	==>	Injury - Serious count == YES	4.89	21.45	20.47	4.389
626	Lost control	==>	Injury - Slight count == YES	6.95	30.48	25.33	4.389
627	Lost control	==>	Injury - Slight count == NO	15.84	69.52	40.54	4.389
629	Lost control	==>	Accident - Road Section Detail == 6E	1.62	7.10	11.74	4.389
630	Lost control	==>	Accident - Road Section Detail == 5B	1.93	8.47	14.80	4.389
633	Lost control	==>	Accident - Road Section Detail == 6N	1.76	7.74	14.00	4.389
639	Negligent driving	==>	Accident Type == Head-Side	3.71	15.88	21.09	4.278
640	Negligent driving	==>	Accident Type == Head-tail	6.50	27.83	29.06	4.278
641	Negligent driving	==>	Accident Type == Multiple pile-up	2.08	8.88	16.23	4.278
642	Negligent driving	==>	Accident Type == Sideswipe	2.65	11.32	19.01	4.278
643	Negligent driving	==>	Accident Type == Single vehicle	7.66	32.78	23.34	4.278
644	Negligent driving	==>	Injury - Fatal count == NO	21.46	91.82	47.26	4.278
645	Negligent driving	==>	Injury - Fatal count == YES	1.91	8.18	11.53	4.278
646	Negligent driving	==>	Injury - Serious count == NO	17.73	75.86	42.36	4.278
647	Negligent driving	==>	Injury - Serious count == YES	5.64	24.14	23.32	4.278

648	Negligent driving	==>	Injury - Slight count == YES	7.68	32.86	27.66	4.278
649	Negligent driving	==>	Injury - Slight count == NO	15.69	67.14	39.66	4.278
651	Negligent driving	==>	Accident - Road Section Detail == 6E	1.40	5.97	10.01	4.278
653	Negligent driving	==>	Accident - Road Section Detail == 5B	1.56	6.68	11.83	4.278
656	Negligent driving	==>	Accident - Road Section Detail == 6N	1.97	8.41	15.41	4.278
658	Negligent driving	==>	Accident - Road Section Detail == 10	1.71	7.31	15.45	4.278
663	Overtaking	==>	Accident Type == Head-on	1.05	11.66	17.79	11.129
664	Overtaking	==>	Accident Type == Head-Side	1.38	15.34	12.63	11.129
665	Overtaking	==>	Accident Type == Sideswipe	2.63	29.24	30.45	11.129
666	Overtaking	==>	Accident Type == Single vehicle	2.00	22.29	9.84	11.129
667	Overtaking	==>	Injury - Fatal count == NO	7.79	86.71	27.67	11.129
668	Overtaking	==>	Injury - Fatal count == YES	1.19	13.29	11.62	11.129
669	Overtaking	==>	Injury - Serious count == NO	5.68	63.19	21.88	11.129
670	Overtaking	==>	Injury - Serious count == YES	3.31	36.81	22.06	11.129
671	Overtaking	==>	Injury - Slight count == YES	3.18	35.38	18.46	11.129
672	Overtaking	==>	Injury - Slight count == NO	5.81	64.62	23.67	11.129
673	Overtaking	==>	Accident - Road Section Detail == 6E	1.36	15.13	15.72	11.129
674	Overtaking	==>	Accident - Road Section Detail == 10	1.12	12.47	16.34	11.129
677	Pedestrian/Cyclist	==>	Accident Type == Single vehicle	3.53	92.75	26.64	26.290
678	Pedestrian/Cyclist	==>	Injury - Fatal count == NO	1.08	28.50	5.92	26.290
679	Pedestrian/Cyclist	==>	Injury - Fatal count == YES	2.72	71.50	40.66	26.290
680	Pedestrian/Cyclist	==>	Injury - Serious count == NO	2.96	77.78	17.52	26.290
681	Pedestrian/Cyclist	==>	Injury - Slight count == NO	3.33	87.44	20.83	26.290
684	Sleeping	==>	Accident Type == Head-tail	1.40	12.42	8.99	8.892
685	Sleeping	==>	Accident Type == Single vehicle	8.25	73.37	36.23	8.892
686	Sleeping	==>	Injury - Fatal count == NO	10.01	89.05	31.79	8.892
687	Sleeping	==>	Injury - Fatal count == YES	1.23	10.95	10.71	8.892
688	Sleeping	==>	Injury - Serious count == NO	8.32	74.02	28.67	8.892
689	Sleeping	==>	Injury - Serious count == YES	2.92	25.98	17.42	8.892
