Maintenance engineering standards to fulfil the legal duty of road authorities towards safe roads

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Declaration

By submitting this thesis electronically, I, Louis de Villiers Roodt, declare that the entirety of the work contained therein is my own work, that I am the authorship owner (unless to the extent explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

March 2016

Abstract

The road network is a mode of communication that is important for the movement of people and the distribution of goods. Ownership of roads is vested in public entities. The provision of roads follows need, but is influenced by policy and funding from the public purse. The supply of roads infrastructure is therefore discretionary. The maintenance of roads is subject to operational needs, safety requirements and treasury guidelines on asset management. Maintenance of road assets, in particular safety-related maintenance, may be mandatory to meet accepted engineering standards and the expectations of communities.

South Africa has a poor road safety record. Deaths per annum resulting from motor vehicle accidents peaked in 2006 at over 15 000 and stabilised at around 13 800 from 2008 to 2012. The road conditions, in particular failures, play a role in many of the accidents. Most road failures result from inadequate maintenance.

The legal duty to ensure that roads are reasonably safe to use has been confirmed in legislation, policy and case law. Failure to perform this legal duty may lead to damages, for which the road authority will be liable in delict. For a case to succeed, the elements of delict must be satisfied. An act or omission that caused the damages must exist and it must be proven that the road authority was at fault. If the act was wrongful and the road authority acting through its employees is found to have acted negligently, the plaintiff's claim will be awarded based on the contributory negligence of all parties involved in the accident, leading to apportionment of damages. Negligence is not only related to failure to maintain the road to generally accepted standards, but also in not having systems to manage, organise, execute and control the maintenance need and actions.

This thesis discusses road safety, the development of standards, asset management processes and legalities. Critical characteristics of the road are identified and standards proposed. The maintenance of such standards will provide a strong defence against claims of negligence. The thesis further analyses case studies of decided claims and investigated accidents to determine principles and norms that have evolved in law.

The thesis proposes a set of standards, threshold values, inspection cycles, reaction times and decision triggers to inform the maintenance of road infrastructure for safer roads. These standards include threshold values for the dimensions of potholes, edge breaks and drop-off, rutting, skid resistance, the affirmation of sight distances through the control of vegetation and location of trees. It lists trigger values for maintenance actions that must be performed to mitigate hazardous conditions, including drainage, signs and guardrails. The research forms a foundation for industry practice guidelines on maintenance for safer roads in the context of the road authorities' legal duties towards road safety.

Opsomming

’n Land se padnetwerk is ’n belangrike kommunikasiemiddel vir beweging van mense en verspreiding van goedere. Eienaarskap van paaie berus op die openbare sektor. Die voorsiening van paaie volg behoefte, maar word beïnvloed deur beleid en die beskikbaarheid van fondse. Die voorsiening van paaie is dus diskresionêr. Die onderhoud van paaie is onderworpe aan bedryfsvereistes, veiligheid, en tesourieriglyne ten opsigte van batebestuur. Onderhoud van bates, veral ten opsigte van veiligheid, mag spesifiek verpligtend wees om aan aanvaarde ingenieursstandaarde en die verwagtinge van die gemeenskap te voldoen.

Suid-Afrika het ’n swak rekord van padveiligheid. Padsterftes per jaar as gevolg van padongelukke het gestyg tot 15 000 in 2006 en daarna rondom 13 800 van 2008 tot 2012 gestabiliseer. Padtoestande en -falings speel in baie gevalle ’n rol. Die meeste padfalings is die resultaat van onvoldoende padonderhoud.

Die regsplig om paaie op ’n redelike vlak van veiligheid te onderhou is gevestig in wetgewing en beleid en in regspresedente. Gebrek om hierdie regsplig na te kom kan tot regseise/ skadevergoeding lei en die padowerheid kan verantwoordelik gehou word in terme van die deliktereg. ’n Handeling of gebrek aan handeling moet tot skade lei en daar moet bewys word dat die padowerheid verkeerd was. As die handeling of late dan verkeerd was en die padowerheid het nalatig deur die aksies van sy werknemers gehandel, kan die eiser se skade verhaal word. Die omvang van die verhaling word uit die bydraende nalatigheid van al die partye bepaal en die skade word in verhouding verdeel. Nalatigheid word nie net gekoppel aan die gebrek om die paaie ooreenkomstig aanvaarbare standaarde te onderhou nie, maar ook aan die doeltreffendheid van die stelsels wat daargestel is om onderhoud te beplan, te organiseer, uit te voer en te beheer.

Hierdie verhandeling beskryf die agtergrond van padveiligheid, ontwikkeling van standaarde, batebestuurstelsels en regaspekte. Kritieke eienskappe van die pad word uitgewys en standaarde aan die hand gedoen. Handhawing van standaarde bied ’n sterk verweer teen eise wat op nalatigheid gegrond is. Gevallestudies van afgehandelde eise en botsingsondersoeke word ontleed om regsbeginsels te bepaal.

Die verhandeling stel standaarde, drempelwaardes, inspeksiesiklusse, reaksietye en besluitnemingsoorwegings voor om onderhoud van paaie vir veiligheid te rig. Sodanige standaarde sluit in die afmetings van slaggate, kantverbrokkeling en vlakverskille, spoorvorming, glyweerstand, en die handhawing van sigafstande deur beheer van plantegroei en plasing van bome. Dit lys die drempelwaardes vir onderhoud wat nodig is om onveilige toestande te verhoed of te versag ten opsigte van dreinering, padtekens en skramrelings. Die navorsing vorm ’n grondslag vir bedryfsriglyne vir onderhoud vir veiliger paaie in die konteks van die padowerheid se regsplig ten opsigte van padveiligheid.

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The support of Prof Gideon van Zijl and my colleagues at the Department of Civil Engineering is appreciated.

My involvement as expert witness in cases involving negligence in road design, maintenance and operations, brought me in contact with legal practitioners who through skilful reasoning provided me with new and alternative insights into the legal duty of engineering.

The research leading to this dissertation resulted in conference presentations at the International Road Federation / South African Road Federation conference in 2010, titled “Preserving functionality of and safety on Africa’s road network” and “Road transport safety in the maintenance environment”, at the South African Transport Conference titled “Maintenance and claims for damages” (2014), “Skid resistance of roads contaminated with gravel” (2013) and “Managing trees in road reserves for road safety” (2012). A peer-reviewed paper titled “Engineering for road safety” was published in the accredited journal IMIESA (2014). A presentation titled “The municipal engineer as caring parent” was given at the Institute of Municipal Engineers of South Africa (IMESA) in October 2015.

Cilliers Willers checked the formatting and accuracy of the report.

Thanks, too, to Nelly, my wife, who supported me and compelled me to finish what I had started.

Dedication

This dissertation is dedicated to my parents, family and all persons who have been affected by maintenance failures in the road system.

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List of Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
AADT	Average Annual Daily Traffic
ADT	Average Daily Traffic
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CoF	Coefficient of Friction
COTO	Committee of Transport Officials
CSIR	Council for Scientific and Industrial Research
DHV	Design Hourly Volume
ECSA	Engineering Council of South Africa
e-NATIS	National Traffic Information System
ETD	Estimated Texture Depth
FHWA	Federal Highway Administration
GRAP	Generally Recognised Accounting Practice
GVM	Gross Vehicle Mass
HDM	Highway Development and Management
IRVM	Integrated Roadside Vegetation Management
ISO	International Organisation for Standardisation
ITE	Institute of Transportation Engineers
km/h	kilometres per hour
KPI	Key Performance Indicator
MMS	Maintenance Management System
MPD	Mean Profile Depth
mph	miles per hour
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board SAE Society of Automotive Engineers
NZTA	New Zealand Transport Agency
PMS	Pavement Management System
RAF	Road Accident Fund
RABS	Road Accident Benefit Scheme
RAP	Road Assessment Program
RCB	Roads Coordinating Body
RMC	Road Maintenance Category
RMS	Road Maintenance System
RRM	Routine Road Maintenance
RSA	Republic of South Africa
RTMC	Road Traffic Management Corporation

RTSM	Road Traffic Signs Manual
SABS	South African Bureau of Standards
SADC	Southern African Development Community
SANRAL	South African National Roads Agency SOC Ltd
SANS	South African National Standard
SCA	Supreme Court of Appeal
SCRIM	Sideways force Coefficient Routine Investigation Machine).
SPTD	Sand Patch Test Depth
TRB	Transportation Research Board
UK	United Kingdom
US	United States (of America)
VPDPL	vehicles per day per lane
WHO	World Health Organization

Acts referenced

CARA	Conservation of Agricultural Resources Act 43 of 1983
CPA	Consumer Protection Act 8 of 2008
GTIA	Gauteng Transport Infrastructure Act 8 of 2001
HA (UK)	Highways Act 1980
ISTEA (US)	Intermodal Surface Transport Efficiency Act
MSA	Municipal Structures Act 117 of 1997
NRA (a)	National Roads Act 42 of 1935
NRA	National Road Act 54 of 1971
NRTA	National Road Traffic Act 93 of 1996
NVFFN	National Veld and Forest Fire Act 101 0f 1998
OHSA	Occupational Health and Safety Act 83 of 1993
SANRAL and NRA	South African National Road Agency Limited and National Roads Act 7 of 1998
Standards Act	Standards Act 8 of 2008
Constitution	Republic of South Africa. 1996. Constitution of the Republic of South Africa as adopted by the Constitutional Assembly on 8 May 1996 and as amended on 11 October 1996 (B34B-96). (ISBN: 0-260-20716-7).

Glossary

Austroads	The Australian and New Zealand Road System and Road Authorities tasked with promoting improved Australian and New Zealand transport outcomes, providing expert technical input to national policy development on road and road transport issues, promoting improved practice and capability by road agencies and consistency in road and road agency operations.
bi-annually	Occurring twice each year.

conspicuity	Being conspicuous or clearly discernible.
edge drop-off	A vertical height difference between two adjacent roadway surfaces. It usually occurs at the interface of the surfaced roadway and gravel shoulder due to erosion.
forgiving road	A forgiving and safe road transport system allows for reasonable levels of human error and ensures that the forces in collisions do not exceed the limits of human tolerance that may result in death or serious injury.
highway	High speed (70 to 80 km/h urban, 80 to 120 km/h rural), continuous, vehicle priority major route. In urban areas they are characterised by widely spaced coordinated traffic signals. Can have grade-separated, priority or roundabout intersections but these are less common. See ''local road/street'' for definition of minor route.
hydroplaning	Movement of a wheeled vehicle that slides out of control on a wet road surface due to a layer of water building between the wheels and the road surface, leading to a loss of traction that prevents the vehicle from responding to control inputs
law of delict	The branch of law that deals with the unlawful act in Roman-Dutch law.
law of torts	The branch of law that deals with the unlawful act in English law (in the UK, US, Australia and New Zealand).
local road/street	A Class 5 road (rural) or street (urban) carrying traffic with origins or destinations in the immediate (local) area with the main purpose of giving access to individual properties.
macro-texture	The characteristics of road surface texture with depth determined by the size of the aggregate in the surfacing, with wavelengths in the same order of size as tyre tread elements.
main road	Mobility road capable of safely carrying traffic at speeds of around 70 km/h.
mega-texture	The characteristics of road surface texture with wavelengths in the same order of size as a tyre/road interface as is often created by potholes or "waviness" in the road surface.
micro-texture	The characteristics of road surface texture determined by the harshness or roughness of the stones in the road surface.
Performance based maintenance (PBM) contract	An agreement between a government department or state enterprise and a private contractor whereby the private contractor maintains the road to achieve specified condition standards for a certain period of time, in return for an agreed payment stream
ponding	The pooling or accumulation of standing water on the road surface.
pothole	A road failure that manifest as a rounded or oblong opening in the road surface and the underlying layers, induced by traffic action on weak spots in the roadway.
ravelling	Progressive loss of pavement material from the surface downward – the road surface breaking up and losing aggregate.
retroreflectivity	Retroreflectivity is the capability to reflect light back to the light source. For highway signs, the unit of measure for reflectivity is referred to as the "coefficient of retroreflection", $R_{A=(}$Light Out)/(Light In), measured in "candela per incident lux per square meter", often abbreviated to "cd/lx/m^2".
road	The area of the public road that is open to or used by members of the public and is developed by a road authority for the driving or riding of motor vehicles.
road geometric design	The road engineering discipline of positioning the physical elements of the roadway (alignment, profile, and cross section) according to standards and constraints, with the objectives of optimising efficiency and safety while minimising cost and environmental damage.
road reserve	All of the area of land within the boundaries of a road as shown on a cadastral plan.

roadside	Any land within the boundaries of a road (other than the shoulders of the road) that is not a roadway or a pathway, It includes the land on which any vehicle crossing or pathway that connects from a roadway or pathway on a road to other land has been constructed.
roadstud	Device fitted to the road with a retroreflective surface that reflects the light from vehicle headlights making them visible to drivers in darkness. The colour reflected gives the meaning of the marker.
rutting	A depression or groove worn into a road due to traffic in the wheel path.
scrubbing	The rubbing of the sidewall of a tyre on a vertical surface.
shoulder	The cleared area, whether or not constructed or sealed, next to a roadway that provides clearance between the roadway and the roadside but does not include any area that is not in the road reserve.
shoving	Localised displacement or bulging of pavement material in the direction of loading pressure.
siltation	The process by which sediment or silt (fine mineral particles) is suspended in water making the water dirty.
standard	A standard is an agreed criterion that ensures that products and services meet minimum threshold values. A standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose (ISO, n.d.)
superelevation	The amount by which the outer edge of a curve on a road is banked above the inner edge.
treasury	The place in which public funds (the revenue of government) are received, kept, managed, and disbursed.
Vicroads	The road authority in the state of Victoria that plans, develops and manages the arterial road network and delivers road safety initiatives and customer-focused registration and licensing services.

Chapter 1: Introduction

This chapter gives the background to the study, presents the problem statement and the aim of the research. The scope of the research is described as well as the methodology and the structure of the thesis.

1.1 Background

The road network of a country is a mode of communication that is important for the distribution of goods. Roads are integral elements in public infrastructure, providing mobility and access for people and goods. The ownership of roads is typically vested in public entities. The provision of roads follows need, but is influenced by policy and available funding from the public purse. The supply of roads infrastructure is therefore discretionary. The maintenance of these roads is subject to treasury guidelines on asset management, operational needs and safety requirements. Safety-related maintenance, in particular, may be mandatory in order to meet accepted engineering standards and the expectations of the communities.

The function and competence to provide and maintain roads in South Africa are contained in legislation, originating from the Constitution of the Republic of South Africa, 1996 (the Constitution) that allocates functions to the three spheres of government. Specific legislation include the superseded National Roads Act 42 of 1935, the National Roads Act 54 of 1971, the South African National Road Agency Limited and National Roads Act (SANRAL and NRA) 7 of 1998 (as amended, hereafter referred to as SANRAL and NRA). The provision of provincial roads was founded on the various ordinances such as the Transvaal Provincial Road Ordinance No. 22 of 1957 and the Cape Province Roads Ordinance No. 19 of 1976 and some were repealed or augmented after 1994 by various provincial acts such as the Gauteng Transport Infrastructure Act (GTIA) 8 of 2001. The Municipal Structures Act (MSA) 117 of 1997 elaborates on the competence of local authorities. The allocation of powers and functions does not refer to any standard, assuming that engineers will draw up and work to the necessary guidelines, manuals and codes for application in the design and maintenance of roads, with road safety as a concurrent requirement.

While providing for explicit powers and functions to construct roads and provide for mobility, South African law-makers have not found it necessary to state in law pertaining that there is a legal duty of road authorities to ensure safety on provincial and local roads. This duty follows from policy and legal precedent. Policies state the expectations and values of the community and government’s role and commitment to achieving these expectations.

The provision of roads to enhance mobility and access has negative consequences. Road safety is a serious concern in the world. In 2010 the World Health Organization (WHO) estimated that road-related fatalities were becoming the major cause of death of persons in the age group 25 to 35 (WHO, 2009). Road crashes (collisions) are accepted as consequences of mobility, but the extent of fatalities and serious injury is not acceptable.

South Africa's record in road safety is poor. More than 11 000 deaths per annum resulting from motor vehicle accidents were recorded in 2001, peaking at over 15 000 in 2006 and stabilising around 13 800 from 2008 to 2012 (Letsoalo, 2012). In 2008 13 707 fatalities were recorded on our roads. The fatality rate in 2008 was 30.1 fatalities per 100 000 of population, compared with 4.5 for the Netherlands in that year, the lowest rate in the 2009 edition of the WHO report on the Global Status Report on Road Safety (WHO, 2009). In the similarly named report of 2013, the fatality rate in South Africa worsened to 31.9 while Sweden, achieving the lowest rate in the 2013 report, succeeded in reducing the fatality rate from 5.2 to 3.0 fatalities per 100 000 of population. A comparison with Australia would seem to be more equitable, given the fairly similar road conditions. Their road-related fatality rate reduced from 7.8 to 6.1 in the respective reports (WHO, 2013). Note that a number of island states with low fatality rates such as the Maldives (1.9 fatalities per 100 000 of population) were not considered for comparison as their driving conditions are too different.

Various policy studies, such as Moving South Africa (Department of Transport, 1998) and Road to Safety (Department of Transport, 2002) have commented on the need to reduce crashes, with strategies to achieve such reductions.

> The safety, security, and quality of service of some modes of transport are currently unacceptable. The government is committed to a concentrated and integrated effort to bring them into line with international best practice. Particular attention will be paid to road safety. (Department of Transport, 1996).

It formulated the following mission:

> Mission: The mission to be fulfilled by institutions and persons involved in road traffic is: To ensure an acceptable level of quality in road traffic, with the emphasis on road safety, on the South African urban and rural road network. The acceptable level of quality and road-traffic related needs are to be determined by the community. It will be determined and provided for by a transparent, consultative, and accountable process.

The South African road network has grown since the enactment of the first National Roads Act in 1935 and the promulgation of the various provincial Road Ordinances in 1957. Growth in the length of national roads accelerated further in the 1970s with the National Road Act 54 of 1971 that started, as what Mitchell described, as two golden decades of national roads construction (Mitchell, 2014).

Changes in the national transport policies led to a partial relaxation of the protection that the railway had in 1977. By 1988 freight transport economic deregulation was complete. The deregulation and slow deterioration of the railway system diverted freight tonnage from rail to road. Motorised vehicle registration increased from one million in 1960 to 1,8 million in 1970, three million in 1980, six million in 2000 and 8,8 million in 2010 (Arrive Alive, n.d.). In the 1990s the more intense usage and an aging road network brought an understanding of the serious consequences of failure to invest in and effectively maintain the road network, in particular the deterioration of safety, reliability and quality. It became increasingly clear that deferred maintenance would lead to the need for earlier rehabilitation or reconstruction and thus increase the required levels of future investment (Roads Liaison Group, 2005). The deterioration of road safety due to the lack of road maintenance results in an increase in accidents attributable to the road, which is evident in the increasing number of claims for damages against the road (Chowdury, Ogle, Gowan, Tupper, Familian and Dey, 2011).

The legal duty of the road authority and the road engineer is pressing in cases of delict, where damages have been suffered and the road authority is sued for the damages on the grounds of wrongfulness and fault. The judgment in Graham v Cape Metropolitan Council 1999 (3) SA 356 (C) states that the good values of our society require that the road authority be responsible to provide a safe road. The South African courts, however, treat each case on its merits, preferring to neither prescribe the legal duty nor the standards of care in provision or maintenance.

A source of danger is created or develops on roads when the conditions deteriorate due to lack of maintenance. Unsafe roads result from a road environment where all the aspects of maintenance are not integrated and do not meet acceptable standards.

The public has a legitimate expectation that the roads will be fit and safe for use and that the road authorities have a legal duty to prevent hazards to the safety of others and that they will not act in a negligent manner.

Road authorities usually achieve safety by adherence to design standards and guidelines, principles of road traffic signage, construction and maintenance standards, specification and procedures, as well as to intuitive norms or rules of thumb that the reasonable, competent and experienced practitioner and authority would subscribe to. Norms essential for maintenance are often not comprehensive or accessible to road users and not contained in the maintenance codes of road authorities. Notwithstanding existing norms, failures of road elements do occur, resulting in hazards for the road users. This leads to successful claims for damages.

Engineers working for road authorities are often ignorant of the legal duties that society imposes on them and how their work is viewed by the legal profession. Road authorities often neglect supervision of maintenance due to lack of resources, ignorance, incompetence or complacency. Failures are exacerbated by inadequate funding through the politicised process of budgeting within government.

1.2 Problem statement

The problem that was investigated is the absence or inadequacy of explicit engineering criteria as well as use of asset and risk management systems for **safety** in road maintenance in South Africa. This problem was approached from both engineering and legal perspectives.

The first engineering component of this research is the collation, review and establishment of norms and standards for road infrastructure, where standards are agreed criteria to ensure that the characteristics meet minimum values. The focus is on characteristics of the road that have a direct or indirect bearing on road safety. Standards constitute, as was stated by Kardon "That level or quality of service ordinarily provided by other competent practitioners of good standing in that field, contemporaneously providing similar services in the same location and under the same circumstances" (in Harris, Pritchard, & Rabins, 2008). Such norms and standards are presently scattered in guidelines, manuals and directives. References to standards are contained in judgments, often with the proviso that the standards were applied to the facts of the case. Published norms and standards must be collated and interpreted, and confirmed to expand the body of knowledge.

The second engineering component of the research is the asset and risk management systems that need to be in place to utilise the engineering norms and standards for safety in road maintenance. With the publication of guidelines by the Generally Recognised Accounting Practice (GRAP, such as the GRAP 17: Property, Plant and Equipment) (Department of National Treasury, 2014) asset management for public infrastructure became a statutory requirement in South Africa. According to these guidelines, a full inventory and condition register of all public capital works such as buildings and roads must underpin maintenance programmes. Risk assessments must be made to inform government of operational and safety risks of the inventory. Such risk assessments are also a statutory requirement in terms of the Occupational Health and Safety Act (OHSA) 83 of 1993, especially for an activity of an employer that affects the public.

The legal problem investigated is the interpretation of road maintenance engineering standards and systems in court, as most of the claims against road authorities arise from lack of or negligence in road maintenance. The research starts from engineering as a discipline and then explores the interdisciplinary area between engineering and law. The intention is not to conduct legal research. It is hoped that this research will lead to future collaboration in empirical legal research in this overlapping area. The Nuffield Inquiry into Empirical Legal Research in 2006 stated the need to reveal and explain the practices and procedures of legal systems and the impact thereof on institutions and society (Genn, Partington & Wheeler, 2006).

> As empirical legal research is important for underpinning many areas of legal and social policy, there will be an increasing demand from a wider range– business, NGOs and others – that evidence about how law works be made available (Genn *et al*, 2006).

In principle, the court judges each case based on the facts of the specific matter and some inconsistencies arise with respect to the application of standards. The law looks at failures in road safety and maintenance engineering through the principles of the law of delict. Specifically, the legal duty of road authorities towards road safety must be explored in order to understand the expectations and good values of the public and the role of engineering norms and standards. One view of negligence has been formulated as a balance between benefits of taking a positive action and the product of probability of an event happening and the consequential cost or damages. This approach is essentially risk management. Another approach is relating negligence to cost-benefit ratios. This is known in the US as the Learned Hand Rule, after a verdict by Judge Learned Hand in 1947 in the case of United States v. Carroll Towing Co., 1947.

No research available in the public arena has been done at the level of holding individual employees of road authorities responsible for their conduct. Some of the reasons for acting negligently can be interpreted from judgments. Negligence for delictual acts by employees is assigned to the employer authorities under vicarious liability.

1.3 Aim of research

The rationale for choosing the research subject was to investigate the interdisciplinary area between engineering and the law to synthesise knowledge of road maintenance standards and legal duty into standards for maintenance of safety related road infrastructure. There is a need to inform the engineering profession, specifically road authorities and road engineers, of its legal duty to care for the health and safety of the public by *inter alia* applying safe norms and standards in roads maintenance. This is especially important in an engineering environment where fatalities, injuries and damage lead to claims and where public policy is aimed at reducing crashes on our roads.

The aim of this research is to compile and develop engineering standards for road elements and systems in maintenance that are sufficient to fulfil the legal duties of the road authorities towards road safety. These standards can form the basis of a comprehensive suite of practice guidelines.

The use of practice guidelines is well developed in the medical field. Mackay and Bryan state in the American Medical Association Journal of Ethics in a paper titled “The Role of Practice

Guidelines in Medical Malpractice Litigation" that "Clinical Practice Guidelines play a dual role in medical malpractice claims. They can be used by an accused physician as defence (exculpatory evidence) and by patients alleging a breach of the standard of care (inculpatory evidence)" (Mackay & Bryan, 2011).

The first objective of the research was the development of local road maintenance standards for safety, based on existing pavement and appropriate guideline values, procedures and standards. These values were also reviewed against criteria used in legal proceedings and cases that set precedents used in English-speaking countries in relation to their system of legal duties in delict or under tort law. Norms and standards are not only applicable to physical road characteristics, but also to the management systems required to achieve appropriate standards. The requirements of public asset and risk management have become part of government obligations and subject to auditing.

The second objective was to compile a systematic body of knowledge of the legal duties of road authorities that will empower engineers to interpret the legal consequences and context of their work. South African engineering education does not incorporate a course in legal aspects that affect the engineer, other than certain aspects of contract law incorporated in engineering management. The engineers in the employment of road authorities and their agents such as consulting engineers and contractors often learn the hard way by facing claims for damages caused through negligence. Although the legal profession is there to deal with legal issues, engineers often do not communicate effectively as a result of being unfamiliar with the terms and processes. This limitation is often exposed when the engineer must testify as expert witness.

The third objective was to identify reasons why road authorities do not apply such standards that currently exist in the form of good practice guidelines, manuals and specifications. From these reasons, recommendations will be made for further research and measures to

- improve the adherence to safety standards, such as practice guidelines;
- meet educational and in service training needs; and
- enhance capacity building.

1.4 Scope of research

This study focuses on road maintenance characteristics that have a bearing on road safety. There is a close correlation between operational efficiency and safety. Potholed roads are, for example, unsafe because vehicles are damaged driving through them and the damage often leads to loss of control and further damage. Potholed roads necessitate lower average speed and traffic is therefore less efficient.

The study does not consider situations where hazards are created on the road by the road authorities. An example of such a hazard is where a speed hump is constructed (a positive action) and no warning signs are displayed to warn of the danger. In the case of a positive action, legal duty is automatically established.

> A person acts *prima facie* wrongfully when he creates a new source of danger by means of a positive conduct (*commissio*) and subsequently fails to eliminate the danger (*ommissio*), with the result that harm is caused to another person. Prior conduct in the form of a positive act which created a danger of harm may in other words be a strong indication that a legal duty rested upon the defendant to take steps to prevent the damage from materializing (Neethling, Potgieter, & Visser, 2001).

The research explores literature published in English. This is not based on the limitation of language, but on the premise that English is the preferred language for publication in the road engineering and safety field. In addition, contributions from European countries are available in English journals as well as conference proceedings.

Sources from the US, UK, Australia and New Zealand were consulted. The US has a well-developed body of knowledge on road engineering, having well-financed transportation research bodies and institutions. It has a tradition of litigation. Data on cases and causes for claims are well researched. The southern US rural areas are similar to South Africa with respect to climate and therefore road maintenance issues. The UK has a history of early precedent-setting cases and development of legislation and guidelines to ensure safety. Australia and New Zealand cooperate in road safety research through bodies, such as Austroads (the Australian and New Zealand Road System and Road Authorities) which are on the forefront of developing and implementing road safety systems. Australia and South Africa also share a similar climate and rural road environment. European sources mainly apply with respect to policy and systems considerations. The climatic conditions in European countries differ substantially from South African conditions. Travel distances are also much shorter on the densely developed continent. This has led to different design approaches and different maintenance issues.

Hazards caused by failures in road maintenance affect mostly motorcars and other vehicle with more than four wheels as the mode of choice of the majority of road users. Most of the literature is thus concerned with the safety of four+ wheeled vehicles. Non Motorised Transport (NMT) is gaining popularity but published research is limited. Two-wheeled vehicles, such as bicycles and motorcycles, are mentioned in passing, especially with respect to potholes, but the research was not aimed at a comprehensive treatment of the impact of road maintenance failures on two-wheeled vehicles. Similarly, some cases refer to pedestrians. These cases are used to illustrate principles of law and maintenance. Again, pedestrians are not comprehensively investigated in this research.

The research only looked at paved (surfaced) road. These roads carry the greatest proportion of traffic and most traffic accidents occur on these roads. With the focus on maintenance standards for safety, the research aimed at the area where the greatest benefit can be obtained. The safety of unpaved (gravel) roads, even if they are 61% of the declared road network, is a subject that justifies a study in its own right.

1.5 Methodology

The dissertation explores the field where road safety engineering and the law interacts. The research methodology was primarily qualitative for it sought to understand, illuminate and extrapolate the current state of knowledge in this field. Qualitative research findings are not arrived at by extensive experimental data and statistical analysis as is characteristic of quantitative research. (Strauss and Corbin, 1990:17 in Hoepfl, 1997).

The research was done through a systematic study of technical literature such as textbooks, journals, guidelines, manuals, directives and codes. Legal principles were similarly researched through the study of relevant literature and reported and investigated court cases.

The research methodology is elaborated on in Chapter 4.

1.6 Chapter overview

Chapter 1: Introduction

This chapter gives the background and motivation for the research. It then sets out the problem statement, aim and scope and introduces the methodology that is further elaborated on in Chapter 4.

Chapter 2: Literature review

This chapter covers the literature that was studied and deemed relevant to this research. The literature surveyed explores industry guidelines and research on road maintenance for ensuring safer roads in the context of road authorities' legal duties towards road safety. The standards identified can form the basis of a comprehensive suite of practice guidelines.

Chapter 3: Legal duty

The aim of the establishment of safety standards in maintenance is to provide a reference framework that will allow the road authorities to measure their performance and be able to show that they adhere to reasonable industry-accepted practice. This chapter evaluates the legal duty that the court imposes on the road authority in the event of claims for damages. The legal theory is explored with the purpose of understanding the role of engineering standards in the establishment of legal duty, wrongfulness, negligence and causation. It does not delve into fine points of legal discourse in the field of delict that characterise the legal research into the so-called municipal cases.

Chapter 4: Methodology

The importance of justifying the research methodology, especially when using a qualitative method in a discipline that normally uses quantitative methods, is recognised and the methodology applied is elaborated on in this chapter.

Chapter 5: Maintenance standards

The various attributes of the characteristics and features that have safety impacts are analysed in this chapter. The terms to be used are defined at the start, as the use of some terms varies between countries and continents.

Chapter 6: Road maintenance procedures

Chapter 6 shows how the maintenance standards inform the maintenance systems for safety, by evaluating the infrastructure asset management approach and establishing the procedural imperatives that will ensure that safety is accounted for in road authorities' operations.

Chapter 7: Case studies

The case studies are presented to extract, illustrate and confirm certain values and norms that have been used in claims and pleas. This chapter brings a practical view of how standards will be used to both claim and defend in matters where the qualities of the road played a role in an accident.

Chapter 8: Synthesis

This chapter combines standards for the features and characteristics that have been selected for their safety impacts, as well as procedural standards that will ensure the implementation of safety as a quality in maintenance management as part of infrastructure asset management.

Chapter 9: Conclusions and recommendations

The conclusion consolidates the findings of the research and assesses the value of the proposed standards for attributes and procedures for the promotion of road safety, accomplishment of legal duties and the management of claims. Future research into, guidelines for and dissemination of standards are suggested.

Chapter 2: Literature review

2.1 Introduction

The aim of the research is to compile and develop engineering standards for road elements and systems in maintenance that are sufficient to fulfil the legal duties of the road authorities towards road safety. Such standards could form the basis of a comprehensive suite of practice guidelines. The literature surveyed in this chapter therefore explores industry guidelines and research on road maintenance for ensuring safer roads in the context of the road authorities' legal duties towards road safety.

The literature review specifically focuses on the elements of maintenance that affect road safety and are most often cited in claims for damage from road authorities. It covers road safety in general, pavement management systems, road infrastructure asset management and maintenance codes of practice. Although the engineer may be tempted to dwell on these interesting factors and the intricacies of legal theory on delict and negligence, the literature review had to be restricted to cases that specifically contribute towards defining road maintenance standards.

The elements of road maintenance that feature in South African court cases are often gross defects, such as potholes and edge drop-off, of dimensions not reported in other countries. Aspects such as maintenance of roads in winter conditions of snow and frost obviously have limited bearing on the South African situation. The mountain passes in the Eastern Cape that are subject to short-duration snowfall are typically monitored and closed when unsafe for traffic, for example, Barkly Pass R58 between Barkly East and Elliot.

There is a multitude of road design guides, academic handbooks, research publications and web-based resources on values for road attributes that involve road safety. Care was taken to be selective with respect to quality and not quantity, in line with the qualitative method used in the research. Recent sources and integrated individual research inputs were preferred to research into fine detail and refinement of methods or values of attributes. The research is aimed at categories of value for attributes or characteristics of road maintenances elements.

Many of the proposed standards of maintenance to achieve safety are attributes of characteristics and road features that are known to the industry. These attributes are, however, described with various terms such as norms, guidelines, and trigger and terminal values. The term ''standard'' is often avoided due to the connotation to compulsory values.

The chapter is structured to start with definitions of road authorities and roads, followed by a broad overview of the road safety situation in South Africa in terms of fatalities, policies and strategies. It then looks at road maintenance systems and asset management for safety, not only as good practice, but also as a compulsory general set of rules for accounting practice in public service. The core themes of the thesis, the elements and attributes of and procedures for road maintenance for safety, are introduced (and developed further in Chapters 5 and 6). The legal concepts of delict, of which road authorities' legal duty is an element when claims for damage arise, are introduced at a level appropriate for understanding the reasonable conduct of the engineering profession. The legal duty of the road authority is elaborated further in Chapter 6. Cases that illustrate the interpretation of the safety features of road element by the courts are discussed in the literature review and specific cases are analysed in Chapter 7. The outcome of the study is guidelines and standards and the last section in the literature review discusses existing guidelines and how standards are derived.

2.1.1 Clarification of terms used interchangeably

The terms **accident, crash** and **collision** seem to be used interchangeably in literature, legislation and guidelines. In the thesis, accident is the preferred term due to its use in legal documents. However, where an external source uses the term crash or, less often, collision, it can be assumed to be synonymous, unless it is otherwise clear from the context.

Accident is the term used in the NRTA 93 of 1996 and its regulations, as well as on the SAPS accident report form. It is also used in older US statistical reports, the American National Standards Institute (ANSI) D16-1 Manual on Classification of Motor Vehicle Traffic Accidents (American National Standards, 2007) and authoritative publications and journals such as Accident Analysis and Prevention. The World Bank Global Status Report on Road Safety uses **accident** in the definition of fatality, but **crash** is used extensively to denote an incident (WHO, 2009). **Accident** is used in European statistics (Unitied Nations Economic and Social Council, 2003).

The road safety community has an objection to the term **accident** as it interprets it as suggesting that the parties involved had no control over the situation. The preferred term is **crash**: an event that produces negative consequences such as injury, death, or damage where at least one vehicle is involved. The US National Highway Traffic Safety Administration (NHTSA) has adopted the policy to use the term **crash** throughout the Fatal Accident Reporting System (FARS) (Department of Transportation, 2014). It states that **crash** will always refer to a motor vehicle traffic accident as defined in ANSI Standard, D16.1 – The Manual on Classification of Motor Vehicle Traffic Accidents (American National Standards, 2007). **Crash** includes non-collision scenarios such as the following: A single-motor vehicle crashing on a roadway, a motor vehicle runs off of a road into water, an occupant of a motor vehicle is injured by falling from that vehicle, by shifting cargo or flying objects and where a vehicle suffers damage from a pavement irregularity (loose plate, high manhole, pothole, *etc*.).

Collision describes an event involving a motor vehicle and fixed objects (poles, walls, buildings, barriers, bridge supports, *etc*.) or a motor vehicle and non-fixed objects (pedestrians, animals, pedal cyclists, other motor vehicles, *etc*.).

In the thesis, various references are made to **engineer**. Road geometric design, pavement design, traffic engineering, transport (transportation in the US), planning and road safety are all subdisciplines of civil engineering. The term **engineer** may therefore be qualified in the context to put emphasis on the function or designation of the engineer. It also indicates a registered person who subscribes to the code of conduct of the controlling professional body, in the case of South Africa, the Engineering Council of South Africa (ECSA).

2.2 Road authorities and roads

Road authorities in South Africa are the national Department of Transport, the various functions within the provincial departments that include roads functions and the 283 municipalities ranging from metropolitan, district to local level. The national Department of Transport delegated its roads functions to the South African National Roads Agency SOC Ltd (SANRAL), an agency established under the SANRAL and NRA. The provincial and municipal authorities are mandated in the appropriate schedules to the Constitution with the functions of roads and transport. Road authorities are the only institutions empowered to establish public roads and it follows that they are obliged to build, operate and maintain them in functional condition for reasonable use. The legal duty of road authorities is elaborated on in Chapter 3.

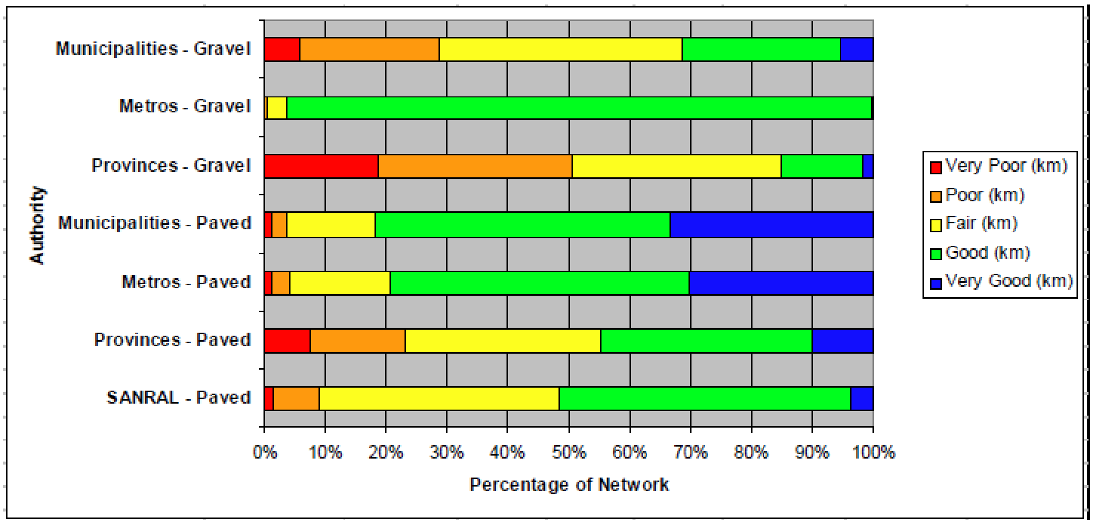
The bulk of our road network comprises of roads that can be defined as classical public goods: "…things [that] do not lend themselves to [market] production, purchase and sale. They must be provided for everyone if they are to be provided for anyone, and they must be paid for collectively or they cannot be had at all" (Galbraith, 1958:111). Note that only a small portion of the national road network is tolled: 3 120 km of the 19 704 km of proclaimed national roads in 2014 (SANRAL, 2015).

Infrastructure assets referred to in the Standards of Generally Recognised Accounting Practice (GRAP) 17: Property, Plant and Equipment (Department of National Treasury, 2014) include, for example, road networks, sewer systems, water and power supply systems and communication networks. Roads are typical infrastructure assets that display some or all of the following characteristics:

- Are part of a system or network;
- are specialised in nature and do not have alternative uses;
- are immovable; and
- may be subject to constraints on disposal (Department of National Treasury, 2014).

The South African road network was estimated to be 747 000 km in extent in 2009, of which 154 000 km is paved roads (21%), 453 000 km is proclaimed gravel roads (61%) and 140 000 km (18%) is unproclaimed and not maintained by any authority. The paved road network of 154 000 km carries the higher volumes of traffic at higher speeds. Most of the claims against road authorities for damage are made for accidents on the paved roads. The paved road network is divided in 16 170 km of strategic national roads, 48 000 km of provincial roads, 52 000 km of metropolitan roads and 38 000 km of other municipal roads (Kannemeyer, 2009). There is a continuous process of reviewing the management of the road network and more strategic road assets are transferred to SANRAL, resulting in them controlling 19 704 km of road in 2015.

The condition (based on visual assessment procedures) of the road network is illustrated by Kannemeyer in a diagram shown in Figure 2-1 (Kannemeyer, 2009). The important feature of this condition report is that the condition of the provincial paved roads, from which most legal claims originate, is significantly poorer than the paved roads under control of SANRAL and the municipalities.



Authority	Total Network	Visual Condition Data (km)[2]						
		Very Poor (km)	Poor (km)	Fair (km)	Good (km)	Very Good (km)	Total km with Data	% Network With Data
SANRAL - Paved	16,170	233	1,199	6,391	7,750	597	16,170	100
Provinces - Paved	48,176	3,532	7,200	15,179	16,470	4,706	47,088	97.74
Metros - Paved	51,682	421	1,256	6,707	20,104	12,250	40,737	78.82
Municipalities - Paved	11,076	121	272	1,579	5,271	3,623	10,866	98.10
Provinces - Gravel	136,640	19,327	33,219	35,344	13,863	1,981	103,733	75.92
Metros - Gravel	14,461	2	7	55	1,722	3	1,789	12.37
Municipalities - Gravel	2,051	123	485	849	557	117	2,131	103.89
Totals km	**280,256**	**23,759**	**43,639**	**66,103**	**65,737**	**23,276**	**222,514**	
Totals %		**10.68**	**19.61**	**29.71**	**29.54**	**10.46**	**100**	

Figure 2- 1 : Road visual condition summary (2009)

The South African Institution for Civil Engineering commissioned the Council for Scientific and Industrial Research to compile infrastructure status reports in 2006 and again in 2011. The results with respect of roads are shown in the Figures 1 and 2. The format changed between the years, but the discussions are insightful.

Roads	**C** for national roads	Most in fair to very good condition, with recent strategic acquisitions in poorer shape. Increasing use of user-pays (tolling), but funding remains a challenge, especially given that key roads will soon require extensive refurbishing.
	D- for all other roads	Generally inadequate funding and management systems leading to neglect of maintenance, combined with over-loading, means that maintenance backlogs are growing. Less condition monitoring than in the past. Shortages of skilled personnel. Decisions have been taken to stop maintaining some roads.

Figure 2- 2 : SAICE Infrastructure Report on Roads 2006

In 2006, only two categories were considered on a 5-point scale: the national roads were C (satisfactory) while the rest of the country's roads were in poor condition (D-). The reasons for the poor roads (all other) were inadequate funding, maintenance systems, maintenance, and shortage of skilled personnel.

Roads	**B** for national roads	The national road network is in the good to excellent range with the proportion of roads in poor to very poor condition never exceeding the international benchmark of 10%. SANRAL demonstrates expert knowledge, world-class management and excellent monitoring and maintenance systems. Close to 80% of the network has exceeded its 20-year structural design lifespan. SANRAL's current success in maintaining the national road network will see its responsibilities and network allocation expand further. These will be severe challenges.
	D- for paved provincial roads	The paved provincial road network has deteriorated significantly over time. Shortages of skilled personnel in provincial departments, inadequate funding and outdated systems, and the lack of routine and periodic maintenance, have contributed to the current condition.
	C- for paved metropolitan roads	Generally, these roads are in satisfactory condition. Less than 10% (except for Buffalo City) of the paved metropolitan roads are in poor to very poor condition. Balancing the need for the upgrading of township roads with the necessity to perform routine and periodic maintenance remains a challenge given the limited resources at their disposal. Concerns about the lack of capital expenditure on capacity improvements and signalling upgrades.
	D for paved district and local municipal roads	In general, municipalities lack capacity, skilled resources and funding to efficiently and effectively manage their road networks. Reliable condition data is scarce. Few municipalities make use of pavement management systems to prioritise their needs. Capacity improvements amount to much less than that required, especially with high urbanisation rates. Based on the limited data available, the paved road network on average, nevertheless appears to be in a fair condition.
	E for all provincial, metropolitan and municipal gravel roads	Maintenance of gravel roads, which constitutes 75% of the total length of the proclaimed South African road network, has been neglected. Condition data is scarce (only available for 24% of the network). Approximately 50% of the provincial gravel roads and 30% of the municipal gravel roads, for which condition data is available, are in a poor to very poor condition.

Figure 2- 3: SAICE Infrastructure Report on Roads 2011

By 2011, the roads were split into five categories and the national roads improved to good (B). Provincial, district and local municipal paved roads were at D- with significant deterioration. Shortages of skilled personnel, inadequate funding, outdated systems and lack of maintenance were seen as the contributors. Metropolitan municipalities did better at C-, but all gravel roads in the country were considered neglected, although it is admitted that conditions data is scarce.

A discussion of the problems and constraints facing road maintenance cannot be complete without mention of the Provincial Roads Maintenance Grant, implemented by the Department of Transport's S'hamba Sonke Programme (SSP). It came into effect in 2011/12, to supplement provincial roads investments and support preventative, routine and emergency maintenance on provincial networks. The allocation criteria are based on a formula to meet the needs taking into consideration topography, climatic conditions, road network length and traffic volume within the various provinces. Based on the report to the Select Committee on

20 August 2013, the following summarises the project performance in the 2012/13 financial year.

In the 2012/13 year, 90.6% of the allocated budget of R7.982 billion to the nine provinces was spent; an improvement on the previous year's spending of 88%. There were various problems observed in compliance by the provincial departments of roads. The grant required provinces to implement road asset management systems that would ensure that data was kept on road conditions, traffic and climatic conditions. The provinces, however, tended to give limited information on the evaluations and how they had been conducted. There was lack of clarity on the setting up of evaluation teams and the methodology for data collection. Reports did not contain executive summaries, they provided risk, impact and mitigation outlines, instead of a SWOT analysis, and there was insufficient narrative to explain the variances on blacktop patching and maintenance of coal haulage networks. There had not been reporting on certain data analysis, despite the allocation of R488 million to specific projects. The issues that the provinces raised were not the same as those reported as challenges by the national DOT. The recommendations given in the implementation report lacked detail and no specific interventions were supplied. National Treasury further commented that in recent years, various provincial departments had been plagued by poor technical capacity, and in Free State and Mpumalanga there were also problems around poor contract management and supply chain management. National Treasury was now trying to implement the principles of the Infrastructure Development Programmes to the roads sector and was making funding available to upgrade capacity in the provincial departments (PMG, 2013).

2.3 Road safety, design and maintenance policies and strategies

2.3.1 Road safety

The following discussion and the four tables in this paragraph come from the Road Traffic Management Corporation (RTMC) Strategic Plan 2015 to 2020 and this report quotes from the e-Natis data base. Unless specifically referenced, the source is (RTMC, 2015).

South Africa's population grew from just over 46 million in 2006 to 54 million in 2014 as indicated in Table 2-1.

Table 2- 1: Total population per province 2007 to 2014 (in thousands)

Province	2007	2008	2009	2010	2011	2012	2013	2014
Western Cape	5 360	5 466	5 573	5 682	5 792	5 904	6 017	6 116
Eastern Cape	6 431	6 460	6 491	6 522	6 554	6 586	6 620	6 787
Northern	1 105	1 114	1 124	1 134	1 143	1 153	1 163	1 167

Cape								
Free State	2 732	2 735	2 737	2 740	2 744	2 749	2 753	2 787
KwaZulu-Natal	9 816	9 918	10 023	10 129	10 237	10 346	10 457	10 694
North West	3 310	3 355	3 401	3 448	3 497	3 547	3 598	3 676
Gauteng	11 202	11 446	11 694	11 946	12 202	12 464	12 728	12 915
Mpumalanga	3 814	3 866	3 917	3 970	4 022	4 075	4 128	4 229
Limpopo	5 141	5 201	5 262	5 325	5 388	5 452	5 518	5 631
Total	**48 910**	**49 561**	**50 223**	**50 896**	**51 580**	**52 275**	**52 982**	**54 002**

From December 2005 to December 2013 the total vehicle population increased from about 8 million vehicles to over 11 million vehicles as indicated in Table 2-2. The 2015 fleet composition is approximately 65% cars, 3% minibuses, 0.6% buses, 3.5% motorcycles, 23% light delivery vehicles, 3.5% trucks and the balance is trailers and caravans, as shown in Table 2-3. The average age of vehicles in 2006 was: sedan cars 10 years, minibuses 13 years and buses and trucks between 11 and 12 years. Excluding the minibus taxi fleet that was recapitalised and motorcycles, the average age of vehicles shows an increasing tendency, as vehicles are kept on the roads longer The high average age of vehicles is confirmation of a mixture of first-world and third-world economies. In third-world economies vehicles tend to be very old, not maintained well and overloaded. In combination with roads that are not maintained well, the poorly maintained vehicles put the objectives of road safety programmes under severe pressure.

Table 2- 2: Total vehicle population per province 2007 to 2013

Province	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Western Cape	1 515 147	1 550 484	1 568 622	1 594 785	1 640 723	1 698 173	1 752 417
Eastern Cape	619 448	637 292	659 829	677 597	694 821	715 548	734 139
Northern Cape	199 628	205 900	214 226	219 660	228 778	242 454	252 559
Free State	511 950	524 702	539 704	548 098	563 594	579 461	592 665
KwaZulu-Natal	1 258 720	1 280 322	1 308 090	1 334 316	1 381 721	1 438 997	1 488 702
North West	512 130	525 951	540 786	511 092	527 402	546 669	564 193
Gauteng	3 486 073	3 575 571	3 680 158	3 817 291	3 960 078	4 112 343	4 271 588
Mpumalanga	545 212	567 993	608 676	635 718	672 481	718 213	760 170
Limpopo	419 812	436 293	467 690	490 843	523 452	558 813	589 751

Total	**9 068 120**	**9 304 508**	**9 587 781**	**9 829 400**	**10 193 050**	**10 610 671**	**11 006 184**

Table 2- 3: National vehicle fleet composition on 30 June 2015

Self-propelled vehicles	**Number**	**% of total self-propelled vehicles**
Motor cars and station wagons	6 752 593	64.82
Minibuses	295 397	2.84
Buses, bus-trains, midibuses	58 134	0.56
Motorcycles, quadrucycles, tricycles	368 059	3.53
Light delivery vehicles, panel vans, other light load vehicles (GVM ≤ 3 500 kg)	2 348 922	22.55
Trucks, heavy load vehicles (GVM >3 500 kg)	363 738	3.49
Other self-propelled vehicles	231 347	2.22
Total self-propelled vehicles	10 418 190	
Tow vehicles	**Number**	**% of total tow vehicles**
Caravans	103 973	9.32
Light load trailers (GVM ≤ 3 500 kg)	829 774	74.40
Heavy load trailers (GVM > 3 500 kg)	181 583	16.28
Total tow vehicles	1 115 330	
All other and unknown vehicles	33 040	
Total number of live vehicles	**11 566 560**	

The cost of crashes in 2005 was estimated in the region of R40 billion per annum. By 2011 the National Road Safety Strategy 2011 – 2020 Decade of Action and Arrive Alive estimated the cost at approximately R133 billion per annum to the state, communities and individuals (Department of Transport, 2011). The dramatic increase in monetary value, given that the number of fatalities remained stable, can be attributed to the change in the basis of the Value of Statistical Life used in the cost of accidents. The two primary approaches used in South Africa for the value of life or loss of ability are the Human Capital approach to a Willingness to Pay approach, with the latter now being used.

The Human Capital approach (also Gross Output) is based on the sum output lost by the victim in the accident, the medical costs, the loss of income and property, pain, suffering and administrative costs to society. The Willingness to Pay approach estimates individuals' willingness to pay to reduce the risks of death, injury or damage to an acceptable level. It results in higher values than any of the rational methods.

> Therefore, the component of pain, grief and suffering of serious accidents, which was less than 32% at the beginning of the nineties, amounted to about 80% in light of the human cost approach when adopting the willingness-to-pay approach (Mohamed, 2015).

About 13 800 people die annually on South Africa's roads, more than 40% of these being pedestrians. The role of the human, vehicle and road factors is discussed in a subsequent paragraph. Around 7 000 people are permanently disabled annually, and 40 400 seriously injured. The number of fatalities from road trauma for the period 2004 to 2011 is shown in Table 2-4. Note that the number of fatalities and rates quoted from the RTMC differ from the values used by the World Health Organization (WHO) in the same year, as the WHO uses a modelled value for fatalities to compensate for underreporting.