690	Sleeping	==>	Injury - Slight count == YES	4.52	40.20	23.46	8.892
691	Sleeping	==>	Injury - Slight count == NO	6.73	59.80	24.50	8.892
692	Sleeping	==>	Accident - Road Section Detail == 6E	1.34	11.93	13.86	8.892
695	Speed differential (rear-end)	==>	Accident Type == Head-tail	9.17	69.02	54.32	7.527
696	Speed differential (rear-end)	==>	Accident Type == Multiple pile-up	1.69	12.72	17.53	7.527
697	Speed differential (rear-end)	==>	Accident Type == Single vehicle	1.47	11.07	5.94	7.527
698	Speed differential (rear-end)	==>	Injury - Fatal count == NO	12.42	93.50	36.28	7.527
699	Speed differential (rear-end)	==>	Injury - Serious count == NO	10.47	78.84	33.19	7.527
700	Speed differential (rear-end)	==>	Injury - Serious count == YES	2.81	21.16	15.42	7.527
701	Speed differential (rear-end)	==>	Injury - Slight count == YES	4.63	34.85	22.11	7.527
702	Speed differential (rear-end)	==>	Injury - Slight count == NO	8.65	65.15	29.01	7.527
703	Speed differential (rear-end)	==>	Accident - Road Section Detail == 6E	1.16	8.71	11.01	7.527
704	Speed differential (rear-end)	==>	Accident - Road Section Detail == 5B	1.16	8.71	11.63	7.527
709	U-Turn / Reversing vehicles	==>	Accident Type == Head-Side	2.59	51.65	31.78	19.934
710	U-Turn / Reversing vehicles	==>	Injury - Fatal count == NO	4.43	88.28	21.05	19.934
711	U-Turn / Reversing vehicles	==>	Injury - Serious count == NO	3.45	68.86	17.81	19.934
712	U-Turn / Reversing vehicles	==>	Injury - Serious count == YES	1.56	31.14	13.94	19.934
713	U-Turn / Reversing vehicles	==>	Injury - Slight count == YES	1.71	34.07	13.28	19.934
714	U-Turn / Reversing vehicles	==>	Injury - Slight count == NO	3.31	65.93	18.04	19.934
717	Wrong direction of travel	==>	Injury - Fatal count == NO	1.73	76.42	12.23	44.244
718	Wrong direction of travel	==>	Injury - Serious count == NO	1.47	65.04	11.29	44.244
719	Wrong direction of travel	==>	Injury - Slight count == NO	1.40	61.79	11.35	44.244
1738	Injury - Fatal count == YES, Injury - Serious count == NO	==>	Accident Type == Single vehicle	3.80	57.18	21.72	15.033
1743	Injury - Fatal count == YES, Injury - Serious count == NO	==>	Pedestrian/Cyclist	2.57	38.67	51.14	15.033
1744	Injury - Fatal count == YES, Injury - Serious count == YES	==>	Accident Type == Head-on	1.10	21.58	24.83	19.575
1745	Injury - Fatal count == YES, Injury - Serious count == YES	==>	Accident Type == Single vehicle	1.29	25.18	8.38	19.576
1750	Injury - Fatal count == YES, Injury - Serious count == YES	==>	Lost control	1.23	24.10	11.41	19.575
1751	Injury - Fatal count == YES, Injury - Slight count == YES	==>	Accident Type == Single vehicle	1.07	27.36	7.95	25.670
1755	Injury - Fatal count == YES, Injury - Slight count == NO	==>	Accident Type == Head-on	1.12	14.25	20.35	12.715
1756	Injury - Fatal count == YES, Injury - Slight count == NO	==>	Accident Type == Head-Side	1.08	13.79	10.62	12.715
1757	Injury - Fatal count == YES, Injury - Slight count == NO	==>	Accident Type == Single vehicle	4.02	51.17	21.13	12.715
1762	Injury - Fatal count == YES, Injury - Slight count == NO	==>	Lost control	1.19	15.19	8.92	12.715
1763	Injury - Fatal count == YES, Injury - Slight count == NO	==>	Negligent driving	1.21	15.42	8.94	12.715
1764	Injury - Fatal count == YES, Injury - Slight count == NO	==>	Pedestrian/Cyclist	2.50	31.78	45.69	12.715
1779	Injury - Fatal count == YES, Lost control	==>	Accident Type == Single vehicle	1.03	51.85	10.76	50.389