Table 2- 4: Fatal road accidents, fatalities and rates for 2004 to 2011

Year	Fatal Crashes	Fatalities	Deaths per 100 000 population	Deaths per 10 000 registered vehicles
2004	10 607	12 778	27.42	19.51
2005	11 736	14 135	30.15	20.48
2006	12 456	15 419	32.54	20.86
2007	12 011	14 920	31.18	18.9
2008	10 805	13 875	28.72	16.83
2009	10 857	13 768	27.91	16.22
2010	10 837	13 967	27.94	15.84
2011	11 229	13 954	27.58	15.25

The number of fatalities seems to have stabilised at 14 000 per year. The deaths per 100 000 population and per 10 000 registered vehicles have reduced due to increases in the population and vehicle fleet.

The 2013 Global Road Safety Status Report (WHO, 2013) uses a modelled rate for 2013 for South Africa of 31.7 deaths per 100 000 population, compared with the following average values: global average 18.8; Africa 24.1, Australia 6.1 and United Kingdom 3.7.

The Road Traffic Management Corporation (RTMC, 2015) investigates accidents in which more than five persons died or more than four vehicles were involved. From these investigations (approximately 250), it cites the following causes:

- Speeds too high for the circumstances;
- alcohol abuse by drivers and pedestrians;
- driver fatigue;
- improperly trained motorists;
- defective tyres;
- un-roadworthy vehicles (defective brakes, faulty steering, *etc*.); and

- overloading (freight/passengers).

These causes are presented as the primary causes. The top four causes are human factors and the next two vehicle factors. The list excludes road elements, but Wolhuter states that despite the road environment factors (with reference to Figure 2-2) contributing 34% to the causes of accidents, road designers (also road authorities in general) cannot shrug their shoulders and blame all on drivers (Wolhuter, 2015). This is especially true in maintenance, where hazardous conditions such as potholes should not develop on a road that was previously reasonably safe at high speed but became unsafe due to poor road conditions.

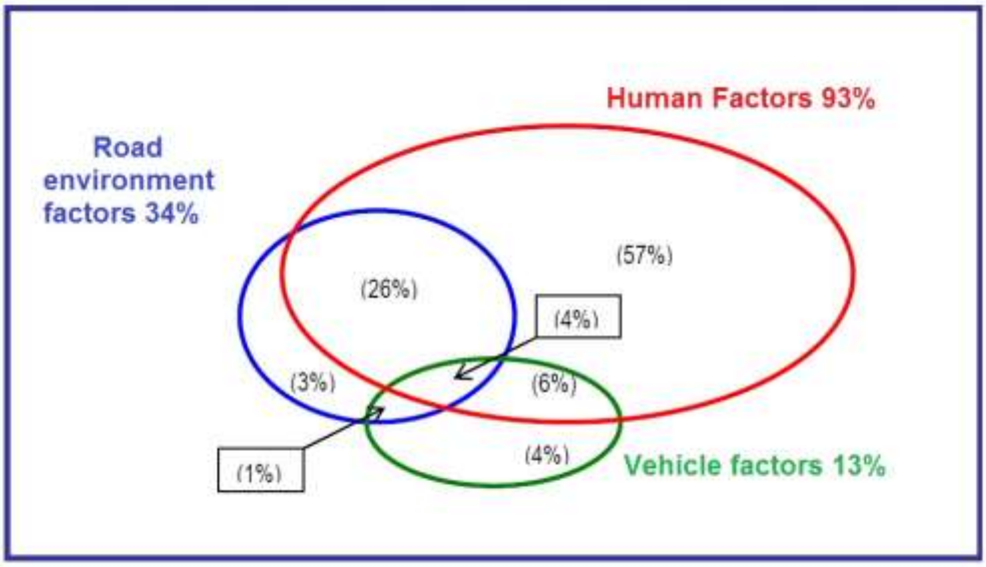


Figure 2- 4: Factors contributing to crashes

Source: (RTMC, 2012)

The road is recognised as part of the system in which drivers perform and it often contributes to the final system demand that cannot be met (Glennon & Hill, 1996).

Ogden in his seminal book Safer Roads: A Guide to Road Safety Engineering places the responsibility to design the system to accommodate the fallible human with the road authorities:

> We saw the need to determine what a human was capable of, and found that humans need certain information to make decisions, that they take time to receive and process that information and arrive at those decisions, and that they sometimes make incorrect decisions. This put the responsibility upon road authorities and others to design the system to accommodate the human, and not the other way around (Ogden, 1996).

Older roads often lack safety design features and additional information must be given through road signs and markings to compensate. Furthermore, the road and its environment change and deteriorate continuously. To ensure that the road remains reasonably safe, the road elements that affect safety, such as the road surface, signs and recovery areas must be properly and systematically maintained. Hirasawa, Asano and Saito noted that in Japan between 1997 and 2002, 120 court-settled disputes involved road management defects; however, 165 311 claims were settled out of court. Most of these claims related to differences in road level and holes in the road surface, as well as flaws in safety facilities (Hirasawa, Asano, & Saito, 2005).

2.3.2 Road design and maintenance policies and strategies

Two types of policies are relevant for road safety, namely:

- Policies on the design and maintenance of roads that are addressed below; and
- policies with respect to road safety and the political will to reduce road fatalities and accidents. These community value-driven policies are elaborated on in Chapter 3 on legal duty.

Road design policies are typically contained in the road design guidelines and manuals. The 2003 Geometric Design Guidelines (SANRAL, 2003) states that design must subscribe to a more holistic philosophy founded on the concept of reducing the probability of failure and minimising the consequences of those failures that do occur. Road designs must have a clear understanding of purpose and functionality that will lead to the selection of appropriate design elements. These elements must be integrated into the road environment and cater for the road's current and future use. Road design is the ability to optimise conflicting objectives of which safety is the prime consideration. The road design engineer (which includes the road engineer, civil engineer, construction engineer or whatever is appropriate) must provide, through road signs and markings, all the information the driver needs to make a correct decision timeously, and at a rate that does not exceed the driver's performance.

The most comprehensive road design policy is the Policy on the Geometric Design of Highways and Streets published by the American Association of State Highway and Transportation Officials (American Association of State Highway and Transportation Officials, 2004):

> A common characteristic of many high-accident locations is that they place large or unusual demands on the information-processing capabilities of drivers. Inefficient operation and accidents usually occur where the chance for information-handling errors is high. At locations where the design is deficient, the possibility of error and inappropriate driver performance increases.

At design time, the designer of the road accepts that the road will be in a good condition, and failure to maintain the design elements to the expected standards can then increase the system demands on the driver beyond the guidelines used by the engineer. These additional demands can then result in more and unexpected accidents at the points of maintenance failure.

SANRAL recognises the interaction between safety and maintenance. Its comments on the Programme Performance Indicator for Strategic Objective 2: Provide safe roads is that the target of 100% is achieved because it has a longstanding policy to have active maintenance contracts on all of its roads (SANRAL, 2015).

These Routine Road Maintenance (RRM) contracts cover the entire proclaimed national road network. The aspects maintained are crack sealing and patching, repair and cleaning of existing drainage systems, repair and renewal of fences, road signs, road studs and guardrails, burning of firebreaks, protection of the environment through maintenance of trees and shrubs, weed and litter control and emergency assistance. The site management team provides:

> assistance in the management of the national road network by monitoring the performance of the roads and alerting SANRAL to matters like illegal practices, road safety issues, road performance and encroachments. The team is required to inspect the site frequently so that problems are identified, the causes investigated and assessed and the actions required identified and carried out timeously (SANRAL, 2009).

Botswana's road policy falls under the direction of the Ministry of Works, Transport & Communications (Roads Department). It is responsible to provide adequate, safe, cost-effective and efficient road infrastructure within Botswana and at border crossings. Implied in these far-ranging responsibilities is the obligation to

> 1. Ensure that *existing roads are adequately maintained* in order to provide appropriate level of service for road users;
>
> 2. *improve existing roads* to required standards to enable them to carry prevailing levels of traffic with the required degree of safety; and
>
> 3. *provide new roads* to the required geometric, pavement design and safety standards" (Ministry of Works, Transport and Communications, Botswana, 2000).

The Australian strategy it is based on the Safe System approach to road safety. This approach is pre-emptive and requires that the condition of any element of the road system does not deteriorate below safe values or standards. Road safety elements such as guardrails that mitigate damage during and after accidents must not only be provided, but maintained, as they are often in vulnerable locations, as indicated in the National Road Safety Strategy 2011 – 2020 (Australian Transport Council, 2011):

> Safe System approach to improving road safety. Safe System principles require a holistic view of the road transport system and the interactions among roads and roadsides, travel speeds, vehicles and road users. This is an inclusive approach that caters for all groups using the road system, including drivers, motorcyclists, passengers, pedestrians, bicyclists, and commercial and heavy vehicle drivers. Consistent with our long-term road safety vision, it recognises that people will always make mistakes and may have road crashes — but the system should be forgiving and those crashes should not result in death or serious injury.

The Safe System approach was adopted in Australia during the period of the previous national strategy, through the National Road Safety Action Plans and the strategies of individual states and territories. It is consistent with the approaches adopted by the safest countries in the world, and is a central theme of the landmark Organisation for Economic Co-operation and Development (OECD) report Towards Zero: Ambitious road safety targets and the safe system approach, published in 2008 [9].

There are several guiding principles to this approach:

1. People make mistakes. The transport system must be designed to accommodate or compensate for human error. Death or serious injury should not be an inevitable consequence of errors on the roads;

2. Human physical frailty. There are thresholds to the energy and forces that the human body can absorb in relation to the severity of injuries. Designers and operators must factor in the limits of the human body in designing and maintaining roads, vehicles and speeds;

3. A 'forgiving' road transport system. A Safe System ensures that the forces in collisions do not exceed the limits of human tolerance. Speed as the determinant of energy must be managed so that humans are not exposed to excessive impact forces; and

4. Safe Roads. Roads and roadsides designed and maintained to reduce the risk of crashes occurring and to lessen the severity of injury if a crash does occur. Safe roads prevent unintended use through design and encourage safe behaviour by users." (underlining: LdVR).

2.4 Road maintenance systems and asset management for safety

The literature review in this section explores road maintenance systems and asset management for ensuring safer roads. Knowledge of the processes contained in these systems leads to understanding the need to develop engineering standards for road elements and systems in maintenance that are sufficient to comply with the legal duties of the road authorities towards road safety.

Road Maintenance Systems (RMS) started with the development of Pavement Management Systems (PMS), as this represented the most costly elements of the road. The most urgent task was not only for road authorities to prioritise maintenance that addressed the road sections in the worst condition first, but also to predict the long-term funding needs. Pavement includes lanes and shoulders. These elements degenerate due to traffic loading, leading to surface and base failures that manifest as potholes, rutting, and loss of texture if preventative maintenance is not done. The precursor to PMSs developed from strategies to prioritise maintenance in the 1960s. The best known pioneer PMS was implemented in 1982 by the WSDOT as the Washington State Pavement Management System (WSPMS) (FHWA 2008). The PMS is a pavement preservation philosophy based on engineering analysis: Good roads cost less to maintain and operating cost for the road users are lower. Preventative maintenance extends a pavement's service life and provides safer road conditions.

Management systems for road infrastructure started developing in the 1970s. They were one of the first applications of the mainframe computers to civil engineering. In 1991 the federal Intermodal Surface Transport Efficiency Act (ISTEA) highlighted the management and monitoring systems. It mandated such systems for highway pavements, bridges, congestion, safety, public transit assets, intermodal facilities and functions and the monitoring of traffic data (Markov, 1995). The development and declining cost of fast personal computers and field survey equipment since then has allowed road authorities and consultants to evolve these systems into modern asset management systems that have been extended to all civil and building infrastructure, especially in the public sphere.

Operational management systems, such as for pavements and bridges, were integrated with economic analysis and design standards to identify optimal strategies and trade-off of initial construction cost and maintenance over the design life analysis period. In the 1980s the World Bank financed the development of the Highway Development and Management Tool (HDM) to support projects that would last (Markov, 1995).

The Asset-Management Framework for the Interstate Highway System (NCHRP 2009) states that the two main thrusts of road infrastructure asset management are pavement and maintenance. The following excerpts define what these systems entail:

> **Pavement**
>
> PMSs are used to collect, store and retrieve pavement inventory and condition data. These systems are used to reduce data, summarise conditions, support development of pavement treatment rules, model future conditions, and perform analysis of investment needs, and develop standard query reports.
>
> Typically PMSs allow for specification of multiple measures of distress, including roughness, rutting, cracking/ faulting, and other measures. Most systems support flexible specification deterioration models for each measure of distress and decision rules, allowing for a range of treatments triggered by different distress measures. The available systems use different approaches to project-level analysis for recommended specific treatments over time for given pavement section and network-level analysis for predicting overall conditions over time given a budget constraint and/or other constraints.
>
> **Maintenance**
>
> Maintenance management systems (MMS) often are used to inventory and characterise conditions of roadside assets besides pavements and bridges, including road shoulders, non-bridge structures, and safety features. Transportation agencies use a number of different tools to support their maintenance management functions (NCHRP, 2009).

Locally, SANRAL designs the maintenance of sections of the route based on its PMS. The two main thrusts are combined to determine strategies for reseal, rehabilitation or new construction projects, depending on the residual life of the pavement, projected traffic and availability of funding (SANRAL, 2009).

The NCHRP (2009) confirms that there is a need for standard measures of condition for other assets beside pavement and bridges. This includes level of service standards for asset management. This need for standards also applies to road safety. This thesis provides a starting point to define characteristics and appropriate standards that need to be measured for local asset management for maintenance to achieve road safety.

Pavement management systems progressed to infrastructure asset management systems. Asset management systems can be traced to systems that manage operations and life cycle analysis of capital goods and the systems that value these capital goods for accounting purposes such as current values for the balance sheet and depreciation. Asset management supports and guides managers to ensure funding is targeted towards the best use of limited resources to deliver the maximum community benefit. Road asset management is defined in the Australia's Guide to Asset Management (GAM) (Austroads, 2009) as follows:

> Road asset management is a comprehensive and structured approach to the long-term provision and maintenance of physical road infrastructure using sound engineering, economic, business and environmental principles to facilitate the effective delivery of community benefits.

The Austroads report on Asset Management within a Safe System defines the key objective of asset management as the minimisation of life-cycle costs of road assets, while aiming to meet the needs and expectation of the community and to fulfil government objectives such as safety, environment and equity of access (Austroads, 2013a).

Note: Australia and the US are leaders in road safety research. Both countries' asset management systems are discussed. However, as Australia's road conditions are similar to South Africa's and its published research is current, a discussion on its road maintenance systems is deemed appropriate. Further, its Safe System has been globally recognised and applied.

The report on Road Safety Engineering Risk Assessment – Part 11: Road Safety and Maintenance (Austroads, 2010b) sets out to integrate road safety and asset management, a logical extension of the concepts of geo-referenced inventories of assets, with supplementary sets of attributes, associated standards and trigger values to direct attention to road safety issues.

- The report describes how a series of workshops was held with road authority personnel and other stakeholders in most Australian jurisdictions and in New Zealand to determine whether better safety outcomes could be achieved through adjustments to asset management practice. The conclusions and recommendations regarding maintenance were that it is important to develop the knowledge base in this area to enable a more evidence-based approach and to rely less on subjective judgments (Austroads, 2014a).

Each of the maintenance issues was considered in terms of:

- the recommended assessment level (i.e. the condition of the asset at which restoration should be considered);
- the expected effects of the intervention on crash reduction; and
- an appropriate risk model based on expected crash reduction values.

The researcher supports such an evidence-based approach in setting standards for maintenance to achieve safer roads.

An appropriate risk model for maintenance issues was developed during a research project to design an Australian National Risk Assessment Model (ANRAM) in 2014. The main aim of the project was to develop a guide on severe crash risk reduction programmes to help achieve progress towards a Safe System. Secondly, the project sought to develop an implementation guide for adoption of the ANRAM by road agencies (Austroads, 2014a).

The relevance of such a risk model for South African road authorities is the following: If a similar model could be calibrated for South African conditions per class of road under their jurisdiction, a defence against a claim could be formulated, based on a justification of the importance of the route and the reasonableness of the priority given to maintaining the road.

The Safe System approach as the end state to be progressed to, establishes an ethical position that no person should die or be seriously injured on the road. To fulfil this vision there is a requirement to identify parts or segments of the road network that require treatment (Austroads, 2014a).

The risk matrix in Figure 2-2 shows the application of a risk assessment on roads. The collective risk of severe crashes is presented on the horizontal axis, as the predicted number of Fatal or Severe Injury (FSI) accidents per km. The individual risk is presented on the vertical axis, as the section-averaged total ANRAM Safety Rating Scale (SRS). The illustrative road categories are based on an Australian trial and are not transferable to the South African road safety environment. The bottom left green zone representing freeways with a low SRS and low predicted FSI accidents is, however, analogous to South African freeways and the risk management strategy in the green zone is to maintain the safety features. South African freeways are well-designed and the accident rates in fatalities per million Vehicle Km Travelled (VKT) are low. The right top zone in red represents hazardous roads: a high SRS value with high number of predicted FSI accidents. The risk management strategy aims to transform the roads to Safe System principles. It identifies which road types should be attended to as a priority and justifies the allocation of resources (Austroads, 2013a).

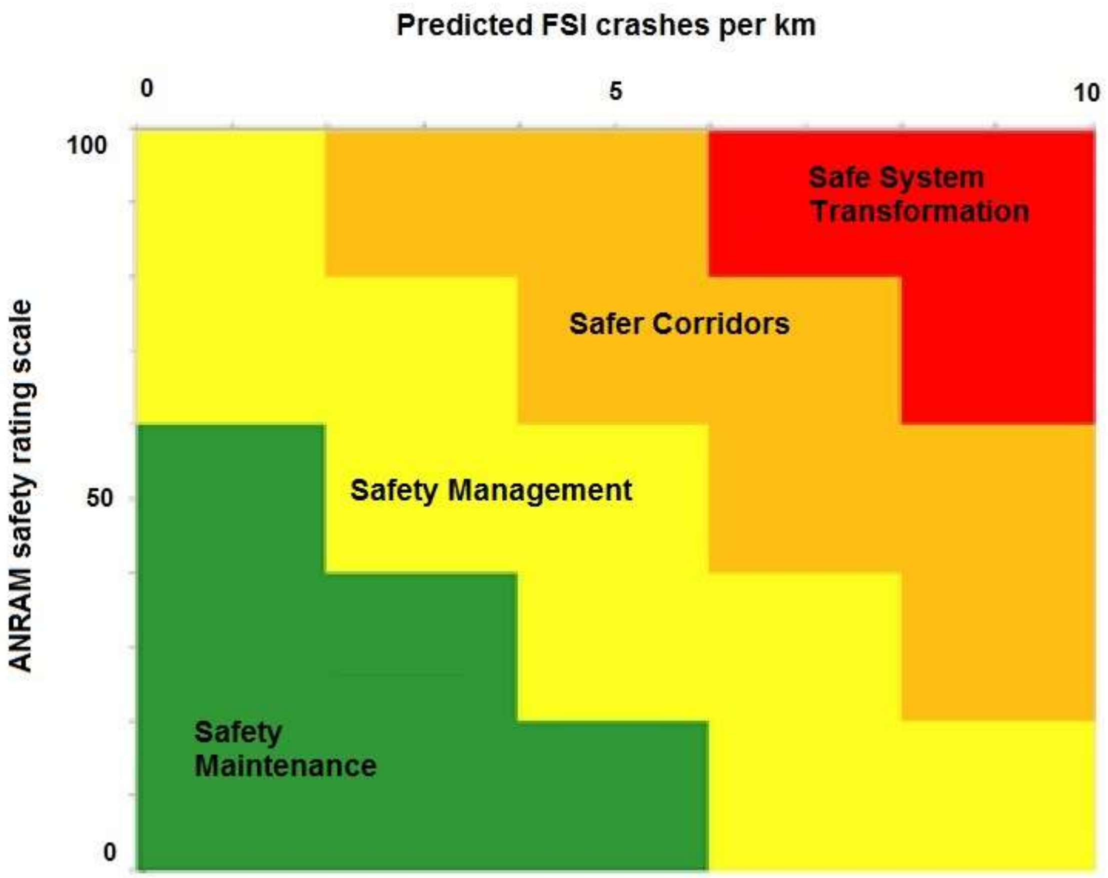


Figure 2- 5: Risk matrix for the application of a risk assessment on roads

Source: (Austroads 2013a)

In this matrix, the zones identified indicate the following strategies:

- *Safety Maintenance* is appropriate where personal crash risk and crash density is low, and there is little evidence of a serious safety problem. However, there may be scope for treating crash clusters or shorter sections of the route for which crash data or other tools such as KiwiRAP and ANRAM predict higher levels of risk.
- *Safety Management* responses would be well-suited to a common scenario on road sections found in a rural or local government setting, where low traffic volumes and legacy road design contribute to unsafe travel for relatively few road users of that section (high individual risk). The impact of low traffic volumes is the low collective risk and possibly no crash history. Recognising the low economic return on investment into Safe System transformation works for such road sections (for example, road duplication, freeway-style interchanges), the framework proposes a low-cost approach to treatment selection, preferably extending across the entire network of similar roads.
- *Safer Corridors* are likely to be effective in circumstances such as an inner-metropolitan arterial, where much of the viable road safety investment has occurred already, and the high collective risk is often driven by high traffic volumes and mixed road use (for example, pedestrians, public transport, and cyclists). In such a context, a targeted black spot approach and other forms of road safety intervention such as route safety reviews and strategic reassessment of route function may also be highly effective (for example, rerouting through traffic to safer routes, and/or pedestrianisation).

- *Safe System* transformation works, for example, a major upgrade or provision of an alternative, safer standard route, should be considered on road sections with higher volumes and constrained design or poor alignment. These typically include rural/outer-metropolitan highways which are likely to score relatively highly in both collective and individual risk areas Asset Management within a Safe System: Final Report.

The use of a risk assessment approach in South Africa requires values to calibrate the Safety Rating Scale. The development of standards for the attributes of road elements and for road maintenance in particular would be required to calibrate this approach for a local context.

When risks have been identified, mitigation measures should be implemented. These treatments should be borne in mind when defining road maintenance standards for safety as the value of a standard may depend on the treatment that can be implemented. For example, the risk of rock falls on Chapman's Peak Drive near Cape Town was a focus point in the case of Graham v Cape Metropolitan Council 1999 (3) SA 356 (C) (as discussed in Chapter 7). The risk could be treated by closing the road, stabilising the slopes, building rock shelters or informing users of the level of risk.

These treatments fit into a typology developed by the International Organisation for Standardisation (also known as the ISO). The ISO describes risk treatments that deal with negative consequences as "risk mitigation", "risk elimination", "risk prevention" and "risk reduction". Risk treatment could involve:

- Avoiding the risk by deciding not to start or continue with the activity that gives rise to the risk;
- taking or increasing risk in order to pursue an opportunity;
- removing the risk source;
- changing the likelihood;
- changing the consequences;
- sharing the risk with another party or parties (including contracts and risk financing); and
- retaining the risk by informed decision.

It is noted that risk treatment could create new risks or modify existing risks.

A 2012 Transport Research Laboratory for Transport Scotland study on economic, environmental and social impact of changes in maintenance spend on roads in the country investigated different expenditure scenarios and found that every £1 reduction in local road maintenance spend could result in a cost of between £1,67 and £1,76 to the wider Scottish economy. The reduction of road maintenance funding below the sustainable levels results in externalities in the form of higher operating cost, accidents and inefficiencies (Audit Scotland, 2013).

This is highly relevant in South Africa and underscores the importance of road asset management.

2.5 Features, characteristics and attributes of road maintenance

This section of the literature review focuses on identifying the most important road maintenance features and their attributes that have a road safety implication. Sources that list multiple features that impact on safety have been reviewed and the specific features relevant to road maintenance are listed. The attributes of these features and characteristics are discussed in further detail in Chapter 5.

2.5.1 Road maintenance terminology

The terminology of road infrastructure asset management can be confusing as many terms are synonymous or closely related. Two conventions of state road officials in the US and Canada on maintenance quality assurance defined the terms to be used as a first priority:

- The National Workshop on Commonly Recognized Measures for Maintenance, which was held in Scottsdale, Arizona in June 2000 (Booz-Allen & Hamilton. Inc., 2000); and
- first Maintenance Quality Assurance (MQA) Peer Exchange, which was held in October 2004 in Madison, Wisconsin.

Smith and Adams reviewed the outcomes of these conventions and presented a paper on Measures for Highway Maintenance Quality Assurance (MQA) to the Mid-Continent Transportation Research Symposium. MQA is a process that uses quantitative or qualitative indicators to assess the performance of maintenance programmes. These programmes are outcomes-based and provide statistically valid, reliable, and repeatable measures of asset conditions (Smith & Adams, 2005).

The results were also presented as a paper on the synthesis of measures for highway quality assurance at the Transportation Research Board Annual Meeting that formed the basis of further reports using the terminology (Smith & Adams, 2006). The definitions of the fundamental terms were listed as follows:

1. *Maintenance category*: A maintenance category is a logical grouping of maintenance features based on their location or function along a highway. Examples include pavement, shoulders, and traffic management. Categories are made up of features whose condition is measured with respect to a particular characteristic.

2. *Maintenance feature*: A maintenance feature is a physical asset or activity whose condition is measured in the field. There is one or more maintenance feature in each category. Collectively, the maintenance features describe the maintenance quality of a maintenance category.

3. *Maintenance characteristic*: A maintenance characteristic is a specific quality/ defect in a maintenance feature that is condition-evaluated (for example, signs can be

evaluated with respect to retroreflectivity, appearance, sign height, and other characteristics/deficiencies).

4. *Standards*: A standard is a criterion for determining whether a characteristic or feature requires maintenance attention. A standard can be thought of as a tolerance level that helps identify whether a feature is functioning as intended. Standards may also help identify the particular aspect of the feature that should be measured.

5. *Measures*: Measures describe ways to quantify the deficiency of a maintenance feature (for example, linear feet, percentage area, or amount of deficiency).

6. *Thresholds*: Thresholds are predetermined system-wide maintenance levels for features and categories. Thresholds can be thought of as a grading scale or LOS indicator for MQA. Thresholds indicate how much or what percentage of the system is with or without deficiency. Thresholds also relate measures to customer satisfaction.

7. *Targets*: Targets relate thresholds to the maintenance budget. The target represents the expected threshold level that is attainable.