1785	Injury - Fatal count == YES, Pedestrian/Cyclist	==>	Accident Type == Single vehicle	2.54	93.24	22.65	36.770
2114	Injury - Serious count == YES, Injury - Slight count == YES	==>	Accident Type == Head-on	1.21	10.31	18.00	8.503
2115	Injury - Serious count == YES, Injury - Slight count == YES	==>	Accident Type == Head-Side	2.28	19.38	18.25	8.503
2116	Injury - Serious count == YES, Injury - Slight count == YES	==>	Accident Type == Head-tail	2.09	17.81	13.19	8.503
2117	Injury - Serious count == YES, Injury - Slight count == YES	==>	Accident Type == Multiple pile-up	1.60	13.59	17.62	8.503
2118	Injury - Serious count == YES, Injury - Slight count == YES	==>	Accident Type == Sideswipe	1.29	10.94	13.03	8.503
2119	Injury - Serious count == YES, Injury - Slight count == YES	==>	Accident Type == Single vehicle	3.29	27.97	14.13	8.503
2122	Injury - Serious count == YES, Injury - Slight count == YES	==>	Accident - Road Section Detail == 6E	1.07	9.06	10.77	8.503
2125	Injury - Serious count == YES, Injury - Slight count == YES	==>	Lost control	2.21	18.75	13.47	8.503
2126	Injury - Serious count == YES, Injury - Slight count == YES	==>	Negligent driving	2.77	23.59	16.74	8.503
2127	Injury - Serious count == YES, Injury - Slight count == YES	==>	Overtaking	1.65	14.06	16.09	8.503
2128	Injury - Serious count == YES, Injury - Slight count == YES	==>	Sleeping	1.23	10.47	10.71	8.503
2129	Injury - Serious count == YES, Injury - Slight count == YES	==>	Speed differential (rear-end)	1.54	13.13	12.35	8.503
2130	Injury - Serious count == YES, Injury - Slight count == NO	==>	Accident Type == Head-on	1.10	8.31	15.41	7.537
2131	Injury - Serious count == YES, Injury - Slight count == NO	==>	Accident Type == Head-Side	2.08	15.65	15.66	7.537
2132	Injury - Serious count == YES, Injury - Slight count == NO	==>	Accident Type == Head-tail	2.28	17.17	13.51	7.537
2133	Injury - Serious count == YES, Injury - Slight count == NO	==>	Accident Type == Sideswipe	1.14	8.59	10.87	7.537
2134	Injury - Serious count == YES, Injury - Slight count == NO	==>	Accident Type == Single vehicle	5.68	42.80	22.96	7.537
2140	Injury - Serious count == YES, Injury - Slight count == NO	==>	Lost control	2.68	20.22	15.43	7.537
2141	Injury - Serious count == YES, Injury - Slight count == NO	==>	Negligent driving	2.87	21.61	16.28	7.537
2142	Injury - Serious count == YES, Injury - Slight count == NO	==>	Overtaking	1.65	12.47	15.15	7.537
2143	Injury - Serious count == YES, Injury - Slight count == NO	==>	Sleeping	1.69	12.74	13.84	7.537

2144	Injury - Serious count == YES, Injury - Slight count == NO	==>	Speed differential (rear-end)	1.27	9.56	9.55	7.537
2190	Injury - Serious count == YES, Lost control	==>	Accident Type == Single vehicle	3.49	71.43	23.26	20.459
2197	Injury - Serious count == YES, Negligent driving	==>	Accident Type == Head-Side	1.12	19.87	12.97	17.726
2198	Injury - Serious count == YES, Negligent driving	==>	Accident Type == Head-tail	1.36	24.10	12.36	17.726
2199	Injury - Serious count == YES, Negligent driving	==>	Accident Type == Single vehicle	1.36	24.10	8.43	17.726
2210	Injury - Serious count == YES, Sleeping	==>	Accident Type == Single vehicle	1.64	55.97	14.09	34.226
2216	Injury - Serious count == YES, Speed differential (rear-end)	==>	Accident Type == Head-tail	1.71	60.78	22.01	35.569