The terminology was subsequently used in reports such as the Model Guide for Condition Assessment Systems (Zimmerman & Stivers, 2007) and Australian research into asset management. The authors, however, added the important term "attribute" without defining it. This term has defined meaning in computer programming, where attribute is described as the part of a tag with an equal sign and a value, a descriptor of a characteristic. The term will be used in subsequent chapters, as the standards for characteristics to be developed are specific values (criteria) of attributes that will trigger safety maintenance.

The term "standard" has a specific meaning in quality management as manifested in the International Standards Organisation and its national equivalents. The following important definition and aspects were obtained from the ISO website under Frequently Asked Questions:

> A standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose.
>
> ISO standards are voluntary. ISO is a nongovernmental organisation and it has no power to enforce the implementation of the standards it develops. A number of ISO standards – mainly those concerned with health, safety or the environment – ha e been adopted in some countries as part of their regulatory framework, or are referred to in legislation for which they serve as the technical basis. However, such adoptions are decisions by the regulatory authorities or governments of the countries concerned. ISO itself does not regulate or legislate. Although voluntary, ISO standards may become a market requirement, as has happened in the case of ISO 9000 quality management systems, or ISO freight container dimensions. (ISO, n.d.)

The South African Bureau of Standards (SABS) is a statutory body that was established in terms of the Standards Act, 1945 (Act 24 of 1945) and continues to operate in terms of the Standards Act, 2008 (Act 8 of 2008) as the national standardisation institution in South Africa, mandated to:

- Develop, promote and maintain South African National Standards (SANS);
- promote quality in connection with commodities, products and services; and
- render conformity assessment services and assist in matters connected therewith (South African Bureau of Standards, 2016).

South African National Standards (SANS) have been developed for many products and processes used in civil, road and traffic engineering. The SANS 1519-1: 2014 Road signs Part 1: Retro-reflective sheeting material is a prime example (South African Bureau of Standards, 2014). Clients specify the quality standards to the SANS specification and the supplier is bound to supply material that satisfy these standards.

It is proposed that the standards for road maintenance for safety become a regulatory requirement or at least an industry requirement over time as the norms proposed become entrenched in both technical and legal use.

2.5.2 Road features

The road maintenance features are a subset of a wide range of features of the road. These features can be categorised in functional groups, which are further divided and subdivided to the level where a range of values can be assigned as attributes to a characteristic. Specific values in the range could be identified as descriptors of safety, with some being hierarchical ranges (low risk to high risk), others being triggers or thresholds. This breakdown of categories of features, down to attributes, is illustrated in the Table 2-5.

Table 2- 5: Road features portrayed in categories of features

				Road		**Assets**				
Categories										
	Bridge			Roadway		Roadside			Drainage	
Features								Features		
Ballustrade	Deck	Pier						Side drain	Culvert	Cut off
			Features				Features			
	Lane	Shoulder	Marking	Median		Guardrail	Vegetation	Fence	Verge	Signs
Character-istics	with	Attributes					Characteristic		Attribute	
Width	Cross fall	Texture	Edge	Drop-off				Wire fence		
Measure-ment		Depth of aggregate					Measurement	Present		
Norms		1 to 3 mm					Norm	Present		
Standard		1 mm					Standard			

Zimmerman and Stivers (2007) list commonly-used features in condition assessment in 40 states in the US. The attributes are given per asset category and type (feature). Each of the categories, except the special facilities, has features of which the maintenance has a safety implication. Features may have more than one attribute. They include the following:

- Drainage, including culverts, flumes, curbs and gutters, sidewalks, ditches or slopes, drop inlets, and underdrains/edge drains;
- roadside, including fence, landscaping, plant beds, and sound barriers;
- pavement, including paved shoulders, unpaved shoulders, and paved roadways;
- bridge, including all bridge structures;
- traffic items, including signals, signs, pavement markings, pavement markers, guardrail end treatments, overhead sign structures, impact attenuators, and protective barriers; and
- special facilities, including rest areas, tunnels, weigh stations, and traffic monitoring systems (Zimmerman & Stivers, 2007).

2.5.3 Road characteristics or attributes

Glennon and Hill co-authored a book that presents an extensive overview of the road safety issues that could lead to liability of road authorities arising from claims (Glennon & Hill, 1996). The book is divided into the engineering aspects written by Glennon and the legal aspects by Hill. The engineering section identifies and describes the broad categories of road safety problems that lead to the most frequent accidents and therefore claims. Values for measurable characteristics or attributes are given, but standards or thresholds are not prescribed. According to Glennon, roadway defects were still common in 1996 despite claims and research into road safety effects of road elements and advances in roadway safety technology. Older roadways had become more hazardous due to increased speed limits. The increase in accidents in the US after the repeal of the National Maximum Speed Law in 1995 from 55 to 65 mph was estimated to be 3.2% in the period 1995 to 2005 compared with the period 1974 to 1995 when the 55 mph limits were in force (Friedman, Hedeker, & Richter, 2009).

The typical hazards related to maintenance that Glennon identified as dangerous were hydroplaning, pavement edge drop-offs, sight-restricted intersections, non-crashworthy bridge rails, hidden, unmarked or ill-marked roadway curves and intersections. Other features were of lesser concern, but were also discussed and measures to mitigate or eliminate these hazards proposed. These features with a safety implication on maintenance are presented in the Table 2-6:

Table 2- 6: Typical road hazards that require maintenance

Category	**Feature**	**Typical problems**
Drainage	Structures culverts	Clogged or interrupted flow; structural deterioration
	Curb and gutter	Structural damage or deterioration; settlement; interrupted flow
	Ditch/Slope	Inadequate drainage due to settling or debris; eroded

		flowline
	Drop inlet	Blockage; broken/missing grate; structural deterioration
	Underdrain and edge drain	End protection damage; pipe blocked or crushed
Roadside	Fence	Length of fence (or fabric) damaged; length of broken posts
	Grass mowing	Grass height
	Brush	Obstructions; encroachment on travelway
Pavement	Paved shoulders	Drop-off; structural distress
	Unpaved shoulders	Drop-off; build up
	Paved surfaces	Structural distress; cracking; faulting; functional distress; roughness
Traffic Items	Signs (ground and overhead)	Post or panels damaged; pole or post plumb (or orientation); visibility at a standard distance (or legibility)
	Pavement marking	Day visibility; missing or damaged marking; night retroreflectivity
	Pavement marker	Number of missing, damaged, or nonreflecting; obstruction
	Guardrail	Post or rail damage; length functioning as originally intended; structural integrity
	Guardrail end treatment	Post or rail damage; orientation; functionality
	Impact attenuator	Damage; functionality; percent operational

Horak, Emery and Agaienz (2001) refer to key performance indicators (KPIs) designed to be objective measures of performance for a road authority. Under the performance aspects that need to be addressed in asset management KPIs for roads, they list the following aspects that have a maintenance implication: skid resistance, rutting, texture, roughness, corridor vegetation control and timeliness of response to complaints (Horak, Emery, & Agaienz, 2001).

The US Transportation Research Board surveyed the quality management of pavement data (Flintsch & McGhee, 2009). The survey was aimed at the structural maintenance of the pavement, but many of the features listed in the responses were safety-related. Rutting, bleeding and edge cracking were particularly unsafe.

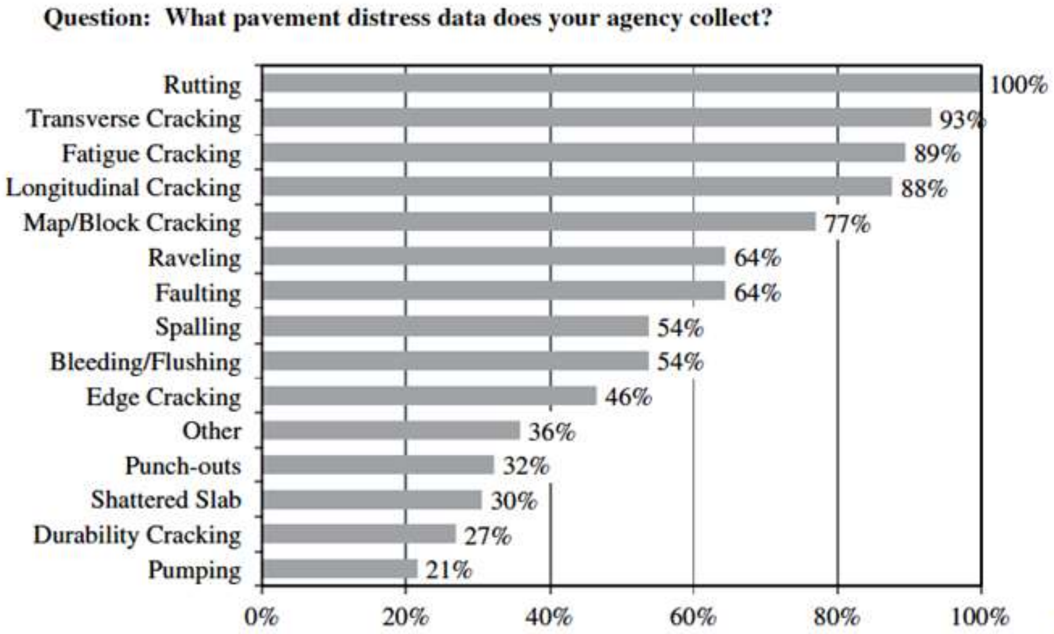


Figure 2- 6: Pavement condition distress factors

Source: (Flintsch & McGhee, 2009)

The Austroads report on Road Safety Engineering Risk Assessment Part 11: Road Safety and Maintenance compiled a list of issues and safety implications. What is described as issues are the attributes of road elements or characteristics. The attributes and a short description of the safety implications are presented in the Table 2-7 (Austroads, 2010b):

Table 2- 7: Road attributes and safety implications

Attributes	**Safety implications**
Skid resistance	High risk of wet weather crashes occurs when skid resistance is low. Resurfacing reduces this risk.
Macro-texture	For spray seal surfaces, crash risk increases considerably when macro-texture is less than 1 mm in sand patch test depth (SPTD) units. Resurfacing reduces this risk.
Rutting	Crash rate increases by 25% when rut depth exceeds 20 mm.
Roughness	There is no good data relating crashes to roughness.
Drainage	If a water film forms across a road, it will result in partial or total loss of contact between the tyre and the road surface. Loss of contact between the tyre and the road greatly reduces the ability of the vehicle to stop and steer.
Signs	Research on reflectivity, positioning, damaged or missing signs provides information about the intervention levels, but much less confidence can be placed on the risk reduction estimates.
Linemarking	Linemarkings with a level of less than 100 mcd/lux/m2 are regarded as ineffective at night. The renewal of centre lines and edge lines would reduce crash risk by 20%.
Retroreflective pavement markers (RRPMs)	The limited research available showed a 2% reduction in overall crashes if RRPMs were more reflective at night.
Guide posts	A 30% reduction in crashes could be achieved if guide posts meet the minimum retroreflectivity standard of 4.6 mcd/lux. However, the issue of guide

	posts is limited to guide post reflectivity.
Edge drop	A drop of 75 mm increases crash risk. Restoring the shoulder level or providing an adequate slope on the face of the drop may also reduce crashes.
Edge wear	Edge wear can result in loose material being thrown onto the road surface, and thus affect the safety of motorcyclists and cyclists. Repairing edge wear is only associated with a crash reduction of 1 – 1.5%.
Roadside vegetation	No relevant literature could be found on overhead branches having effects on traffic control devices. However, it is assumed that there would be an increase in crashes equivalent to that if no sign was present.
Street lighting	No relevant literature was found on vegetation management to prevent trees obscuring lights. It is assumed that proper management of vegetation would reduce night-time crashes.
Vegetation reducing sight distance at intersections	Vegetation obstruction of sight distance at intersections can increase the risk of crashing by 33%.

Austroads (2013a) gives a wide range of features of a Safe System from which the following attributes for maintenance were taken:

- *Roadside elements* that include clear zones (to be maintained to function adequately) and barriers (to be functional); and
- *cross sections* that include sealed shoulders and line marking.

The Safe System interestingly does not consider failures, such as the presence of potholes, and the focus is on safety features that deteriorate over time or due to impacts. For this policy to succeed, the nominal safety features, such as functional roadway, are given.

The UK Road Board and Institute for Civil Engineers listed circumstances that cause accidents with associated potential consequences and the possible liability of the road authority. The circumstance that could be rephrased as road attributes affecting maintenance are listed as:

- Trips / rocking slabs (pedestrian sidewalks);
- potholes;
- obliterated markings at road junctions;
- poor surface friction (skid resistance);
- aquaplaning;
- defect arising from utility apparatus (missing manhole covers);
- unexpected hazards on the road, for example, debris, plant materials;
- worn-out signs warning of obvious hazard; and
- restricted visibility at a junction (UK Highway Liability Joint Task Group, 2009).

2.6 Road maintenance procedures

In this subsection, the literature review looks at road maintenance procedures, with the focus on types of maintenance, inspections, monitoring and reaction to events and incidents that have an implication on road safety. The actual road maintenance methods and work breakdowns, often also called procedures, are not discussed.

Maintenance is defined as the preservation and keeping of the roadway, facilities and structures functional to keep traffic moving safely (Woods, 1960). This early source is quoted to illustrate that the notion of maintenance and safety has been around for a long time. It follows that procedures must be in place to identify, plan and execute maintenance.

When investigating road management procedures, the components and types of road maintenance must be defined. The types most often defined in literature are reactive, routine, periodic and preventative and special (World Bank, 2015).

2.6.1 SANRAL maintenance types

Road authorities select the types to fit in with their strategies and objectives. In South Africa, SANRAL is the most influential and progressive road authority that implements contracted routine road maintenance. The SANRAL definitions are as follows:

Routine *ad-hoc* (R): Routine maintenance may be defined as those treatments that are applied to a pavement, in order to keep the pavement functioning properly. As such, routine maintenance is sometimes referred to as “reactive maintenance.” This suggests that it is work that is performed as a reaction to a specific distress. Routine maintenance is performed on pavements as they begin to show signs of deterioration. However, it is generally considered to be a wasted effort on pavements that are severely distressed.

Filling a pothole is an example of a routine maintenance activity: It cannot be scheduled before the pothole appears and it should not be left unattended once the pothole has developed. However, if there are too many potholes present, more comprehensive repair may be needed. In addition to pothole repair, routine maintenance treatments applied to pavements include edge patching, crack sealing and filling, and shoulder repair. Routine maintenance works are divided into the following works types:

- Non pavement (N): These include all the activities that are accomplished outside of the road surface, like clearing side drains and culverts, vegetation control, line-marking, road signs repair, guardrail repair, *etc*.; and
- Pavement (P): These are works responding to minor pavement defects caused by a combination of traffic and environmental effects, for example, crack sealing, patching, edge repair; shoulders re-gravelling and grading

Routine operations (O): Routine operations may be defined as those activities that are conducted on an annual basis to ensure that the road is functioning properly. Routine Operations are not only limited to pavement-related treatments, but also include other operational activities. Routine operation works are divided into the following works types:

Special maintenance: As with routine maintenance, special maintenance could be classified as “reactive" road works due to unplanned circumstances. These circumstances could be the result of natural phenomena such as flash floods, or damage caused due to accidents. Special maintenance is divided into the following works types:

- Non pavement (N): This comprises works undertaken to clear a road that has been cut or blocked. Included are traffic accident removal, clearing debris, and repairing washout/subsidence;
- Pavement (P): This normally involves the repair of selected pavement areas that fail due to latent defects, thus enabling the rest of the pavement to achieve its anticipated design performance or life; and
- Bridge (B): This normally involves the repair of selected bridge elements that fail mostly due to latent defects, thus enabling the rest of the bridge to achieve its anticipated design performance or life (SANRAL, 2009).

2.6.2 Other maintenance types

The UK Code of Practice for Well Maintained Highways, 2005, brings in programmed and regulatory maintenance as types, as follows:

- Reactive maintenance responding to inspections, complaints or emergencies;
- routine maintenance providing works or services to a regular consistent schedule, generally for patching, cleaning and landscape maintenance;
- programmed maintenance providing larger schemes primarily of resurfacing, reconditioning or reconstruction to a planned schedule; and
- regulatory maintenance inspecting and regulating the activities of others.

The Code of Practice for Well Maintained Highways adds the weather and other emergencies providing a planned emergency response as a type of maintenance. It is rather viewed as a special service that can be efficiently rendered by the maintenance teams or contractor (Roads Liaison Group, 2005).

2.6.3 Standard operating procedures

Road maintenance procedures provide guidance for maintenance execution. The standard operating procedures are based on the collective wisdom and technical knowledge of the industry. The Preface to the SANRAL Routine Road Maintenance Manual tells how the manual was compiled by two experts in 2000 following extensive discussions with engineers and route managers. It was based on proven South African experience. It was updated following further experience and industry input gained in applying the manual and the second edition was published in 2009 (SANRAL, 2009).

Procedures involve the inspection and monitoring of the road conditions and the performing of the work. The specifications for inspection frequencies for classes of roads per asset type and feature type – and not detail work procedures – are key aspects of the thesis.

In order to spend the limited budget in a reasonable and logical manner, it is accepted practice that high-volume, strategic and economically important roads are prioritised over lesser roads. The institutionalisation of hierarchies of roads, based on the primary functions of mobility and access, has developed based on the separation of through and local traffic. The South African guideline on classification of road was developed from Proposed Functional Classification of the Statutory Road Network in South Africa (RIFSA). It culminated in the TRH 26 South African Road Classification and Access Management Manual (COTO, 2012). The classes of road are given in the Table 2-8:

Table 2- 8: South African classification of roads

Class	Definition
Class 1	Roads that form the principal avenue of communication, namely • between and through major regions of South Africa; • between provincial capitals and key towns which have significant national economic/social interaction; • between South Africa and adjoining countries; and • have the main function of providing access to major freight terminals, including ports.
Class 2	Roads not being Class 1 with the main function of forming an avenue of communication: • between important centres and between Class 1 roads and key towns within a specific province, on a province-wide basis; and • between important centres, within a specific province which have a significant economic, social tourist or recreation role (e.g. tourism and resource development).
Class 3	Roads other than Class 1 or 2 roads that have the main function of providing the principle arteries for intra-metropolitan traffic and freight movements.
Class 4	Roads that are not Class 1, 2 or 3 and have the main function of carrying inter-municipality social, commercial and industrial traffic within specific metropolitan and district municipality areas.
Class 5	Roads that have the primary function of collecting and distributing all traffic within local municipality areas including developing townships and providing access to the wider road network, as well as the abutting properties.
Class 6	Roads, often undesignated, that have the function of providing the only access to scattered rural settlements and communities of up to 500 persons and which primarily serve local social services as well as access to markets and generally form the first phase of the journey for commuters and migrant workers. These roads often form part of a rural infrastructure development framework.
Class 7	This category comprises special purpose public roads that cannot be assigned to any other class above and, for example are provided almost exclusively for one specific activity or function, such as recreational, forestry, mining, national parks or dam access (COTO, 2012).

Class 1 roads are typically maintained under Routine Road Maintenance (RRM) contracts. The complete SANRAL road network is currently maintained under such contracts. Table 2-9 shows the inspection frequencies for categories and asset features (referred to as elements) (SANRAL, 2009):

Table 2- 9: SANRAL inspection frequencies of road infrastructure assets

Road Elements	Frequency	Road Elements	Frequency
Signs	Yearly	Instabilities	Dependent on degree of problems
Road marking	Yearly		
Guardrails	Weekly		
Structures	Yearly	Informal settlements	Weekly
Flexible road condition	Yearly	Illegal access	Weekly
		Fencing	Monthly
Rigid road condition	Yearly	Illegal signage	Weekly
Drainage	Monthly	-	-

2.6.4 Safety inspections

Authorities in England and the Devolved Administrations are required to undertake condition surveys in order to satisfy the requirements of statutory performance indicators. The inspection of road infrastructure to determine conditions for service and safety is based on a hierarchy of roads and routes in the different categories in the network. The safety inspection frequency proposed in Well Maintained Highways is set out in Table 20-10 (Roads Liaison Group 2005).

Table 2- 10: Safety inspection frequency proposed in Well Maintained Highways

Feature	Description	Category	Frequency
Roads	Strategic route	2	1 month
	Main distributor	3(a)	1 month
	Secondary distributor	3(b)	1 month
	Link road	4(a)	3 months
	Local access	4(b)	1 year
Footways	Prestige area	1(a)	1 month
	Primary walking route	1	1 month
	Secondary walking route	2	3 months
	Link footway	3	6 months
	Local access footway	4	1 year
Cycle route	Part of carriageway	A	As for roads
	Remote from carriageway	B	6 months
	Cycle trails	C	1 year

2.6.5 Codes of practice

Interestingly, road authorities in the UK are not statutorily obliged to undertake inspections of all highway elements under all of these categories. They are, however, strongly advised to undertake safety inspections in accordance with the principles of this code of practice for maintenance management so that they are able to support a defence under Section 58 of the UK Highways Act of 1980 and equivalent legislation. This section requires that a court shall have regard to "whether the highway authority knew or could reasonably be expected to know, that the condition of the part of the highway to which the action relates was likely to cause danger to users of the highway" (Roads Liaison Group, 2005).

The Australian Road Management Act 2004 enables the states to compile codes of practice for road management. The State of Victoria published its road management plan in 2014 (State of Victoria, 2014). With respect to inspection and monitoring, it states that:

> If a road management plan determines an inspection standard, this should include the nature and frequency of inspections to be carried out on road infrastructure. In determining appropriate inspection standards and prioritisations to be specified in the road management plan, the road authority should consider:

- The type of road infrastructure, and the volume and nature of public road usage;
- the scope of inspection;
- community expectations;
- any relevant risk factors; and
- the resources available, and
- the competing demands for those resources.

The road management plan may set out a priority order in which particular road infrastructure, public roads or classes of public roads may be inspected. Vicroads (State of Victoria, 2014) compiled a list of roads in six categories, being Road Maintenance Category (RMC) 1 to 6, based on road classification, road type, traffic volume and traffic composition. The frequency of inspections is shown in Table 2-11 below:

Table 2- 11: Hazard inspection type and frequency by road maintenance category

Inspection type	RMC 1	RMC 2	RMC 3	RMC 4	RMC 5	RMC 6
Day-time	Each week day	Twice per week	Weekly	Every 2nd week	Monthly	Not exceeding 6 months
Night-time	Not exceeding 6 months	Not exceeding 6 months	Not exceeding 6 months	Not exceeding 1 year	Not exceeding 1 year	Not exceeding 1 year

In the Canadian state of Ontario, the maintenance of municipal roads is regulated by law. The patrolling (inspection) frequency is specified as in Table 2-12 (State of Ontario, 2015):

Table 2- 12: Inspection frequency for the maintenance of municipal roads in Ontario

Class of highway	Patrolling frequency
1	three times every 7 days
2	twice every 7 days
3	once every 7 days
4	once every 14 days
5	once every 30 days

2.6.6 Reaction times

The last aspect of procedure is the reaction times for incidents and events. These reaction times will be dictated by urgency (the extent of hazard to safety) and importance of the road. Response codes were developed by VicRoads for categories of features and defects per incident (description of hazards) and road category code. The response codes for pavements are given in Table 2-13 as an example (State of Victoria, 2014). The full list of appropriate response codes is discussed in Chapter 6.

Table 2- 13: Response code by hazard and road maintenance category: Pavements

Description of hazard RMC	1	2	3	4	5	6
Obstructions and substances in traffic lanes						
Materials fallen from vehicles, dead animals, wet clay and other slippery substances, hazardous materials, accumulation of dirt or granular materials on the traffic lane of sealed roads	A	A	B	B	C	F
Ponding of water >300mm deep, fallen trees, oil spills, stray livestock	A	A	A	B	B	F
Pavement or surface defects						
Potholes in traffic lane of a sealed pavement greater than 300mm in diameter and greater than 100mm deep or in the traffic lane of an unsealed pavement greater than 500mm diameter and 150mm deep	A	B	C	C	D	F
Where assessment in accordance with the skid resistance policy indicates remediation is required.	C	D	D	D	D	F
Deformations >100mm under a 3m straight edge	A	B	C	C	D	F
Edge drops onto unsealed shoulder >100mm	n/a	B	C	C	D	F
Drainage						
Damaged or missing drainage pit lids, surrounds or grates in pedestrian areas or traffic lanes	A	B	B	D	D	F

The action to follow the identification of a hazardous condition or failure to be repaired must then be done within the specified time as given in Table 2-14.

Table 2- 14: Road risk action response

Response code	Control mechanism	Response time
A	Inspect and rectify, if feasible, or provide appropriate warning	Within 4 hours of inspection or notification
B		Within 24 hours of inspection or notification
C		Within 1 week of inspection or notification
D		Within 1 month of inspection or notification
E		Within 3 months of inspection or notification
F		Within 6 months of inspection or notification
G*		Within 8 hours of inspection or notification
H*		Within 12 hours of inspection or notification

* These response codes are only relevant to traffic-signal related hazards.

The reference to "appropriate warning" is necessary because factors such as the nature of the work, the cost and resources required, workload and need to get permission from the client can prevent the contractor from responding in the specified time. In the interim, warning of the hazard must be provided. Appropriate warning can be in the form of warning signs, traffic control, traffic diversion, lower speed limits, lane closures, restriction on type of vehicles or total road closures (State of Victoria, 2014).

The Ontario Regulations for Municipal Maintenance specifies the reaction times per failure and road class as separate tables. The reaction times for potholes on a paved surface of roadway are given in Table 2-15 (State of Ontario, 2015).

Table 2- 15: Potholes on paved surface of roadway

Class of highway	Surface area	Depth	Time
1	600 cm^2	8 cm	4 days
2	800 cm^2	8 cm	4 days
3	1000 cm^2	8 cm	7 days
4	1000 cm^2	8 cm	14 days
5	1000 cm^2	8 cm	30 days

Tables of road classifications, inspection frequencies and response times can be obtained from various sources and at national, provincial and municipal levels. The examples discussed here highlight some of the range of approaches. A more detailed analysis follows in Chapter 5.

2.7 Legal duty and cases

Legal duty (strict liability) is to not cause harm; (generally) to act without negligence or intent to cause harm (Loubser, Midgely, Mukheibir, Perumal, & Niesing 2009).

This section provides background on the meaning and development of liability of road authorities internationally and in South Africa. Legal duty as applicable to development of road maintenance standards, with a focus on the current South African interpretation within the context of the road safety environment, is discussed more fully in Chapter 3.

2.7.1 Legal duty – international

In the UK, US, Australia and New Zealand, the branch of law that deals with the unlawful act is the law of torts, while in the Roman-Dutch law it is the law of delict. The main differences lie in the definition of legal duty versus duty of care and the way that reasonableness is tested with respect to the conduct of the road authority. The "duty of care" doctrine used in English law means to take reasonable care; to conform to a certain standard of conduct

> A Duty of Care is a moral or legal obligation to ensure the safety or well-being of others: employers *have a duty of care to* their employees; road authorities *owe a duty of care to* keep roads as safe as possible (Oxford Dictionaries, n.d.-a)

Road authorities are public service bodies, enacted and enabled to provide road infrastructure and operate it to provide mobility and access in national, provincial and local transport networks. The mandate to provide roads is typically expressed in broad terms and the implementation is based on policies and strategies based on political agendas. The South African situation with respect to policies and strategies is elaborated on in Chapter 6.

The duty of care (as the equivalent of legal duty in the English law) developed from the Donoghue v Stevenson (1932) case, where a rotting snail in a bottle of ginger beer caused illness and shock to Mrs Donoghue. The case was considered by the House of Lords and Lord Atkins established the neighbour principle that you must take reasonable care to avoid acts or omissions you could reasonably foresee may be likely to injure your neighbour. Your neighbour is anyone you could reasonably foresee may be closely and directly affected by your actions. This principle developed into the three-stage test in Caparo Industries v Dickman (1990), where the following questions were asked:

> Was damage a reasonably foreseeable result of the defendant's actions?
>
> Was there proximity (legal relationship/closeness) between the claimant and defendant?
>
> Does the court consider it fair, just and reasonable to impose a legal duty of care?

In order to comply with the duty of care, local government associations in the UK published the first Code of Practice for Highway Maintenance in 1983. It was revised in 2001 and 2005.

The objectives of the code include:

- To encourage harmonisation of highway maintenance practice and standards where this is consistent with users' expectations, whilst retaining reasonable diversity consistent with local choice; and

- to encourage the adoption and regular review of a risk management regime in the determination of local technical and operational standards, rectification of defects arising from safety and serviceability inspections and investment priorities (underlining LdVR)(Roads Liaison Group, 2005).

The recommendations of the Code are presented as explicitly non-mandatory, but it is recognised that the content of the Code is relevant in cases of claims or legal action where the claimant will seek to establish non-compliance. The best defence against claims in the areas of road maintenance are compliance with policies, programmes and recommendations of this Code.

The UK Roads Board in conjunction with the Institution of Civil Engineers compiled a guide, the *Highway risk and liability claims: a practical guide to Appendix C of the well maintained highways: code of practice for highway maintenance management* (UK Highway Liability Joint Task Group, 2009).

The stated purpose of the guide is:

- To provide local authority engineers, transport planners, landscape architects, elected members, insurers, risk managers and anyone else with responsibility for providing and maintaining the roads infrastructure, an overview of the current position on highways liability arising from maintenance, including latest philosophy and views on best practice and legislation;
- to set out the ground rules for good practice and prepare the foundation for a national claims trend and performance indicator database. Sharing highway related claims information will help participating Highway Authorities to monitor their performance against others and national trends; and
- to encourage all UK highway authorities to support a national highways claims initiative.

The guide gives an overview of some legal concepts that are of interest. Some of these are also elaborated on in Chapter 6, from the South African legal system's point of view. The guide enumerates the generic types of liability as used under British law.

(a) Negligence

The breach of a duty of care that results in damage or loss or injury to a party. It may occur through doing something which a prudent or reasonable person would not do, or by omitting to do something a prudent or reasonable person would do. The consequence must be reasonably foreseeable.

(b) Liability under statutory duties: There are two classes of statutory duty, being

- Specific or private law duties: These are owed to individuals and over which individuals may take legal action if they suffer injury or loss – examples include the duty to maintain roads in terms of the provisions of the Highways Act of 1980, such as to conduct sufficiently regular inspections to ensure the safety of the highway, identifying defects and to remedy the defect within reasonable time; and

- General or public law duties: These are general or target duties owed to society as a whole. Examples include the duty to improve road safety under the Road Traffic Act 1988. The individual generally has no remedy in law for loss arising from the failure of a local authority to discharge one of these duties.

(c) Public nuisance

An action without lawful cause or excuse which causes danger, injures health, or damages property, for example, the dangerous obstruction of the highway by a parked vehicle.

In Scotland the key road maintenance legislation is contained in the Roads (Scotland) Act 1984, Section 1, which provides a duty for local roads authorities to keep a list of "public roads" and to maintain and manage them. There is no direct equivalent of the Highways Act of 1980 in Scottish legislation. The Highways Act of 1980 provides for a defence against the road authority's alleged failure to maintain roads to a satisfactory standard. Scottish case law will have established some basis for this (Roads Liaison Group, 2005).

The duty of care principle with respect to road users and authorities was substantially reviewed in the Australia High Court in 2001 in two cases that were heard and decided together as they both raised the issues of historical highway immunities and the application of the law of negligence. In *Brodie v Singleton Shire Council; Ghantous v Hawkesbury City Council,* the High Court concluded that where the statutory powers of an authority give it a significant measure of control over the safety of persons, and persons are in a position of vulnerability, then a duty of care will be owed by the authority to those persons. Specifically, highway authorities are in a position whereby they do have physical control over the objects or structures that could be the source of the harm and they are therefore obliged to address the risk that a roadway poses in order to discharge their duty of care.

In reaction to the removal of immunity from liability of highway authorities, after Brodie and Ghantous, Premier Bob Carr introduced the concept of a "special protection" to the New South Wales legislative assembly on 20 March 2002:

> We will revisit the High Court's removal of the immunity from liability of highway authorities. While reinstating the immunity might not be the best approach, we want to protect public authorities from unrealistic standards imposed with hindsight by a court. What we expect of public authorities must take into account their obligations to the community generally and their resources to perform those obligations. Their actions or omissions should not be judged as though the particular case is the only case in which they are required to act (Austroads, 2012).

In November 2002 the Honourable Michael Egan informed the NSW legislative assembly that:

> [Civil Liability legislation]……will make important changes to the way that courts deal with claims against public authorities. These changes simply recognise that services provided to the community by public authorities are not provided for commercial gain but for the public good. The bill will not, therefore, sanction a public authority to act in

> a negligent or unsafe way. It will, however, require the courts to take into account principles relating to the financial and other resources available to the authority, the general responsibilities of the authority, and its compliance with general practices and applicable standards. The bill will also protect regulatory and roads authorities if they could have done something to avoid a risk but did not do so. Public authorities carry out what is often a limitless task with necessarily limited resources (Austroads, 2012:52).

The legal duty of the road authorities towards safety in Australia has thus become accepted. Only the extent of the damages that road authorities can reasonably be held accountable for is still an issue.

2.7.2 Legal duty – South Africa

Loubser, *et al* (2009) discuss duty of care under the element of delict of wrongfulness. Neethling, *et al* (2001) discuss duty of care under the element of delict of negligence. They remark that the duty of care doctrine has on occasion been followed in South African courts to first establish whether the defendant owed the plaintiff a duty of care and thereafter whether that duty had been breached. Should both elements be affirmed, negligence is established.

Legal duty, as formulated in South Africa, is tested by applying it to the element or wrongfulness. Wrongfulness is established if a reasonable expectation could be placed on the defendant to have acted to avoid damage, based on the good values of society or public policy. The test for negligence in the Roman Dutch tradition is the more direct test of the reasonable man who would have foreseen and guarded against damage. The confusion stemming from using the same reasonableness test in two different elements of delict has been the subject of many academic discussions and was acknowledged in a case as recent as May 2015:

> [19] It should be readily apparent that if the test for wrongfulness is whether it would be reasonable to have expected the defendant to take positive measures, while the test for negligence is whether the reasonable person would have taken such positive measures, confusion between the two elements is almost inevitable. Za v Smith 2015

The views of the Constitutional Court on wrongfulness can be found in *le Roux v Dey (Freedom of Expression Institute and Restorative Justice Centre as amici curiae*) 2011 para 122):

> In the more recent past our courts have come to recognise, however, that in the context of the law of delict:
>
> *(a)* the criterion of wrongfulness ultimately depends on a judicial determination of whether – assuming all the other elements of delictual liability to be present – it would be reasonable to impose liability on a defendant for the damages flowing from specific conduct; and

> *(b)* that the judicial determination of that reasonableness would in turn depend on considerations of public and legal policy in accordance with constitutional norms. Incidentally, to avoid confusion it should be borne in mind that, what is meant by reasonableness in the context of wrongfulness has nothing to do with the reasonableness of the defendant's conduct, but it concerns the reasonableness of imposing liability on the defendant for the harm resulting from that conduct.

An investigation into the legal duty of road authorities must acknowledge the fact that their activities are executed by employees. The conduct of road engineers working for the road authorities should be measured against the requirements of the position. The incumbent should have a reasonable measure and degree of the expertise that is standard for the profession or occupation. The test for negligent conduct will be the test of the reasonable expert. The views of the profession, such as the Engineering Council of South Africa (ECSA) Rules of Conduct (ECSA, 2013), will be taken into account, but the court is not bound by these views (Neethling, *et al,* 2001:137). The level of skill, experience, knowledge and expertise appropriate to the persons acting for the road authority in the specific position or circumstances will be evaluated on the facts of the particular case. These aspects are discussed in Chapter 3.

The Consumer Protection Act 68 of 2008 also has implications for road engineering practice and the principles on which it was founded may in future be used in claims for damages. The principles formulated by this Act may be interpreted as policy input into the test for wrongfulness. The Act provides for extensive consumer protection. It aims to cover any conceivable tangible and intangible product. It is irrelevant whether the supplier is promoting, offering or providing the relevant service or whether he/she participates in, supervises or engages directly or indirectly in the service. Despite the plain and understandable language requirement included in the Act, the Act itself is not easily interpreted and will probably be very difficult for the average consumer or supplier to make sense of. Suppliers – including road authorities and road engineers – need to familiarise themselves with the Act sooner rather than later and ensure that they comply with it (Smith, 2011).

2.7.3 Vicarious Liability

In the case of K v Minister of Safety and Security 2005 (6) SA 419 (CC) para 21 O'Regan J held:

> The common law principles of vicarious liability hold an employer liable for the delicts committed by its employees where the employees are acting in the course and scope of their duty as employees. The principles ascribe liability to an employer where its employees have committed a wrong but where the employer is not at fault. As such, the principles are at odds with a basic norm of our society that liability for harm should rest on fault, whether in the form of negligence or intent.

There are many theories as to why vicarious liability is justified. To discuss these is not in the scope of this dissertation. One of the more appropriate views is that the employer cannot avoid liability simply because it was not involved in the transgression or did not know it was happening. This is because the employer has the duty to employ responsible, capable employees and to exercise proper control over them.

The discussion of cases below illustrates the actions of officials in doing inspections or rigidly following procedures but failing to identify hazardous conditions for road users. In such cases the officials are not held liable in court, but may face internal disciplinary hearings.

In the case of Schultz v MEC PWRT Gauteng Province GDHCP 4905 2010 [19 August 2014], an official of the province (Senior Roads Superintendent) testified that she travelled the road on a daily basis and that the signs at the curve in the road were adequate. Based on the evidence presented to the Court, the judge found that the signs were not adequate and:

> [66] A reasonable person would not only have foreseen this danger, but would also have guarded against it by putting up adequate signage and by properly marking the verge of the road as well as the painted island. There is no evidence that it was not possible for employees of the first defendant to have done so. It should therefore be inferred that these employees either did not frequently inspect the road, or, if inspections were held, they simply ignored the dangerous situation. I therefore find that employees of the first defendant, acting in the course and scope of their employment, were negligent by failing to provide and maintain proper signage and road markings to guide motorists safely through a dangerous section of the road.

The official also maintained that the road marking was fairly good. The judge ruled the independent expert witness was of the view that the longitudinal line was so faded that it was probably totally ineffective, with reference to the photographs that were taken a day or two after the accident. The judge found it difficult to understand the official could describe the road markings as fairly good. In his view she demonstrated a certain degree of bias that not only affected the reliability of her evidence, but also her credibility.

In Day v Suffolk County Council & Ors [2007] EWCA Civ 1436 (23 November 2007) Case No: B3/2007/0218, the judge referred the fact that the council had a system of inspection and to the evidence that Mr Howe, when he had done the October 2001 inspection relied on by the defendants, was travelling at 25 miles an hour. The judge stated:

> I have to say that at first blush inspecting a road surface at twenty five miles an hour strikes me as being too fast. What is the evidence about it, bearing in mind that the onus is on the Defendants? The defendant has produced no official guidance about what amounts to 'at a slow speed.' [He accepted that inspections should be conducted at a slow speed.] There is no expert evidence about it. The burden of proof is on the Defendant on this issue, and at the end of the day I am not satisfied that twenty five miles an hour is a slow enough speed for a reasonably efficient inspection of the road surface. Having regard to the plain existence of a serious pot hole on 26 December 2001, it seems to me that it probably already existed on 28 October 2001. It is perfectly possible that Mr Howe missed it as he inspected at twenty five miles an hour. On the balance of probability, I am satisfied that the pot hole existed on 28 October 2001.

In Reid v Department for Regional Development [2006] NIQB 3 (13 January 2006), the Section Engineer, explained that the defendant's maintenance policy applies only to abrupt changes of level in particular surfaces. An inspector ‘’will look for and measure a change in level between two flagstones on the pavement or an edge resulting from damage or deterioration in the asphalt surface of the carriageway but will ignore a change in level caused by damage or deterioration at the juxtaposition between a kerbstone and the carriageway’’. The judge considered this a policy that smacks of the sort of "mechanical jurisprudence" and awarded damages to the Plaintiff who tripped at a level difference between the road and the sidewalk.

In McGovern v Glasgow City Council [2009] ScotCS CSOH_148 (06 November 2009) the judge found that the inspector may have overlooked a pothole:

> [14] While I accepted Mr Dougan as an honest witness I was not persuaded that I should accept his evidence that there was no pothole on 27 November 2006 given the pursuer's clear evidence that there was a pothole of the size I have found in January and Mr Paton's evidence that such a pothole was not likely to be created in the period of time involved. He agreed in cross examination that he may have missed it though he did not believe he had.

In AC & Anor v TR & Anor [2012] EWHC 796 (QB) (29 March 2012), the application of the Well Maintained Highways Code of Practice (COP) was reviewed. The local authority of Devon compiled its own policy and deviated from the COP. They did not record their reasons for deviating in an adequate manner and the judge found that:

> Mr Sharp submitted that Devon cannot make out a defence under HA Section 58. Once it is shown that Devon was in breach of their duty to maintain the highway, it is for them to establish that they took such care as in all the circumstances was reasonably required to secure that the part of the highway to which the claim relates was not dangerous for traffic. Mr Sharp contended that Devon have failed to do so. They carried out maintenance inspections on the relevant stretch of road at six monthly intervals and not monthly as recommended by the COP. Whilst the COP guideline was not mandatory, Devon had not advanced any good reason for departing from it... I find on the balance of probabilities that the failure to carry out monthly inspections with consequential repairs was causative of the accident.

A second aspect of inspections came to the fore in this case. The road under discussion was deteriorating and the frequency of inspections should have been adapted to the circumstances. The previous justification for six month intervals was based on low traffic, no accidents reported and no complaints but the road was progressively damaged and the frequency should have been increased. The risk assessment approach was also mentioned.

> It was contended that Devon failed to have regard to the fact that the highway tended to become waterlogged, water would seep in under the edges of the road and render it susceptible to failure. It was known that the heavy agricultural vehicles which used the road frequently would override the metalled edges of the carriageway and damaged the verge and the carriageway edge. Notwithstanding the known long standing problem of edge deterioration Devon had not carried out a risk assessment nor implemented permanent haunching repairs as recommended in reports published by the Transport Research Laboratory in 1991 and a second edition in 1994 and a guide to repairing haunches issued in 1991.

2.8 Development of standards

The development of standards is a collective process to ensure that the standards represent the commonly held values and views of the community, interest groups and, importantly, the experts and practitioners in the specific field of knowledge. The process starts with a review of activities in the international arena and the publishing of a position paper in local context.

This thesis aims to lay a foundation for a more detailed and comprehensive position paper or guidelines for the development of South African road maintenance standards for road safety. The guidelines that are proposed in this thesis could be used in the interim to develop the dimensions of asset management systems. Subsequent experience in the industry would facilitate the development of a formalised set of standards regulating road safety and maintenance.

A wide range of standards, guidelines and codes for road maintenance are available in South Africa. For most of the legal cases discussed later a guideline value or standard for maintenance did exist but the road authorities neglected to pay heed to them. This thesis does not attempt to question the existing local norms or demonstrate that they are inadequate. The study aimed to assess these norms against other sources. The contribution that the researcher set out to make was to highlight, refine, and quantify standards with a pertinent safety implication so that the road authorities have additional grounds to secure funding for maintenance. The contribution is also the collation of such safety-related standards in a single document.

The most comprehensive of stated or implied standards are found in pavement design, management and maintenance, such as rutting, surface failures and edge conditions (CSRA, 1992). Attributes are also found in design manuals (COTO, 2014).

An important source of industry-accepted manuals on road design, construction procedures and assessment in South Africa, published by the Department of Transport, is the Technical Recommendations for Highways (TRH) and Technical Methods for Highways (TMH) series. These documents were compiled by state road officials participating in committees such as the previous Committee for State Roads Authorities (CSRA) and the Committee of Land Transport Officials (COLTO), now renamed as the Committee of Transport Officials (COTO). The TRH series of documents ‘’are intended as guides for the practicing engineer and leaves room for engineering judgement to be used’’. The TMH series are described as ‘’manuals, prescribing methods to be used in various road designs and construction procedures.’’ The purpose of these manuals is to ensure uniformity of results

In the TRH12 on flexible pavement rehabilitation - now superseded by the South African Pavement Engineering Manual (2014) - it is stated that different road authorities may have their own policies with respect to applicable standards for pavement rehabilitation projects. Standards normally relate to the pavement category (pavement structure or class), traffic loading and the riding quality of the road. It recognises that policy changes and changes in level of funding could influence standards. It warns of the lowering of standards to "balance the books" to prevent "sub-standard" rehabilitated road sections in a network. The aim for road authorities is to maintain appropriate standards (COLTO, 1997).

The TRH26 South African Road Classification and Access Management Manual (COTO, 2012) sets out to prescribe requirements for the management of access and the functional classification of roads. It states that:

> Access management requirements are the compulsory provisions necessary to ensure the road performs its function adequately. Authorities must ensure that these requirements, as a minimum, are complied with. Requirements differ from typical features (next chapter) which are desirable characteristics for the various road classes but are listed for information only. If the access management *requirements* for a particular functional road class are not currently met, it will be necessary to implement the corrective measures such as retrofitting (COTO, 2012).

While this manual sets out to have compulsory provisions, there are no legal sanctions in the form of regulations or penalties enacted. The only control that the central government via the Department of Transport has on provinces and municipalities is in the form of withholding of funds such as the Provincial Roads Maintenance Grants or Municipal Infrastructure Grants.

The approach followed by the Department of Transport to impose the road classification and access management standards on provinces and municipalities can also be used in imposing maintenance standards for safety.

The performance of road signs and markings is one set of attributes that is contained in a South African National Standard and values for the attributes of characteristics such as retro reflectivity and paint coverage are prescribed (SABS, 2014).

The UK Well Maintained Highways Code of Practice (Roads Liaison Group, 2005) states that the suggested recommendations of this Code are explicitly not mandatory on authorities. It is, however, also acknowledged that:

> 1.3.2 Authorities also have certain legal obligations with which they need to comply, and which will, on occasion, be the subject of claims or legal action by those seeking to establish non-compliance by authorities. It has been recognised that in such cases, the contents of this Code may be considered to be a relevant consideration. In these circumstances, where authorities elect, in the light of local circumstances to adopt policies, procedures or standards differing from those suggested by the Code, it is essential for these to be identified, together with the reasoning for such differences.

When reflecting on the reasons why road authorities do not adhere to know standards or good practice, the real question is why do officials as employees of the authorities not perform their duties with due diligence. One of the aspects lies in the principle of vicarious liability. This is the dictum of “respondeat superior’’ or “let the master answer’’. Neethling, *et al* (2014) state that where an employee acts within the scope of his employment and commits a delict, his employer is fully liable for the damage. Employees may therefore have reduced incentive to not act negligence, or differently put, do not fear sanctions if they do act negligently.

The ISO (International Organisation for Standardisation), discussed under 2.4 and 2.5.1, is a worldwide federation of national standards bodies, the ISO member bodies. The work of preparing international standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organisations, governmental and non-governmental, in liaison with ISO, also take part in the work. The main task of technical committees is to prepare international standards. Draft international standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75% of the member bodies casting a vote (ISO, 2011).

Standards for road maintenance are not a panacea for road safety, but lay a formal basis and minimum set of values for road authorities to adhere to. Standards are the metrics that are used in specifications. Using these minimum specifications as a starting point, the system could be optimised by solving safety problems in context.

Kopac discusses the limitations of the evolution of specifications (by implication standards) in the form of a set of myths. Myth No. 3 was stated as: “With the Evolution of Specifications Come Continual Improvements in Quality”. Kopac is of the opinion that the improvements in quality evolve from advances in the engineer’s knowledge of and experience with the product being specified, including the materials, processes, and equipment. The evolution of standards that are based on political, economic, and societal demands made on the product or on those responsible for the product does not, in his view, lead to improvement in quality (Kopac, 2005).

2.9 Conclusion

The literature surveyed in this chapter explored industry guidelines and research on road maintenance for ensuring safer roads in the context of the road authorities’ legal duty towards road safety. The standards identified could form the basis of a comprehensive suite of practice guidelines.

The elements of maintenance that affect road safety and are most often cited in claims for damage from road authorities were discussed. This covers road safety in general, pavement management systems, road infrastructure asset management and maintenance codes of practice.

Road authorities in South Africa include the national Department of Transport, the various functions within the provincial departments as well as the municipalities that range from metropolitan, district to local level. Road authorities are the only institutions empowered to establish public roads and it follows that they are obliged to build, operate and maintain them in functional condition for reasonable use. Studies show that the condition of the provincial paved roads, from which most legal claims originate, is in significantly poorer condition than the paved roads under control of SANRAL and the municipalities.

One of the guiding principles discussed is that the transport system must be designed to accommodate or compensate for human error. Safe roads and roadsides are therefore designed and maintained to reduce the risk of crashes occurring and to lessen the severity of injury if a crash does occur. A “forgiving” and safe road transport system ensures that the forces in collisions do not exceed the limits of human tolerance. Even if the road environment is a contributory cause in between 30% and 40% of accidents, the road authorities have a duty to reduce or mitigate injury and damages under their control.

The cost of crashes in 2005 was estimated to be in the region of R40 billion. More than 14 000 people die annually on South Africa’s roads, with more than 40% of these being pedestrians. A rate of 28 deaths per 100 000 population per annum is a catastrophe. Furthermore, approximately 7 000 people are permanently disabled and 40 400 seriously injured annually.

Most crashes are caused by driver-related issues, such as high speed, alcohol abuse and driver fatigue. South Africa’s rapidly growing population is the reason for the steep growth in the number of vehicles on the roads. The average age of vehicles shows a rising tendency, with many vehicles that are not roadworthy being a contributing factor to South Africa’s poor road safety record.

This should, however, not distract from the role that the road plays in accidents.

The various road elements should also be recognised as part of the system that causes crashes. Road authorities are responsible to design the road system to accommodate the human driver with all his errors in judgment.

As the road and its environment change and deteriorate continuously, safety of roads requires that the road surface, road signs and recovery areas must be properly and systematically maintained. Older roads often lack safety design features and additional information must be given by means of road signs and markings to compensate for the lack of features.

Professional road design is the ability to foresee and optimise the conflicting objectives that are to be achieved, of which safety is the prime consideration. Road maintenance systems and asset management systems are important for ensuring safer roads. Knowledge of the processes contained in these systems leads to understanding of the need to develop engineering standards for both road elements and maintenance systems sufficient to comply with the legal duties of the road authorities towards road safety.

For the purposes of this research the most important road maintenance features and their attributes that have a road safety implication were identified. Sources that list multiple features that impact on safety were reviewed and the specific features relevant to road maintenance were listed.

The meaning and development of liability and legal duty of road authorities internationally and in South Africa as applicable to development of road maintenance standards were discussed. Legal duty, as formulated in South Africa, was tested by applying it to the element of wrongfulness.

The conduct of road engineers working for the road authorities should be measured against the requirements of the position. The incumbent should have a reasonable measure and degree of the expertise that is standard for the profession or occupation.

The development of standards is a collective process to ensure that the standards represent the commonly held values and views of the community, interest groups and, importantly, the experts and practitioners in the specific field of knowledge.

Chapter 3: Legal duty

3.1 Introduction

Roads are public good, established for the community to use, funded by tax and managed by public entities. The road authorities, as government departments or institutions exist to deliver public services. Road authorities are the only institutions empowered to own public roads and it follows that they are obliged to build, operate and maintain them in functional condition for reasonable use. Toll roads are also public infrastructure and the concessionaires are independent contractors to SANRAL.

A person who uses a road for general public purpose is entitled to expect that he / she could use it with safety. This principle has been established and restated in many cases ranging from Stewart v City Council of Johannesburg 1947 to Monteoli v Woolworths (Pty) Ltd 2000. A legitimate expectation of a user is linked to an obligation of a provider. This brings us to the concept of legal duty. Loubser, *et al* define legal duty as “a duty to act without negligence or not to be negligent” (Loubser, *et al*, 2009).

Legal duty is also

> An obligation arising from contract of the parties or the operation of the law. That which the law requires to be done or forborne to a determinate person or the public at large, correlative to a vested and coextensive right in such person or the public, and the breach of which constitutes negligence. (Legal Dictionary, n.d.).

Legal duty and liability are often used as synonyms. Liability is defined as the state of being legally responsible for something. It is also defined as “Responsibility; the state of one who is bound in law and justice to do something which may be enforced by action. This liability may arise from contracts either express or implied, or in consequence of torts committed (Oxford Dictionaries, n.d.-a).

Liability is thus the condition of being subject to a legal obligation. Legal duty is a test condition that is a part of a legal process while liability results from a proven breach of legal duty or legal obligation. Liability is therefore a wider term that describes the outcome of a process that investigates whether a legal duty existed, whether it was breached and what restitution would be justified. Legal duty is sometimes referred to as “duty to care”. The difference between these two terms is discussed in more detail in section 3.3.

The question of the legal duty of the road authority and road engineer arises where, in delict, claims of road users for damages caused by the road conditions are made on the grounds of negligence. Engineers need to understand the concept of legal duty as they must execute the management of the road system to fulfil this duty. Legal duty is an element of the wider concept of wrongfulness. South African courts treat each case on merit, preferring not to prescribe what the legal duty or the standards of care in provision or maintenance for safety should be.

The origins of legal duty towards road safety are found in three areas: policy on road safety, legislation that refers or implies a legal duty towards safety and case law. This chapter elaborates on policy and legislation in sections 3.2 and 3.3. Policy is discussed before legislation, as the process of developing legislation should be based on public participation to define values and goals, which translate into policy. Legislation is then distilled from policy with acts that enable, organise and structure public service.

In practice, much legislation with respect to roads and transport was promulgated many decades ago and may seem to be more important than policy. This is not true: acts that define statutory duty may have a more direct impact on the legal process than policy (the legal convictions of the community) that must be interpreted by the court, it is policy that will guide the changes in common law, legal precedents and re-formulations and amendments to Acts of Parliament.

Section 3.4 looks at the law of delict as the legal procedure followed in claims against road authorities for damages suffered by road users as a result of road conditions. Legal duty, as a component of wrongfulness, must be viewed in the context of this procedure. The other necessary elements in a case of delict are the act, fault, causation and damages. Actual case studies are evaluated in Chapter 7. The chapter on legal duty cannot end without discussion of the ethical dimension of the conduct of registered persons towards road safety. This is discussed in section 3.6. This leads to a discussion of skills in section 3.7, where it is shown that the road safety crisis is partially due to the severe shortage of competent road engineers and the risk of unskilled persons occupying technical posts in road authorities.

3.2 Road safety policy

Policy is an important area as it defines the legal convictions of society, and the expectations or good values (*boni mores*). Loubser, *et al* (2009:147) state “it is public policy that determines whether a legal duty for the purposes of wrongfulness exists”. Much of the policy initiatives are currently driven by the international thrust to reduce fatalities through the Global Road Safety Programme. While it is the opinion of the researcher that the direct acceptance of these global targets is too ambitious for the developing world, there is the universal truth that a goal, as the ideal-end state, must be set high.

3.2.1 International policies

Since the 1970s society has come to accept road safety as its right and the responsibility of authorities. Internationally road crashes are considered to be a burden on health and financial systems, as well as having grave psychological impact on the community. Society assesses the cost of road crashes in terms of health services, loss of production and opportunities. In 2010 the World Health Organization (WHO) declared the Decade of Action for Road Safety 2011–2020 with the goal of reducing road fatalities. This international drive now forms the basis of the road safety policies of most countries.

> The most important reason, though, is that road deaths are preventable – and it is our collective responsibility to support every effort possible to curb the carnage on our roads. Leading road safety experts believe that, with the right action, up to 5 million lives could be saved and 50 million injuries prevented during the Decade of Action. This will represent a reduction of about 50% on the predicted global death toll by 2020 (WHO, 2011).

The Decade of Action for Road Safety is built on five pillars: Road Safety Management, Safer Roads and Mobility, Safer Vehicles, Safer Road Users and Post Crash Responses. Flowing from the pillar of Safer Roads and Mobility, it is stated that road safety engineering should entail a Roads Development Plan: "a *strategy* that requires that systematic attention be paid to upgrading the road infrastructure and signage on the basis of continuous audits of hazardous locations and accident red spots".

3.2.2 Local policies and strategies

South Africa subscribed to the WHO Organization Decade of Action for Road Safety 2011 – 2020 strategy and the goal to reduce road fatalities by 50% by 2020. This is now considered policy. Road safety policies are seen to be the expression of the good values (*boni mores*) or legal convictions of society and the actions of a road authority are measured against these. However, the development of current road safety policy started 20 years ago and this development is traced to expose the other dimensions of local policies and strategies.

Post-apartheid South Africa formulated its first transport policy 1996, two years after the birth of the "New" South Africa. The transport policy had to address a multitude of historic wrongs and problems, including segregated urban areas resulting in long commuting times and distances in buses and minibus-taxis, long-distance trips between homelands labour reservoirs and urban employment and declining rail services. Many of these ills resulted in high risk exposure on roads and a poor road safety record. The re-alignment of government funding to improve basic services led to deferment of maintenance on roads that appeared to be in good condition. However, by delaying of routine and periodic maintenance, the life of the roads was significantly reduced and this is evident in road failures such as potholes, edge drop-off, blocked drainage and faded road markings. In 1996 the idealism led to a White Paper on National Transport Policy "to improve the safety, security, reliability, quality, and speed of transporting goods and people" (Department of Transport, 1996). The safety, security, and quality of service of transport were described as unacceptable. The government then committed itself to a concentrated and integrated effort to bring policies in line with international best practice.

Policy statements on road traffic safety were based on the premise that traffic conditions on South African roads were unacceptable. The high accident and casualty rates were especially problematic. The policy statement proposed that traffic and safety management systems being applied would be replaced with a new approach based on models from other countries with records of success in this area. An integrated road traffic quality management and monitoring approach would be introduced, which would address, *inter alia*:

- Road traffic control;
- legislation and adjudication;
- training, education, and communication;
- road traffic administration and information systems; and
- road and traffic engineering.

Policy on the engineering discipline states that government is aware of the need to apply sound engineering in the quest to improve traffic safety. This should be balanced with the education and enforcement functions. Transport, traffic engineering and road traffic quality will have an emphasis on safety. National guidelines and standards for the provision of road infrastructure, in the planning, design, construction, in-service and evaluation phases will be developed (Department of Transport, 1996).

Following the 1996 White Paper on National Transport Policy, a strategy for implementation under the theme *Moving South Africa* was developed. The *Moving South Africa* project was designed to produce a programme for strategic action that extends the *policy* in the Transport White Paper into a long-term strategy.

> Provide safe, reliable, effective, efficient and fully integrated transport operations and infrastructure which will best meet the needs of freight and passenger customers at improving levels of service and cost in a fashion which supports government strategies for economic and social development whilst being environmentally and economically sustainable (Department of Transport, 1998).

For the engineering function the strategy proposed was to be aware of high-accident risk areas and to effectively reduce the hazards through the provision of simple remedial measures such as signs, fences and traffic calming. Roads should provide a forgiving environment which allows for reasonable levels of human error. It was acknowledged that provincial and local authority roads lacked adequate maintenance that manifested in pot-holes (Wolhuter, 2015).

As part of the integrated strategy, Arrive Alive was initiated 1997. It aimed to decrease road fatalities by 5% annually. This was repeated in the strategy The Road to Safety 2000–2005 (Department of Transport, 2002). By the time the National Road Safety Strategy 2006 Onwards was formulated, fatalities had risen 40% to more than 14 000 lives, 7 000 permanently disabled people and 40 000 serious injuries annually, at a R43 billion cost to the state, communities and individuals (Department of Transport, 2006).

The next strategy was called the Decade of Action and Arrive Alive National Road Safety Strategy 2011 – 2020. By then the reality of previous targets missed led to the admission:

> Previous road safety strategies (Arrive Alive 1997, The Road to Safety 2000-2005, the Road Safety 2006-2010 Strategy) have made recommendations which have not yet been implemented due to a lack of both human and financial resources, a lack of political will and the challenges of a multi-tiered responsibility for transport functions. These strategies have been recognised as supporting international best practice, but the implementation and political commitment to making a change has been lacking (Department of Transport, 2011).

The statement was made in the conclusion:

> Doing the same thing over and over again and expecting a different result is a sign of no progress. In the South African road safety landscape, and with an enormous amount of consulting and the preparation of at least three strategies in the past decade, South Africa has not made gains in reducing the tragedy of the high levels of fatalities on our roads. Now the Minister, who is self-proclaimed evangelist of the movement of road safety, has the political will to make a change, and has set a clear target of reducing fatalities by 50% by 2015, meaning that by that year no more than 7 000 people should die on our roads. Even these levels are high compared with other nations, and we must ensure that we are successful in reducing the carnage and waste of life and resources in road trauma (Department of Transport, 2011:66).

Notwithstanding the lack of performance, the road safety policies and strategies since 2000 have consistently highlighted the importance of reducing fatalities and concomitant injuries and damages to property. These strategies acknowledge the role of engineering as part of the integrated approach to safety. The need to develop standards for all aspects of road engineering, including maintenance, was acknowledged in the White Paper in 1996. These successive generations of policies and strategies are still the expression of the *boni mores* of the community and the pursuit of these policies can be interpreted as what the reasonable road authority would do and accepts as its legal duty.

3.2.3 A shared responsibility

Responsibility for road safety is shared by all. While individual road users are expected to be responsible for complying with traffic laws and behaving in a safe manner, it can no longer be assumed that the burden of road safety responsibility simply rests with the individual road user. Many organisations - the ‘system managers’ - have a primary responsibility to provide a safe operating environment for road users. They include the government and industry organisations that design, build, maintain and regulate roads and vehicles. These and a range of other parties involved in the performance of the road transport system, and the way roads and roadsides are used, all have responsibility for ensuring that the system is forgiving when people make mistakes.

Road safety responsibilities also extend to various professional groups, as well as the broader community. For example, health professionals have a role in helping their clients to manage their safety on the roads; and parents contribute significantly to the road safety education of their children — not only through their direct supervision of learner drivers, but also by modelling their own driving and road user behaviour.

3.3 Legislation

Legislation is empowering acts and ordinances that allow public funds to be spent on infrastructure and operations. The intention of legislation, often provided in the preface to the acts, provides the rationale for its formulation and is used to interpret its implementation and application. Acts allocate functions to the appropriate spheres of government. In some cases, the requirement of safety is spelt out.

The function and competence to provide and maintain roads in South Africa are contained in legislation, starting with the Constitution that allocates functions to the three spheres of government. Specific legislation includes the previous National Roads Act of 1936, the National Roads Act 54 of 1971, the South African National Road Agency Limited and National Roads Act 7 of 1998 as amended. The Consumer Protection (CPA) Act 68 of 2008, has not been used in the context of road safety, but it may find some application in future.

The provision of provincial roads was founded on the various Provincial Road Ordinances such as the Transvaal Roads Ordinance No. 19 of 1976 and Cape Province Road Ordinance 18 of 1976. Some of the nine new provinces promulgated their own provincial traffic, roads and transport acts such as the Gauteng Transport Infrastructure Act (GTIA) 8 of 2001, Mpumalanga Roads Act 1 of 2008, Kwazulu-Natal Road Traffic Act 7 of 1997. This list is not meant to be exhaustive, as many of the acts, similar to the old ordinances, are pure repetition.

The Municipal Structures Act 117 of 1997 elaborates on the competence of local authorities. The allocation of powers and functions does not refer to any standard, assuming that engineers will draw up and work to the necessary guidelines, manuals and codes for application in the design and maintenance of roads, with road safety as a concurrent requirement.

The highest authority of statutory duty in the context of the road environment stems from the Constitution of South Africa as stated in the Bill of Rights. In terms of Article 24 of the Constitution (1996):

> 24. Environment. – Everyone has the right – to an environment that is not harmful to their health or well-being

3.3.1 National Roads and SANRAL

National roads fall under the Department of Transport. The White Paper on National Transport 1996 advised that the provision, maintenance, and operation of the primary economic road infrastructure network should be facilitated by a professionally managed Roads Agency, with a Board of Control consisting mainly of users from the private sector. This led to the National Roads and SANRAL Act (SANRAL and NRA) 7 of 1998. The functions of SANRAL are stated in section 25 (1):

> **25.** (1) The Agency, within the framework of government policy, is responsible for, and is hereby given power to perform, all strategic planning with regard to the South African national roads system, as well as the planning, design, construction, operation, management, control, maintenance and rehabilitation of national roads for the Republic.

Its legal duty to provide safe roads is highlighted in section 26 (e):

> **26.** In addition to the Agency’s main powers and functions under section 25, the Agency is competent (e) to provide, establish, erect and maintain facilities on national roads for the convenience and safety of road users.

In section 39 (3), an obligation is set:

> 39 (3) The Agency must determine its business and financial plan and strategic plan and the standards and criteria for road design and construction and for road safety within the framework of the national roads policy as determined by the Government and published in terms of subsection (1)

3.3.2 Provincial Acts

The Mpumalanga Road Act, the KwaZulu-Natal Road Traffic Act and Roads Act are used as typical examples, as the purpose of the research was not to compare legislation in detail. The provincial traffic and roads acts of Gauteng (2001) were used as models for the new generation of provincial acts. The Western Cape Province still rely on the 1976 Roads Ordinance to regulate road matters.

Mpumalanga Roads Act 1 of 2008 Powers of Member of Executive Council

> 3.(1) The Member of the Executive Council must, within available resources, develop, declare, implement, administer and promote the Provincial road network in terms of effective, open, accountable and co-operative governance and in accordance with National and Provincial norms, standards and practices in order to
>
> (a) achieve optimal road safety standards within the Province;

Kwazulu-Natal Road Traffic Act 7 of 1997 lists the following powers and duties of traffic officer:

> 10 (g) regulate and control traffic upon any public road, and give such directions as may, in his or her opinion, be necessary for the safe and efficient regulation of the traffic, which may include the closing of any public road, and, where he or she is of the opinion that the driver of a motor vehicle is hampering or impeding the normal flow of traffic on a public road, direct the driver to remove the vehicle from such road and to follow another route with the vehicle.

It is the power of local authority to make bylaws:

> 26. (1) Any local authority may within its area of jurisdiction with the concurrence of the MEC make bylaws not inconsistent with the provisions of this Act or the National Road Traffic Act, 1996, in respect of -
>
> (a) the safety of traffic on any public road, the duty of any user of such road and the use of any such road by any vehicle;
>
> (b) protect and maintain Provincial road network assets;

In the KwaZulu-Natal Provincial Roads Act 4 of 2001, the KwaZulu-Natal Province legislated that it would only be liable should loss or damage result from the *"wilful or negligent act or omission of an official*". Scott JA elaborated on this point in McIntosh v Premier, KwaZulu-Natal (632/07) [2008] ZASCA 62 (29 May 2008). (KwaZulu-Natal Provincial Roads Act 4 of 2001).

> In the present case the second respondent is enjoined in terms of s 3(1) of the KwaZulu-Natal Provincial Roads Act 4 of 2001 to administer the provincial road network in accordance with national and provincial norms inter alia 'to achieve optimal road safety standards within the Province' and to 'protect and maintain provincial road network assets'. In terms of s 3(2) the second respondent's responsibility is said to be 'within the Province's available resources'. However, a public law obligation does not necessarily give rise to a legal duty for the purpose of the law of delict. See Rail Commuters Action Group v Transnet Ltd t/a Metrorail 2005 (2) SA 359 (CC) paras 79-81. But in the present case s 9(3) of the Act puts the issue beyond doubt. It provides: '9(3) The Minister [i.e. the second respondent] is not liable for any claim for damages arising from the existence, construction, use or maintenance of any provincial road, except where the loss or damage was caused by the wilful or negligent act or omission of an official.

3.3.3 Municipalities

Municipalities can only promulgate by-laws in a narrowly defined range of fields. Road safety aspects are implied in the control of street and informal trading, parking and accesses to developments. The municipal function of traffic law enforcement is a statutory duty that affects road safety. The design of a road requires that for safe operation, traffic must keep to design speeds.

3.3.4 International legal aspects

The international legal aspects are of some interest in that the different ways which countries compile legislation can be compared. However, the differences in legal traditions, such as the Roman Dutch, English and European law, make it difficult to translate concepts to the local situation.

US: The legal framework for federal highways in the US is formulated at federal level through the Federal Aid Policy Guide Title 23 Code of Federal Regulations (and Non-regulatory

Supplements) (Title 23 - Code of Federal Regulations (and Non - regulatory Supplements), 2015).

The state level legislatures can pass separate legislation for state highways, but the federal regulations are used as guides and authority in arguments on what is reasonable for the establishment of duty of care. The design standards for highways (streets and roads) are contained in PART 625 – Design Standards for Highways

> § 625.1 Purpose. To designate those standards, policies, and standard specifications that are acceptable to the Federal Highway Administration (FHWA) for application in the geometric and structural design of highways.
>
> § 625.2 Policy. (a) Plans and specifications for proposed National Highway System (NHS) projects shall provide for a facility that will -
>
> (1) Adequately serve the existing and planned future traffic of the highway in a manner that is conducive to <u>safety,</u> durability, and economy of maintenance; and
>
> (2) Be designed and constructed in accordance with criteria best suited to accomplish the objectives described in paragraph
>
> (a)(1) of this section and to conform to the particular needs of each locality.
>
> (b) Resurfacing, restoration, and rehabilitation (RRR) projects, other than those on the Interstate system and other freeways, shall be constructed in accordance with <u>standards</u> which preserve and extend the service life of highways and <u>enhance highway safety</u>. Resurfacing, restoration, and rehabilitation work includes placement of additional surface material and/or other work necessary to return an existing roadway, including shoulders, bridges, the roadside, and appurtenances to a condition of structural or functional adequacy.
>
> (c) An important goal of the FHWA is to provide the highest practical and feasible level of safety for people and property associated with the Nation's highway transportation systems and to reduce highway hazards and the resulting number and severity of accidents on all the Nation's highways (underlining LdVR)(US Government Publishing Office, 2016).

Section 625(1) refers to standards that are acceptable to the Federal Highway Authority (FHWA). Per definition, a standard is a criterion that must be achieved and thus places an obligation on the implementing road authority. Standards are known to be necessary but not sufficient for road safety, but form a basis for imposing legal duty.

Section 625(2) is qualified as policy. As will be elaborated on in the discussion on wrongfulness as element of delict in section 3.4, policy becomes the measure for reasonableness in determining the actions of a road authority, based on the values of the community.

<u>United Kingdom</u>: The UK Highways Act 1980 in section 41 (1) reads: "The authority who are (sic) for the time being the highway authority for a highway maintainable at the public expense are <u>under a duty</u>, subject to subsections (2) and (3) below, to maintain the highway" (underlining LdVR).

Section 41 imposes a duty to maintain. Most of the claims against UK road authorities arise from the alleged breach of this section. "Section 58 provides for a defence against action relating to alleged failure to maintain on grounds that the authority has taken such care as in all the circumstances was reasonably required to secure that the part of the highway in question was not dangerous for traffic" (Roads Liaison Group 2005:61).

In defending an action, the authority will need to establish that it has acted reasonably, by the production of adequate documentation and evidence:

- policies and standards: conformity with standards recommended by this Code of Practice and other national standards can be used as evidence of reasonable actions. Local authorities who wish to depart from the Code should formally record the deliberation process over the departure. Authorities should publish the standards they are working to; and
- a robust inspection and recording system to demonstrate that the policies have been carried out will require a robust system, operated by appropriately trained and qualified inspectors (Roads Liaison Group 2005:244).

Australia: Road-related compensation claims in Australia fall mainly under the common law principles of negligence. The federal state government in Australia results in claims in each jurisdiction being decided by the prevailing civil liability legislation. The plaintiff alleging damages is seeking a monetary compensation with regard to their personal injury and/or damage to their property, for example, long-term medical treatment, loss of earnings, inability to pursue a career or profession to pay for physical repairs to property (Austroads, 2012).

Japan: The legal duty to maintain Japanese road practice is spelled out in law. The following is quoted from an article by Hirasawa, Asano and Seito in the Proceedings of the Eastern Asia Society for Transportation Studies (Hirasawa, *et al*, 2005):

> Article 42 of Japanese Road Law states that road administrators "shall maintain and repair roads such that they are kept in good condition, and shall make it a point to prevent general traffic from experiencing hindrances." Article 2 of The State Redress Law stipulates that "When any defects in the construction or management of roads, rivers or other public structures have caused people to suffer damages, the national government or public organization(s) are liable for the damages (underlining LdVR).

Thus, for accidents caused by road structures or associated facilities caused damages, the legally responsible entities are explicitly stated. The liability does have some condition and Hirasawa, *et al* continue:

> When three conditions are satisfied, the road administrator is responsible for accidents resulting from its failure to remedy road defects:
>
> a) the road has an accident risk,
>
> b) the risk is predictable by the road administrator, and
>
> c) the risk can be eliminated by the road administrator." (Hirasawa, et al, 2005)

3.4 Law of delict

The legal process to claim for damages is part of civil law, specifically the law of delict. The importance of this legal process for road safety is that the cases that involve claims against road authorities for defects in the road environment are based on the elements of delict: the act, wrongfulness, fault, causation and damage. The road engineer and road authority must understand the workings of each of the elements to interpret and learn from court cases. Legal duty is a component of wrongfulness, fault can be allocated to each of the parties involved in an accident, causation is a factual analysis or reconstruction of the accident and damage involves the amount of money involved. Each of these elements will be discussed in the subsections.

The South African Roman Dutch law differs somewhat from English law, where these cases are referred to as torts. The law of delict can also be described as the redress of the wrongful act. Neethling, *et al* (2001), state: "a delict is constituted by the infringement of any legally recognised interest of <u>another</u>, excluding the non-fulfilment of a duty to perform by a contracting party. Consequently, the delictual remedies are primarily directed at damages (or satisfaction) and not fulfilment (underlining LdVR).

One definition of "another" was given by Lord Atkin in the celebrated case of Donoghue vs Stevenson (1932) as our "neighbour".

> …..You must take reasonable care to avoid acts or omissions which you can reasonably foresee would be lively to injure your neighbour. Who, then, in law, is your neighbour? The answer seems to be persons who are closely and directly affected by your act that you ought reasonably to have them in your contemplation to be affected, when you are directing your mind to the acts or omissions that are called into question.

In the case of a road authority, the persons who are closely and directly affected by their actions are the road user in its widest meaning, driver of any legal vehicle, passenger, pedestrian, cyclist, adjacent land owners, owners of services in or over the road reserve, and even public institutions.

To establish a delict, the following five elements (underlined in the sentence below and discussed separately in the following paragraphs) must be present (Neethling, *et al,* 2001): An <u>act</u> that was <u>wrongful</u> for which the defendant must be at <u>fault</u> that <u>causes</u> <u>damages</u> to the plaintiff.

3.4.1 The act

The conduct that leads to damage can be in the form of a positive act or an omission. In the context of maintenance work this may be the erection of misleading signage or not erecting signage where this was required to warn of danger.

The conduct of a road authority can be through its employees working within the scope of their employment (vicarious liability) or through its independent contractors. The actions of its own employees are easy to link to the road authority. These actions are not only with respect to what they do, for example, setting up temporary signs at a road failure in a manner that causes hazards, but also for what they do not do, for example, removing rocks that fell on the road from a cutting. The road authority will remain responsible even if the employees execute their work in a shoddy way that leads to hazardous conditions. The redress of the employees' misconduct is an internal issue with respect to the other party that was injured or suffered damages.

The issue of delegation of duties to an independent contractor is important to road authorities that make extensive use of contracting out construction and maintenance. Judgments such as *Chartaprops 16 v Silberman* (300/07) [2008] ZASCA 115 (25 September 2008) confirm that the independent contractor is liable for his own actions provided the employer did not act negligently in appointing him (Saayman *v Visser* (411/07) [2008] ZASCA 71 (30 May 2008). This principle is welcomed by academics as it provides a healthy differentiation in the legal position of the employer and the independent contractor (Neethling & Potgieter, 2009; Scott, 2009).

There is, however, still reference to non-delegable duties where a special relationship exists between the employer (defendant) and the other party (plaintiff), to see that care is taken. This is also referred to as a personal duty. It is often linked to dangerous conditions or substantive risk. The case typically referred to stems from a claim against a civil engineering contractor. In Langley Fox Building Partnership (Pty) Ltd v De Valence_1991 (1) SA 1 (A), it was stated that the facts of each case will determine if an employer of an independent contractor had a duty to take steps to prevent harm to members of the public. The following factors needed to be considered:

- The nature of the danger;
- the context in which the danger may arise;
- the degree of expertise available to the employer and the independent contractor respectively; and
- the means available to the employer to avert the danger.

Road construction and, more so, maintenance are activities that involve substantive risk to the public using the roads. The road authority, having appointed an independent contractor, will be prudent to err on the safe side by still supervising the independent contractor; to take reasonable steps to see that care is taken.

3.4.2 Wrongfulness

Wrongfulness is described as the breach of the legal duty owed to the public to ensure safety, mitigate, reduce or control risks and hazards and warn of danger. Wrongfulness is firstly determined with reference to the general legal convictions of the community. Policies on road safety put the question of the communities' conviction that road transport safety is important beyond doubt. The policies discussed in sections 2.3 and 6.3 all highlight that road safety and the reduction in damages, especially the reduction in fatalities, are the expectations of the community and institutionalised in public consultations and expert views. The expectations of the community and development of policy are not static and the views on what the convictions with respect to road safety are have changed in the last 15 years.

Cape Town Municipality v Bakkerud (2000 3 SA 1049 (SCA) was a turning point in the so-called "municipal cases". Prior to this case, it was contended that the relevant legislation on roads imposed neither obligation nor duty upon the municipality to build or maintain pavements. It merely empowered it to do so. The courts had consistently held that municipalities had no legal duty in delict to repair a street or pavement. Leading up to this Supreme Court of Appeal case in 2000, the full bench of the Western Cape High Court launched an in depth analysis into the general or relative immunity of municipalities. They found that no immunity is justified any more. The Supreme Court of Appeal ruled that it was wrong to substitute immunity for what amounts to a blanket imposition upon municipalities generally of a legal duty to repair roads and pavements. It held the view that in applying the test of what the legal convictions of the community demand and reaching a particular conclusion, the courts are not setting general principles of law, but making value judgments *ad hoc*. The example of an underfunded municipality's low volume street imposing a lesser legal duty than a busy street in a large well-funded municipality was used to conclude that the court are not setting a principle of law that all municipalities have at all times a legal duty to repair or to warn the public whenever and whatever potholes may occur in whatever pavements or streets may be vested in them. A reasonable sense of proportion should be kept. The public had to have a care for its own safety when using the roads and pavements. Marais JA noted in Cape Town Municipality v Bakkerud that for each case, the plaintiff had submit sufficient evidence to conclude that a legal duty to repair or to warn should be held to have existed and that the failure to repair or to warn was at fault in negligence. He postulated that the factors relevant to the inquiry into wrongfulness will also be relevant to the enquiry of fault, and the onus of proving both the existence of the legal duty and blameworthiness in failing to fulfil it will go a long way to prevent the opening of the floodgates to claims of this type of which municipalities are so fearful.

A seminal case with respect to road safety is the case of Graham v Cape Metropolitan Council 1999 (3) SA 356 (C). In the verdict, van Deventer J said:

> The legal principles to be applied in cases of this kind may be summarised as follows: Wrongfulness in terms of the sense of justice and legal convictions of the community now applies to omissions by a public authority. A duty of care towards road users should apply to the controlling public authority unless there is a valid basis for its exclusion. However, as this, is whether the sense of justice of the community would view the failure of the local authority to take positive action as wrongful, subject to the qualification that the local authority is not required to do more than may be reasonably expected.

Note that van Deventer J used the wording of the English law doctrine of “duty of care”. Neethling, *et al* (2001:150) states that to void confusion, the duty involved in the test for wrongness should be termed a “legal duty” and not a duty to care.

In Telematrix (Pty) Ltd t/a Matrix Vehicle Tracking v Advertising Standards Authority [2006] 1 All SA 6), Harms JA (as he then was) restated the general approach in determining wrongfulness, namely that wrongfulness exists where public policy considerations demand that in the circumstances the plaintiff has to be compensated for the loss caused by the negligent act or omission of the defendant.

Where an act or regulation is explicit in its wording with respect to a duty or obligation, Neethling, *et al* (2001) state: “The causing of damage by means of conduct in breach of a statutory duty is prima facie wrongful”.

The use of the defence of a limited legal duty has since Cape Town Municipality v Bakkerud Council and Graham v Cape Metropolitan Council 1999 (3) SA 356 (C) by road authorities has declined. In the cases since 2008 that the researcher has been involved in, the legal duty to maintain and to ensure safety was mostly acknowledged and the test of reasonable conduct in the determination of fault was rather pursued.

3.4.3 Fault

The two main forms of fault are intention and negligence. The latter is typically the form present in road maintenance-related claims. These terms refer to the legal concepts of blameworthiness. The criterion established to determine if a person acted carelessly is relative to the objective standard of the reasonable person. Note that in a technical environment, the reasonable person is not the man in the street, but an appropriately experienced and competent technical person. A person will act with negligence if he was in a position to foresee the reasonable possibility of his conduct injuring another in his person or property and causing him loss and not taking reasonable steps to guard against such occurrence.

Negligence has been an issue in engineering for a long time, as illustrated in the case of Blyth vs Birmingham Waterworks (1856) II Ex Ch 781, where it was said that:

> Negligence is the omission to do something which a reasonable man, guided upon those considerations which ordinarily regulate the conduct of human affairs, would do, or doing something, which a prudent and reasonable man would not do. The standard demanded is thus not of perfection but of reasonableness. It is an objective standard taking no account of the defendant's incompetence - he may do the best he can and still be found to be negligent."

The determination of fault as conduct of the defendant must be seen against the contributory fault as conduct of the plaintive. The division of fault and subsequent damages are regulated by the Apportionment of Damages Act 34 of 1956. The important sections of this act are:

> Section 1(1)(a): Where any person suffers damage which is caused partly by his own fault and partly by the fault of any other person, a claim in respect of that damage shall not be defeated by reason of the fault of the claimant but the damages recoverable in respect thereof shall be reduced by the court to such extent as the court may deem just and equitable having regard to the degree in which the claimant was at fault in relation to the damage.
>
> Section 1(1)(b): Damage shall for the purpose of paragraph (a) be regarded as having been caused by a person's fault notwithstanding the fact that another person had an opportunity of avoiding the consequences thereof and negligently failed to do so.

The defence of contributory negligence must be proven on a balance of probabilities.

Negligence must be proven by the plaintive: the legal maxim *'res ipsa loquitur'* meaning the facts speak for themselves. This implies that for an accident to happen, some negligence must have been present, but it does not shift the onus of proof from the plaintive. This is an important principle in claims involving road accidents. Often the driver is the only person involved in the accident and cannot remember the detail of the accident. In the case of Snyman v Premier North West Province (614-05) [2009] ZANWHC (3 September 2009), the driver asked his wife on the day after the accident to look at the road. She reported a pothole in the road. A claim was lodged against the province on the basis of the size and location of the pothole and evidence of a local farmer as to the length of time that the pothole was there. The defendants led evidence in court that the pothole claimed to be the cause was not at the location of the accident and the case was dismissed. In the case of Matshoge v Premier NWP and others 279 (2012) [12 December 2014] in the North West Province, the judge found that it was not necessary to identify the exact pothole, as there were many potholes on the road leading up to the accident location that could have caused the blowout of tyres that results in loss of control.

3.4.4 Causation

For a delict to be proven, the wrongful act must be the proximate cause of the damage or loss: there must be a plausible connection to the act. This connection must be determined from the facts of the case (factual causation) and if it is sufficiently close becomes the legal causation. The series of linked actions cannot be stretched to extreme ends: the wrongdoer is not liable for harm that is “too remote” from the conduct.

The definition of the term ‘cause’ was cited by Corbett JA in Minister of Police v Skosana from Prosser’s Handbook of the Law of Torts 4 ed 237 (in Loubser, *et al*, 2009:66) as “a necessary antecedent: in a real and practical sense, the term embraces all things which have so far contributed to the result that without them it would not have occurred. It covers not only positive acts and active physical forces, but also pre-existing passive conditions which have played a material part in bringing about the event. In particular, it covers the defendant’s omissions as well as his acts”.

Motor vehicle accidents are the outcomes of complex chains of events and the determination of a cause or causes involves the investigation of multiple facets and dynamic interaction. The court has in the past steered clear of theoretical, hypothetical and excessively mathematical reconstructions of accidents. The legal approach to causation is a common sense test, the way the ordinary person’s mind work against the background of everyday life experiences (Minister of Finance v Gore N, 2002 (6) SA 431 (SCA)).

The investigation into factual causation analyses the actions and influences that resulted in the accident. It will consist of the plaintiffs behaviour (the way he / she drove), the vehicle’s condition, the road environment, the defendant’s behaviour (was the road inspected, maintained) and the interaction between the actions that lead to the specific outcome. Not all the steps or actions in the factual chain of events will be relevant for determining the cause of the accident. For instance, the purpose of the trip, such as going to work, cannot be a cause of the accident. If the chain of events considered is too long, too many opportunities to have broken the chain could be attributed to the plaintiff, making it impossible to claim for the specific last event.

There must therefore be tests to form the basis for legal causation. Neethling, *et al* (2001) note that building on the basic *conditio sine qua non* theory the adequacy, direct consequences and foreseeability theories have developed. For the purposes of this research, which is to understand causation in the context of road maintenance standards, the basic theory is sufficient. The *conditio sine qua non* theory is the “but for” test.

In International Shipping Co Pty Ltd v Bentley 1990 (1) SA 680 (A) at 700 E – 701 C the general principles of causation were reinstated as follows:

> As has previously been pointed out by this Court, in the law of delict causation involves two distinct enquiries. The first is a factual one and relates to the question as to whether the defendant’s wrongful act was a cause of the plaintiff’s loss. This has been referred to as factual causation. The enquiry as to factual causation is generally conducted by applying the so-called but-for test, which is designed to determine whether a postulated cause can be identified as a *causa sine qua non* of the loss in question. In order to apply this test one must make a hypothetical enquiry as to what

> probably would have happened but for the wrongful conduct of the defendant. This enquiry may involve the mental elimination of the wrongful conduct and the substitution of a hypothetical course of lawful conduct and the posing of the question as to whether upon such an hypothesis plaintiff's loss would have ensued or not. If it would in any event have ensued, then the wrongful conduct was not a cause of the plaintiff's loss; aliter, if it would not so have ensued, if the wrongful act is shown in this way not to be a *causa sine quo non* of the loss suffered, then no legal liability can arise. On the other hand, demonstration that the wrongful act was a cause sine qua non of the loss does not necessarily result in legal liability. The second enquiry then arises, viz whether the wrongful act is linked sufficiently closely or directly to the loss for legal liability to ensue or whether, as it is said, the loss is too remote.

In the Minister of Safety and Security v Van Duivenboden 2002 (6) SA 431 (SCA) at 449 E–F it was held that -

> A plaintiff is not required to establish the causal link with certainty, but only to establish that the wrongful conduct was probably a cause of the loss, which calls for a sensible retrospective analysis of what probably have occurred, based upon the evidence and what can be expected to occur in the ordinary course of human affairs rather than an exercise in metaphysics.

It must be noted that the factual causation must be established as a foundation for legal causation. In Snyman v Premier van die Noordwes Provinsie (2009), the plaintiff was involved in an accident of which he could not remember the details. He asked his wife to go to the road and look for reasons for him losing control over the vehicle. She found some potholes in the road and the case was based on those potholes.

> [24] The issue for determination is whether the pothole in the photos and that identified by the witness Koos de Wet indeed caused the collision. Anja Snyman was unable to tender such evidence, Koos de Wet was unable to tender such evidence, and the Applicant himself was also unable to tender such evidence.
>
> [25] Having found on a balance of probabilities that there was <u>no</u> pothole in the vicinity where the collision occurred or that a pothole caused the accident, it cannot be said that a case had been made out for contributory negligence on the part of the Respondent.

In Lauwrens v MEC Public Works Roads and Transport Limpopo Province (2013), a recurring subsidence of the approach fill to a bridge formed a depression of significant depth (between 60 and 160 mm). The driver lost control over the vehicle at the start of the bridge and veered into the opposing lane, hitting a vehicle travelling in the opposite direction. Notwithstanding testimony of a passenger that the car "jumped" at that specific point, the judge ruled that "Taking all factors into account it would appear that the cause of the collision was excessive speed on the part of Ms Lauwrens". The road feature was in the view of Ranchod J not linked to the accident.

In Matshoge v Premier of North West Province (2014), the accident happened on a road riddled with potholes. In this case, it could not be proven that the potholes photographed three months after the accident in which the plaintiff had been paralysed, were the actual potholes that the plaintiff drove through. Kgoele J, with due regard to the facts of the matter, ruled that

> Even if this Court can accept the submission as put by the defendants that the plaintiff did not point the exact pothole, this proposition does not assist the defendants at all, because, the defendants are not responsible for some of the potholes and not others. They furthermore did not proffer any alternative version in the face of their negligence in not maintaining the road and erecting road signs. The evidence of Mr Roodt in his report is to the effect that most of the potholes there were severe, and anyone of those could have resulted in loss of control.

3.4.5 Damage

Neethling, *et al* (2001:212) give a definition of damage as the diminution, as a result of a damage-causing event, in the utility or quality of a patrimonial (transmissible or relating to money) or personal interest in satisfying the legally recognised needs of the person involved.

The losses typically occasioned in accidents due to lack of maintenance work are real rights (for example, property), loss of rights (for example, income or profit), direct and consequential loss, general (intrinsic, for example, pain and suffering) and specific (for example, medical expenses incurred up to trial) losses. The loss of future right such as income, profit or expenses is the subject of prospective patrimonial damages.

Mitigation of loss places some obligation on the plaintive to take all reasonable steps to limit the damage caused by the defendant’s delict. A plaintive who fails to take reasonable steps cannot recover damages in respect of loss that could have been prevented.

The so-called quantum of a case is mostly separated from the merits of the claim. The focus of this research is primarily on the merits of cases to establish the role of the road factors and determine the standards that should be adhered to. However, the quantum or value of these claims is of interest, as it indicates the money that could have been saved by the road authority if the maintenance work was done. It must be noted that often only the cases with a high quantum are pursued. Attorneys undertaking these cases more likely than not take the cases on contingency (typically 25% of the value of the claim that is awarded). This is separate from the legal cost that follows the verdict; if the plaintiff is successful (independent of the percentage awarded based on contributory negligence), the defendant pays the legal cost of the plaintiff.

The range of magnitude for quantum pursued in the cases that the researcher has been involved with (see sections 7.3 and 7.4) is from R500 000 to R7 million. The final amount would be reduced by contributory negligence if found to exist.

The City of eThekwini (Durban) on 2 February 2015 was ordered by the Durban High Court to pay damages of R21.5 million to Mr Scott Taylor – who was left a paraplegic after his motorcycle hit a pothole in Botanic Gardens Road 26 years ago in terms of a settlement agreement (Broughton & Padayachee, 2011).

3.5 Claims against road authorities

The extent of claims against road authorities could not be determined for this research, as the road authorities are firstly reluctant to divulge such information in fear that more claims will be made and secondly because the financial reporting system aggregates cost of claims with general legal cost in the corporate services budget.

An investigation into the damages awarded in judgments proved to be inconclusive. The investigation was not formally structured, as it was anticipated that the roleplayers would not cooperate. The following remarks are thus anecdotal. The lesser claims with technical merit are often settled administratively and the cost included in general legal cost. Small claims with less merit are often abandoned by the plaintiffs after prolonged correspondence, as the effort to recoup the damages then exceeds the perceived benefits. Attorneys only take the claims with high monetary value and known risk on contingency. These involve technical aspects that have been accepted in previous cases as having merit as well as being understood by the legal parties.

A limited number of cases involving new aspects have been argued in the last five years, specifically Botha v MEC Eastern Cape Province 2447/2008 [2013] (14 August 2014) involving trees and Crafford v South African National Roads Agency Limited, (215/2012) [2013] ZASCA 8 (14 March 2013) involving grass next to the road. Many cases are heard on the merits first and, if successful, a second trial will deal with the quantum. Settlements are often offered if the defendant anticipates that the apportionment at the end of trial will be greater than an early settlement, or where the defendant does not want a legal precedent to develop on a specific technical aspect. The trials on quantum are often settled with confidentiality clauses.

The number of cases against road authorities is, however, set to rise, as changes to the Road Accident Fund (RAF) legislation to limit the value of general damages and to offer medical care for the patient’s remainder of life in place of the current upfront payment will make it attractive to claim directly from the road authority in cases where the road and negligence of the road authority play a role.

The Road Accident Benefit Scheme (RABS) draft bill was published in Government Gazette No 34765 on 21 November 2011. This no-fault benefit system is proposed to replace the RAF. The abolishment of the right to common law remedies is touted as the trade-off to the public for the fact that everyone would be able to claim under a no-fault system. The bill is opposed by lawyers on the grounds that general damages is a constitutional right and where such rights are abolished or affected they must be supplemented by an adequate compensatory advantage.

Increased numbers of claims against road authorities in the United Kingdom were attributed by the Roads Liaison Group (2005) to:

- **Maintenance backlog on local roads and footways** – Claim opportunities occur because roads and footways have deteriorated due to the historic lack of investment and subsequent maintenance backlog. Effective planned maintenance budget allocations can reduce maintenance-based claims to negligible levels.
- **Media coverage of highway liability claims** – There has been extensive media coverage given to the citizen’s right to claim from the highway authority in cases of accident and injury on public or publicly maintained property. Even though many of the claims are small in value, such as tripping on the footway leading to sprains, cuts and bruising; they are expensive to administer and process.
- **High-profile advertising** – Adverts now appear in doctors’ surgeries, local newspapers, television, and national and local radio.
- **Media personalities** – Some figures have been putting their names to such adverts.
- **Growth in no-win no-fee companies** – The legal and claims professions have also increased their advertisements for claimants on a ‘No Win - No Fee’ basis, although recent spectacular failures in this area may temper future expansion.
- **Open government – freedom of information** – Open government raises public awareness of expected service delivery through publicised performance targets and monitoring of the quality of service delivery. The promotion of formalised complaints procedures by local authorities also contributes to raise the level of expectation and the commensurate disappointment in any perceived shortfall.
- **Freedom of Information Act** – This is making public bodies far more accessible to individual members of the public. This act gives the public a statutory right of access to non-personal information held within the highway authorities, i.e. information that does not relate to people. In other words, a council can be asked for virtually any information and will be under a legal obligation to provide it.
- **New types of claims being made** – Recently, actions have been brought, not merely for physical or financial loss, but for ‘loss of face’, that is perceived to cause damage to a person’s standing in society. The potential for such claims is very substantial.
- **Level of awards being made** – There are no set financial compensation figures for the loss of a limb or other physical injuries suffered in road or other accidents for which a third party is proved to be at fault. Awards are usually agreed through out-of-court settlements decided by claims handlers and the injured person’s lawyer after studying previous awards by judges. The settlements can vary enormously depending on the age, state of health, family status and even hobbies of the individual concerned. Society is generally dissatisfied with the levels of awards, particularly for the routine types of injuries that are common in footway trips, *etc*.
- **Fraudulent claims** – Surveys suggest that one in seven persons are prepared to make fraudulent claims on insurance policies. Local authorities are particularly vulnerable to people asserting that they have sustained injury or loss on the highway, as these events often have no independent witness. The local authority is in the difficult position of wishing to treat legitimate claimants fairly and courteously, and yet deal appropriately with fraudsters.

Data obtained from the Queensland Government Insurance Fund (QGIF) relating to the Department of Transport and Main Roads for 1998 – 2008 show that road surface condition issues led to approximately 18% of the total claims. Potholes (approximately 5%) and loose gravel on roads (approximately 3%) are significant maintenance-related claims (Austroads, 2012:46).

Statistics from the UK were quoted (Austroads 2012) to create an awareness of the extent of highways-related civil liability claims in that country. Johns (2007) in (Asphalt Industry Alliance, 2011) reports that Zurich Municipal, an insurer in the UK, estimated that payouts by UK road authorities reached £250 million (approximately A$400 million) per annum by 2007. This figure does not include costs such as staff time in handling and dealing with claims and loss of reputation.

The UK Annual Local Authority Road Maintenance (ALARM) Survey report for 2011 quoted that for England and Wales in 2010:

- Road user compensation payouts totalled £19.3 million;
- a total of 46 300 officer days were spent addressing highway compensation claims;
- the total costs of the road user compensation claims (i.e. cumulative awards + cost officer time) was approximately £35 million;
- the average number of claims received per English road authority (excluding those in London) was 446, with each claim having an average value of just under £200; and
- the majority of claims received were for damaged tyres and wheels. (Asphalt Industry Alliance, 2011).

Research into tort liability and risk management and the extent of claims against the Pennsylvania Department of Transportation was done by Gittings (1987), after the modification of legislation of sovereign immunity came into effect in 1979. The state took a proactive approach and in the early 1980s implemented a tort liability seminar to upgrade the understanding of field staff of the problem, their actions and liability. They also alerted district offices to collect and record information in defence of possible legal action. Despite the early management initiatives, claims grew from settlements totalling $8 300 000 in 1982/83 to a budget of $20 000 000 in 1985/86. A study in 1983 used a random sample of 385 actions from the period 1979 to 1982. The primary factors leading to claims were identified in 247 cases as:

- Signs: Missing / obscured / inadequate (50 cases);
- potholes, dips, and other deformities (55 cases);
- slippery pavements (34 cases);
- shoulder drop-offs (21 cases);

- objects – debris, equipment, etc. (15 cases);
- objects – excess gravel or tar (40 cases);
- steel rods, expansion plates, or holes on bridges (16 cases); and
- roadway geometrics (16 cases).

When these cases were analysed in terms of the severity of the accidents, the primary factors identified were signs, surface deformities (e.g. potholes), slippery pavements and shoulder drop-offs.

Gittings concluded with a statement that the ‘‘most difficult management problem over which the Pennsylvania Department of Transportation have direct control is achieving a proper balance between productivity objectives, which should mitigate the tort liability problem in the long run, and the risk management objectives calling from relatively immediate correction of dangerous conditions’’ (Gittings, 1987).

3.6 Professional ethics

> Engineers need to think ethically. Working in a profession that affects the lives of individuals and communities brings with it significant responsibility to act in an ethical and responsible manner (Maudslay & McCarthy, 2011).

Velasquez, Andre, Shanks, Michael and Michael describe ethics as well-founded standards of right and wrong that prescribe what humans ought to do, usually in terms of rights, obligations, benefits to society, fairness, or specific virtues. Ethical standards include standards relating to rights, such as the right to life, the right to freedom from injury, and the right to privacy. They explain that ethics cannot be equated with feelings, nor identified with religion. Being ethical is not the same as following the law. The law often incorporates ethical standards to which most citizens subscribe (Velasquez, Andre, Shanks, Michael, & Michael, 2010).

Case law and the Bill of Rights, as stated in the Constitution, bind the engineer to the role of caring – the *diligence paterfamilias* (meaning the careful father; the reasonable and responsible person). Failure to fulfil this role has serious consequences.

The Engineering Council of South Africa (ECSA) Rules of Conduct for Registered Persons (South Africa, 2013) as published in the Government Gazette 37123 confirm the commitment to the public and the environment in sections 3(3) and 3(4). The registered person must at all times have due regard for and give priority to the health, safety and interest of the public, and avoid or minimise adverse impact on the environment. The ethical dimension arising from the Rules of Conduct require of registered persons to execute their work with integrity and in accordance with accepted norms of professional conduct. The Rules of Conduct underscore the same values and high levels of commitment and dedication as those of engineering councils internationally.

Section 11 of the Institute of Transportation Engineers (ITE) Canons of Ethics states: “The member will guard against conditions that are dangerous or threatening to life, limb, or property on work for which the member is responsible, or, if not responsible, will promptly call such conditions to the attention of those who are responsible” (Neel, 2004).

Neel elaborates that transportation engineers must be deeply committed to the codes of ethics that bind them. He adds that transportation engineers face different ethical challenges depending on whether they work for the public or private sector or as expert witnesses. In addition, there are grey areas where codes do not seem to apply. Transportation engineers should be educated to recognise and properly respond to unethical behaviour. Paramount is due regard for the safety, health and welfare of the public in the performance of professional duties (Neel, 2004).

Ethics demand of the engineer to relate abstract principles to concrete situations. This responsibility to the public good and public safety is often cited, but sometimes poorly understood, even among practising engineers. A large part of the problem is a lack of legal or other clarity as to how this responsibility should be exercised in the real world. Sometimes the practitioner is trapped in an impossible position, with no clear path out (Maudslay & McCarthy, 2011).

In ECSA v City of Tshwane Metropolitan Municipality 2008, Weyers, an electrical engineer responsible for Power System Control, refused to appoint unsuccessful candidates in posts for network system operators and system controllers. When pressurised to do so despite the fact that the candidates had not passed the required skills test, he reported the matter to the Engineering Council of South Africa. His reasons were that his ethical convictions had been violated because such appointments would jeopardise the safety of the public and the appointees themselves. He was fired, but the Court ordered that he be reinstated.

West (1991) published an article on responsibilities of professional engineers and investigated the need to enhance the teaching of the principles underlying this at universities. He stated that:

> A profession must be able to control its work products. These work products must meet the ideological goals of the profession. These professional goals must agree with the perceptions and needs of the public being served. Yet, as a profession, it has been incumbent on the Professional Engineer to not be an advocate of the client but to protect the public (West, 1991:362).

The road engineers in the employ of road authorities will be challenged to continually promote road safety in the interest of the public as road users, as part of their work duties as well as their ethical convictions. The institutionalisation of safe standards of road conditions will establish an objective basis for maintenance and setting of priorities.

3.7 Skills

In its National Scarce Skills List, the Department of Higher Education and Training (2014) lists the top three scarce skills in the Government Gazette as Electrical, Civil and Mechanical Engineering. It defines “skill” as follows:

> Skill is defined as “the necessary competencies that can be expertly applied in a particular context for a defined purpose” and “competence” has three elements:
>
> a) Practical competence - the ability to perform a set of tasks;
>
> b) Foundational competence - the ability to understand what we ourselves or others are doing and why; and
>
> c) Reflexive competence - the ability to integrate or connect our performance with an understanding of the performance of others, so that we can learn from our actions and are able to adapt to changes and unforeseen circumstances (South Africa, 2014).

Road engineers (a specialisation within Civil Engineering) are knowledgeable, experienced and skilled employees who have to perform in accordance with legislation and common law, as well as to an ethical code. If a person takes on a position such as road engineer that requires special skills, he is expected to be able to perform the tasks.

> The standard by which his conduct is measured is the conduct of a reasonably skilled, competent, and experienced person who is a qualified member of the group authorized to engage in that activity. Anyone who performs these special skills, whether qualified or not, is held to the standards of conduct of those properly qualified to do so, because the public relies on the special expertise of those who engage in such activities (Legal Dictionary, n.d.).

The difference between “qualification” and “competence” should be borne in mind when considering if an engineer in a position of responsibility is skilled or competent in his / her profession. Qualification is an accomplishment that fits a person for some function, office or position. This manifests in degrees and diplomas that cannot be lost. Competence is having suitable skill, knowledge, or experience for some purpose. An engineer undertaking work or a position needs to assess his/her competence to fill this position before agreeing to accept the appointment (Professional Engineers Ontario, 2011).

The guiding principle, originating from Roman Law, is that: “*Spondet peritiam artis, et imperitia culpae adnumeratur” (*meaning that he is responsible for skill in his profession and want of such skill is regarded as a fault) (Bell, 1870).

The road authority that employs inappropriate persons in technical positions faces the risk of negligent acts or omissions under the doctrine of vicarious liability. The purpose of the thesis is not to explore all legal aspects of road building. It is sufficient to define vicarious liability as the doctrine that employers are held liable for any damage caused to third parties by their employees acting within the cause and scope of their employment.

As is evident in the list of scarce skills, South Africa has a general shortage of engineers. An analysis of municipal performance by the Municipal Demarcation Board shows that 50% of municipalities do not have technically qualified persons in service (Municipal Demarcation Board, 2012). Road authorities similarly have unqualified staff in professional posts or high rates of vacancy. Often these posts are filled by project managers, administrative clerks or tradesmen. This phenomenon increases the risk for the individual and vicariously also the road authority.

3.8 Conclusion

This chapter discussed legal duty in the context of road maintenance. The responsibility for maintaining the South African road system is allocated to authorities by legislation at the national, provincial and municipality levels.

Road authorities are the only institutions empowered to own public roads and it follows that they are obliged to build, operate and maintain them in functional condition for reasonable use. Road users expect that roads can be used with safety. Legal duty describes the way an engineer executes his/her duties without being negligent.

Much of the policy initiatives are currently driven by the international thrust to reduce fatalities through the ambitious goals of the Global Road Safety Programme and the Decade of Action for Road Safety 2011 – 2020. It requires road safety engineering with a Roads Development Plan that is a strategy for upgrading the road infrastructure and signage on the basis of continuous audits of hazardous locations and accident red spots.

The high accident and casualty rates due to poor traffic conditions on South African roads are unacceptable. It can no longer be assumed that the burden of road safety responsibility simply rests with the individual road user.

The “system managers” that include the government and industry organisations that design, build, maintain and regulate roads and vehicles have a primary responsibility to provide a safe operating environment for road users.

The law of delict is the redress of the wrongful act against the driver of a vehicle, passenger, pedestrian, cyclist, adjacent land owners, owners of services in or over the road reserve, and even public institutions.

Road engineers (a specialisation within Civil Engineering) are knowledgeable, experienced and skilled employees who have to perform in accordance with legislation and common law, as well as within an ethical code. If a person takes on a position such as road engineer that requires special skills, he is expected to be able to perform the tasks.

The registered professional transportation engineer must at all times have due regard for and give priority to the health, safety and interest of the public, and avoid or minimise adverse impact on the environment. He/she must execute their work with integrity and in accordance with accepted norms of professional conduct.

South Africa has a general shortage of engineers, also in Civil Engineering. Up to 50% of municipalities do not have technically qualified persons in service. Road authorities similarly have unqualified staff in professional posts or high rates of vacancy, with other staff attending to engineering work. This phenomenon increases the risk for the individual and vicariously also the road authority.

Chapter 4: Methodology

> The essence of a dissertation is critical thinking, not experimental data. Analysis and concepts form the heart of the work (Purdue University, n.d.).

This chapter is the introduction to the research design. It describes the research instruments, data used, limitations, ethics and a conclusion.

4.1 Introduction

The objective of this research is to evaluate the knowledge in the field of road maintenance to obtain a coherent framework of standards applicable in the management of safe road systems to withstand legal scrutiny.

This research is an analysis of literature on the characteristics and attributes of road elements that influence safety and the integration of road safety into infrastructure asset management. It defines standards and threshold levels for intervention to prevent deterioration of safety conditions. Asset management as a system that tracks the condition of infrastructure over time is the appropriate tool to predict and warn when road safety critical characteristics reach threshold levels and can be designed to calculate probability of accidents and cost of remedial measures to manage risk.

Similarly, the legal duty towards safety in maintenance is evaluated through literature and analysis of case studies of claims for damage from road authorities or their independent contractors.

4.2 Research design

Selecting a research method starts with reflection on the nature and purpose of the research. This research undertakes a synthesis of the body of knowledge straddling the road safety engineering and legal disciplines in order to create new knowledge and understanding.

Justification for the qualitative nature of the study is found in Bloom’s taxonomy of educational objectives (revised) in Figure 4-1. A dissertation must be commensurate with the highest educational objective of evaluating the current body of knowledge and creating new knowledge. Appropriate key action verbs for evaluating are: appraise, compare, conclude, contrast, criticise, critique, defend, describe, discriminate, evaluate, explain, interpret, justify, relate, summarise, support (Learning Theories, n.d.). This, indeed, warrants qualitative methods.

Figure 4- 1: Bloom's taxonomy of educational objectives (revised)

(Source: Bloom's Taxonomy (Bloom) in (Learning Theories, n.d.)

Cunliffe writing about social research, states that researchers need to decide their assumptions about the nature and purpose of knowledge (epistemology) before deciding which research methods might be appropriate (Cunliffe, 2011).

> Thus, our metatheoretical assumptions have very practical consequences for the way we do research in terms of our topic, focus of study, what we see as 'data', how we collect and analyze that data, how we theorize, and how we write up our research accounts (Cunliffe, 2011:651).

Hoepfl characterises qualitative research (or phenomenological inquiry) as a naturalistic approach that seeks to understand phenomena in context-sensitive settings. Quantitative research seeks cause, prediction and generalisation of findings, while qualitative research seeks illumination, understanding, and extrapolation to similar situations. This results in a type of knowledge that differs from that found in quantitative inquiry (Hoepfl, 1997).

Qualitative research interprets meaning in descriptive data and the spoken word, whereas quantitative research interprets numerical data through statistical methods. The data are organised and categorised to detect patterns and themes, relative importance and relevance. The analysis is more intuitive and the challenge is to find logical and meaningful categories, examine these in a holistic manner and to communicate the interpretation to others (Hoepfl 1997).

Further, the research for this dissertation leans strongly on the experience of the researcher, placing the researcher in the first person point of view. This aligns with phenomenology as a field of philosophy: the study of phenomena, how things appear in the observer's experience and the meaning they have in his or her view.

> Phenomenology studies conscious experience as experienced from the subjective or first person point of view related to the other main fields of philosophy: ontology (the study of being or what is), epistemology (the study of knowledge), logic (the study of valid reasoning), ethics (the study of right and wrong action) (Stanford University, 2013).

4.3 Research instruments

The research is based primarily on literature and case studies. No bespoke research instruments were developed for the collection, collation, analysis and synthesis of the information.

4.4 Data

Data were collected for the development of road maintenance standards from previous studies and policy documents. Values for appropriate characteristics were analysed and interpreted in classes or categories. There was no need to determine averages and standard deviation of values for which the standards (threshold values or ranges) have been described.

As an example: road geometric design elements such as stopping sight distance are influenced by braking performance. The skid resistance of a road surface determines the braking distance of a vehicle. The road geometric design assumptions up to 1990 used worst-case scenarios of skid resistance as the limit states to determine deceleration rates. One such case would be a vehicle with bald tyres on a wet road with a smooth asphalt surface. The design values varied with speed with a range of 0.25 at 120 km/h to 0.35 at 60 km/h. The 1990 revision of the Association of American State Highway and Transport Officials (AASHTO) A Policy on Geometric Design of Highways and Streets widely regarded as the road designers' bible, brought in a new approach to the design value for deceleration rate (braking). Comfort was introduced as the appropriate criterion and was fixed at 3.4 m/s^2 which corresponds with a skid resistance of 0.35 (American Association of State Highway and Transportation Officials, 1990).

4.5 Limitations

The research was based on literature published in English. Similar research in European countries, South America and Asia published in local languages was therefore not taken into account.

4.6 Ethics

The ethical considerations for research at the Stellenbosch University are guided by the Policy for Responsible Research Conduct at Stellenbosch University (Stellenbosch University, 2013). The primary guiding values for research are:

- Transparency;
- mutual respect;
- scholarship; and
- responsibility

In terms of section 6.4 and paragraph 10 of this policy, it is the responsibility of the researcher to be self-critical towards the content of the study and ensure that ethics approval for his research is obtained when required in terms of this policy, or by generally accepted norms and standards for ethical research. If required, the application is to be submitted to the Engineering Faculty research ethics committee to review, provide ethics approval and monitor the research.

Ethics approval is required for research involving human interaction, animals and bio-safety and environmental issues. The human interaction is elaborated in paragraph 10 of the policy:

> However formal ethics review and approval is mandatory in all instances where obtaining prior informed consent from individuals or permission from organisations or institutions would be an obstacle to fulfilling the objectives of the research.

The research involved in this dissertation into road maintenance standards for safety and legal duty is literature-based and the crucial categories of research involving human interaction, animals and bio-safety and environmental issues are not relevant. It was thus concluded that a submission to the ethic committee was not mandatory or otherwise required.

Case studies on claims against road authorities involve individuals claiming for damages, injuries or loss of support where fatalities occurred, affecting confidentiality and anonymity. However, as judgments are public documents, identifying those individuals and the descriptions in the case studies do not expose more information of a personal nature.

A further consideration was that of conflict of interest. A conflict of interest occurs when professional judgement regarding an interest, for example, research, is unduly influenced by another interest such as financial gain or gain in personal status. Conflicts of interests are an inherent and unavoidable part of the academic research environment and can be effectively managed by disclosure and transparency (Stellenbosch University, 2013).

This aspect had to be considered as the researcher not only does research on road safety, geometric design and traffic engineering, but also appears as expert witness in cases relating to claims against the road authorities. An expert witness is an officer of the Court and has the duty to reconstruct crashes and explain technical matters in lay terms for the Court. The expert witnesses are instructed by the plaintiff(s) or defendant(s) and their professional fees are paid by the instructing party.

It could therefore be construed that the researcher, in compiling these guidelines on standards, may use the knowledge gleaned for financial gain. Such an interpretation is, however, baseless. The researcher already has this knowledge. The publication of a dissertation will put the knowledge out in a concise format in public. Sharing the knowledge will benefit society as road authorities are provided with more tools to assist in planning and motivating for adequate road maintenance funding on the basis of their legal duty to safety.

4.7 Conclusion

This chapter introduced the research design, based on the synthesis of the body of knowledge straddling the road safety engineering and legal disciplines in order to create new knowledge and understanding.

The literature study analysed good practice in the field of road safety engineering standards and the legal duty of road authorities. The results of court cases relating to claims against road authorities were analysed.

This dissertation is the result of a qualitative research process, primarily based on literature and case studies. Data collected for the development of road maintenance standards from previous studies and policy documents were analysed and interpreted in classes or categories.

The guidelines on standards for road maintenance is provided in the hope that the sharing of the researcher’s knowledge will benefit society as a whole by assisting road authorities in planning and motivating for adequate road maintenance funding on the basis of their legal duty to safety.

Chapter 5: Maintenance standards for characteristics

5.1 Introduction

> Defects that immediately affect safety should be given first priority in pavement maintenance. Typical defects in this category are slippery pavement, raveling, rutting, potholes, and abrupt vertical variations (California Department of Transportation, 2014b).

This chapter builds on the literature review in Chapter 2 – specifically section 2.8: Development of standards. In the literature review the characteristics of road features that are subject to deterioration were identified for maintenance in general and for their safety implications. The features and characteristics with attributes in the sources were used as basis to identify those with a road safety implication. In this chapter appropriate features and characteristics of road infrastructure that need to be maintained for safety are analysed. By so doing attributes of measurable characteristics are qualified. Standards could then be developed.

5.2 Characteristics proposed for maintenance standards

The development of standards was discussed in Chapter 2, section 2.8. In this section the following terms are used (after Smith and Adams, 2005):

> Asset: A physical item of roadway infrastructure that has value. Assets are roadway “furniture” or “features”. An asset may be a single item, such as a sign, or a linear item, such as a road or guardrail section, or a spatial item, such as a rest area or mowable acreage.
>
> Category: Logical groups of maintained assets that are combined because of their common function or location on the highway, such as pavements and drainage structures.
>
> Feature: Assets that are contained in a category. For instance, the traffic category might include guardrails, impact attenuators, and barriers.
>
> Characteristic: Specific performance measures that are rated for each feature.
>
> Attribute: Quality describing a characteristic belonging to a road feature.

The ISO definition is repeated for ease of reference:

> A **standard** is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose (ISO, n.d.)

The road maintenance characteristics proposed for the development of standards in this thesis meet certain criteria. They are:

- Measurable quantitatively or qualitatively;

- important for maintenance management systems in general; and
- contribute to the safety objectives and safety management in particular.

The selected characteristics are typically collected in infrastructure asset condition assessment surveys, the road safety features identified in literature, road elements mentioned in claims for damages in court cases and the experience of the researcher in investigating accidents. The characteristics proposed as appropriate for road maintenance standards are given in the Table 5-1 :

Table 5- 1: Road maintenance standards characteristics

Category	**Feature**	**Characteristics**
Roadway	Lane and surfaced shoulder	Texture Skid resistance Rutting and ponding Potholes and shoving Loose material
	Gravel shoulder	Edge drop-off Edge break
Traffic Control	Road markings	Visibility
	Road signs	Visibility and readability
Drainage	Side drains	Blockages Grid inlet cover
	Cross drainage	Culvert openings Flow channel
	Roadway	Flow path
Road side	Clear zone/Recovery area	Designed width Slope
	Barrier	Guardrail Guardrail terminals Bridge ballustrade
	Vegetation	Highway trees Lines of sight

The characteristics of the selected features are discussed below and conclusions are formulated with respect to standards that can be proposed for the measurable values.

5.3 Roadway and shoulder

5.3.1 Texture

Texture plays a significant role in wet weather skid resistance, which is the basis of many of the elements, such as stopping distance, in road geometric design. The control of a vehicle depends mainly on steering and braking. These actions require that sufficient friction exists between the road and the tyres of the vehicle, as expressed in the Coefficient of Friction (CoF).

The two important characteristics of surface texture are the surface texture depth (determined by the size of the aggregate in the surfacing and called macro-texture) and the harshness or roughness of the stones themselves (called micro-texture). The nature and dimensions of macro-texture and micro-texture are illustrated in the figure below (Sandberg, 1998):

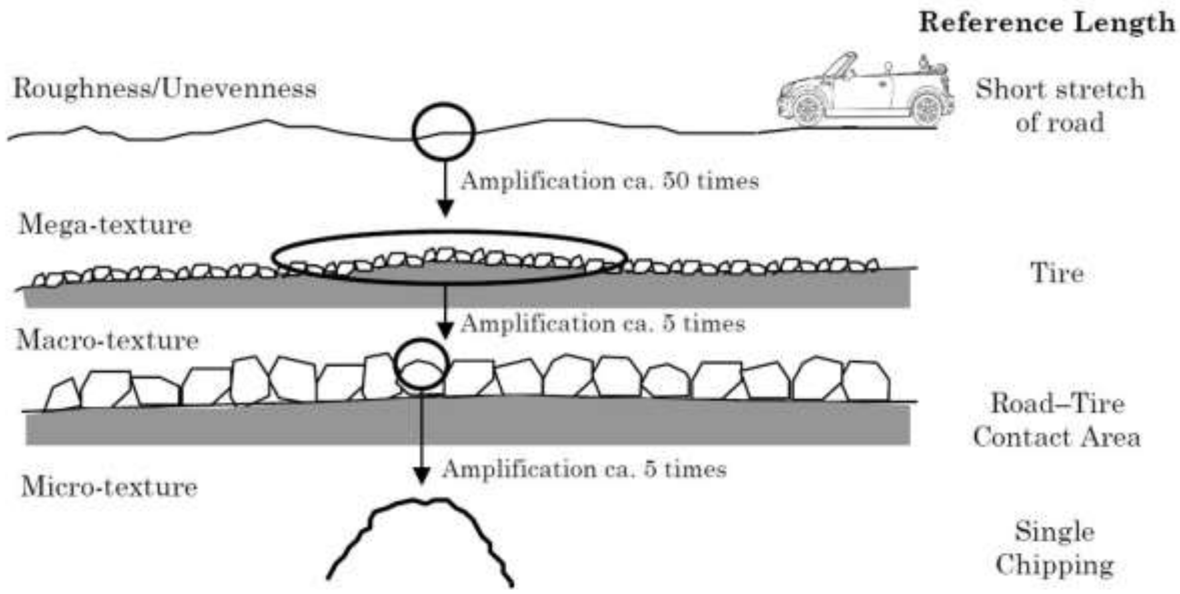


Figure 5- 1:Simplified illustration of texture ranges after Sandberg (1998)

The ranges of values for dimensions of the types of road surface texture were standardised by the International Organisation for Standardisation (ISO, 13473-1:1997). The descriptions are given in the following Table 5-2 (ISO, 1997):

Table 5- 2: Dimensions of surface texture types

	Texture wavelength range	Typical peak-peak amplitudes	Comments
Micro-texture	<0.5 mm	0.001 – 0.5 mm	Texture which makes the surface feel more or less harsh but which is usually too small to be observed by the eye. It is obtained by the surface properties (sharpness and harshness) of the individual chippings or other particles of the surfacing which come in direct contact with the tyres.
Macro-texture	0.5 – 50 mm	0.1 – 20 mm	Wavelengths in the same order of size as tyre tread elements in the tyre/road interface. Surfaces are normally designed with a certain macro-texture in order to obtain a suitable water drainage in the tyre/road interface. The macro-texture is obtained by suitable proportioning of the aggregate and mortar of the surface or by certain surface finishing techniques.

	Texture wavelength range	Typical peak-peak amplitudes	Comments
Mega-texture	50 – 500 mm	0.1 – 50 mm	Wavelengths in the same order of size as a tyre/road interface and is often created by potholes or 'waviness'. It is usually an unwanted characteristic resulting from defects in the surface. Surface roughness with longer wavelengths than mega texture is referred to as unevenness.

The mean texture depth was measured, prior to laser scanning, with the sand patch test, now using more uniform glass beads for better reproducibility. A known volume of glass beads are spread in an approximate circular patch. The average diameter of the resulting patch is used to determine the average texture depth. The measure used in this test is the sand patch test depth (SPTD) in mm. The methodology was standardised in ISO 10844 as quoted in (COTO, 2008). Local measurement of texture depth by means of the sand patch test was time-consuming and considered dangerous due to the need to close the lane.

Texture could previously not be measured efficiently and economically on a network scale other than by visual assessment. Before 2010 most pavement management systems did not use texture in the condition index calculation to determine maintenance needs (including reseals) (CSRA, 1992).

The development of laser scanning technology that can measure the shape and size of aggregate in three dimensions and calculate mean texture depth made it possible to use texture as a surrogate for skid resistance management (NZ Transport Agency, 2013). Laser scanning could be used to collect other data such as line markings and be mounted on a survey vehicle that collects data on road signs, video recordings of road verges and road roughness. The cost of measuring texture has thus become a fraction of the cost of doing skid resistance surveys involving water spraying and tyre wear.

A pavement with high macro-texture presents less reduction of friction with speed and is less probable to contribute to hydroplaning (Flintsch & McGhee, 2009). The surface texture depth has a direct effect on the variation of skid resistance measured using the ribbed tyre contact method (Ahammed & Tighe, 2011).

A further important aspect of macro-texture is the provision of space under the tyres to dissipate water during rain. Modern tyres have tread to assist with this, but hydroplaning (also referred to as aquaplaning) can occur if the depth of water on the road, in combination with other factors such as speed, length of the ponding, contact area and mass of the vehicle, exceeds a critical value. Figure 5-2 illustrates the lifting of a wheel when the hydrostatic pressure exceeds the contact pressure acting on the tyre (Nygardhs, 2003). The film of water can cause partial or total loss of contact between the tyre and the road surface.

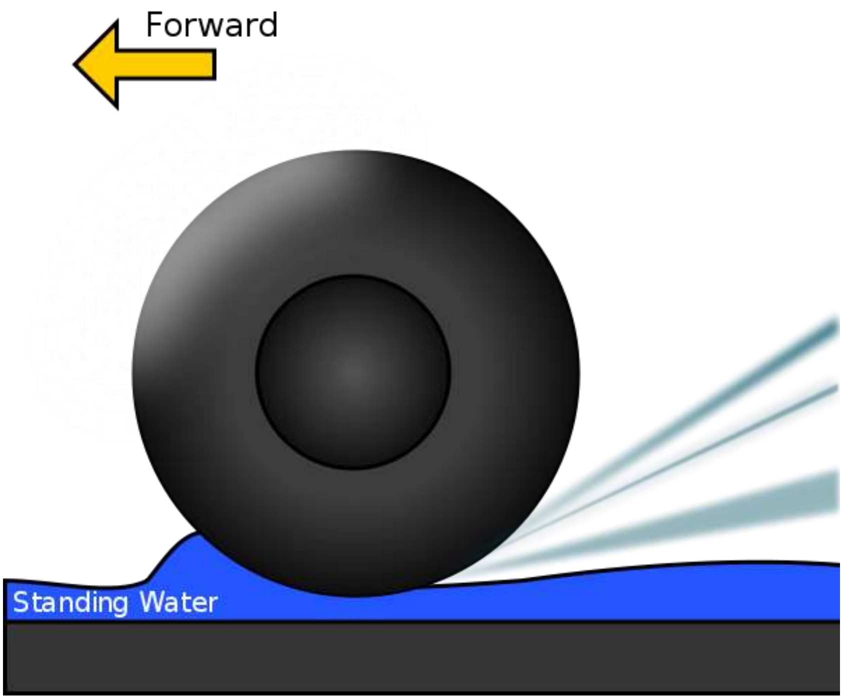


Figure 5- 2: Illustration of hydroplaning

Source: (Victovoi, n.d.)

Pavement macro-texture and tyre tread depth influence the onset of dynamic hydroplaning in two ways. First, they have a direct effect on the critical hydroplaning speed because they provide a pathway for water to escape from the pavement-tyre interface. Second, they have an indirect effect on the critical hydroplaning speed since the larger the macro-texture, the deeper the water must be to cause hydroplaning. However, as described in the Guide for pavement friction NCHRP Project 01-43, the pavement surface must also have the proper micro-texture to develop adequate friction (Smith, Hall, Titus-Glover, Warmbold, Yager, and Rado, 2009).

Once contact between the tyre and the road is reduced, ability to stop and steer is also greatly reduced. Examples show that for a Portland cement surface, critical speeds for hydroplaning are 86 to 90 km/h with water film thickness of 1.6 to 1 mm respectively (Austroads, 2010a).

Hydroplaning is regarded in the literature as in general a low-probability event as high-intensity rainfall is required to build up a deep enough depth of water on the road. In South Africa, Highveld thunderstorms can have intensities of 100 mm in an hour in localised areas, which is sufficient to cause roadway flooding.

The other known hazardous location for hydroplaning is on the development of superelevation at the start and end of curves, where the roadway must rotate through a flat point. If the road is on a gradient, the flow path can curve back and its length can be in excess of 60 m. Two of the case studies in Chapter 7 highlight this problem. In the case study of de Beer v MEC Roads and Transport Mpumalanga, an accident on a rural two-lane road, the quantity of water was increased due to down chutes that were not open. In the other case study of December v SANRAL the one carriageway of a wide freeway the width of the roadway resulted in a flow path in excess of 120 m. This will also be discussed under the section on drainage flow path.

Hydroplaning in wheel ruts where water accumulation can be much greater than the storm water runoff will be discussed under the section on rutting and shoving.

Research in Australia indicates that resurfacing a section of road where texture depth is below a sand patch test depth (SPTD) of 1 mm may be expected to reduce crashes by 50%. It found a rapid rise in crash rate associated with a SPTD of less than 1 mm (Austroads, 2010b).

Investigatory levels for texture depth were proposed for different jurisdictions in Australia (Austroads, 2013b) as indicated in Table 5-3 below:

Table 5- 3: Review of existing texture depth investigatory levels adopted by other jurisdictions

Jurisdiction	Site description	Texture depth investigatory level (in Estimated Texture Depth (ETD), mm)
South Australia	Freeways and other high-class facilities with free-flowing traffic conditions	0.4*
	Highways (speed limits higher than 80 km/h) Other major main roads subject to stopping and turning (speed limits lower than 80 km/h)	0.6
	Other local roads (sealed)	0.4
Tasmania	Highways (speed limits higher than or equal to 80 km/h) Highways and other major main roads subject to stopping and turning (speed limits lower than 80 km/h)	0.7**
	All other sealed roads	0.6
New Zealand	Sealed roads with speed limits of 50 km/h or less	1.0***
	Sealed roads with speed limits higher than 50 km/h and less than (or equal to) 70 km/h	1.0
	Sealed roads with speed limits of 70 km/h or higher	1.0
Victoria	High speed zones with speed limits of 90 km/h or higher with more than 1000 vehicles per day	1.2****

* The texture depth format was not described in the reference, but appeared to be in the ETD format

** The texture depth format was given in sand patch texture depth (considered identical to ETD)

*** The texture depth format was given in Mean Profile Depth (MPD) format. The conversion to ETD was done by ETD=0.8xMPD+0.2 (Sandberg, 1998)

**** The texture depth format was given in sand patch texture depth. This is the minimum initial sand patch surface texture for long term surfacing treatments

Conclusions on standards for surface texture maintenance

Surface texture is an important indicator of the condition of a seal or asphalt layer. Macro-texture and micro-texture play roles in the control of vehicles: both provide friction and therefore skid resistance to enable acceleration, deceleration and steering. Adequate macro texture has been shown to be a surrogate for skid resistance, as it ensures that the aggregate is still exposed and the micro-texture can interact with the tyre surface. Micro-texture is the characteristic that ultimately determines skid resistance. The importance of macro-texture lies in the dissipation of water between road surface and tyre to prevent hydroplaning which occurs mostly on high-speed roads. With adequate macro-texture the risk of hydroplaning is mitigated and the micro-texture is exposed to provide the skid resistance.

From the preceding analysis, it is recommended that texture depth on roads with operating speeds in excess of 80 km/h be set at a trigger value of 1 mm for the estimated texture depth to monitor the road sections in curves and that a minimum value for the estimated texture depth of 0.5 mm be defined as a standard for safety.

For roads in urban areas, where stopping and sharp curves, including manoeuvring through roundabouts, are prevalent, the micro-texture of the aggregate will dominate as it determines the skid resistance. As this characteristic cannot be measured in a condition assessment, the direct measurement of skid resistance will be the proposed measure. This is analysed in the next section.

5.3.2 Skid resistance

The ability to control a vehicle in acceleration and steering is determined by the forces that interact between the tyre surface and the road surface. These forces are dependent on the value of the CoF between the two surfaces. The assumptions made about the CoF were historically used in design criteria for road geometric design with respect to braking ability in stopping sight distance and steering ability for the design of minimum values of curve radii. The AASHTO Policy for the Geometric Design of Rural Highways, 1954, gives a good overview of the research on braking performance that formed the basis of modern highway design (American Association of State Highway and Transportation Officials, 1954). From 2001 onwards the design assumptions changed to comfort criteria and the value of 3.4 m/s^2 was used for braking (American Association of State Highway and Transportation Officials, 2004). This implies a CoF of 0.35, which must be available under worst case condition of a wet road with tyres with at least the legal minimum tread of 1 mm (NRTA Regulation 212(j)(i)).

However, the braking system of a roadworthy vehicle that can exceed a speed of 40 km/h must be able to brake at a deceleration rate of 4.4 m/s^2 from an initial speed of 35 km/h as per (NRTA Regulation 155(1)(a)(i)). See Table 5-4 that shows the regulations. It interprets that the driver, who is required to have a vehicle that complies with the act, has the legal expectation that the road will provide a commensurate CoF of 0.45.

Table 5- 4: Service brake minimum deceleration rate

Requirements for braking performance – Table A

Service brake of motor vehicle or combination of motor vehicles capable of exceeding speed of 40 km/h

[Table heading substituted by GNR.404 of 2007]

	Initial speed in km/h	Maximum stopping distance in m	Minimum deceleration in m/s^2	Minimum equivalent braking force in N/kg
Light motor vehicle	35	14	4.4	4.4
Heavy motor vehicle	35	16	4.4	4.4

Source: NRTA 1996

In the road environment, the term skid resistance is more often used than the more fundamental physical feature of CoF. The measurement of skid resistance covers an extensive body of literature, technologies and methods. The friction between the tyre and pavement is measured through contact testing. Non-contact testing such as the measurement of macro-texture as discussed in section 5.3.1 could be used to estimate skid resistance. A combination of both contact and non-contact testing could also be used for estimating a skid resistance function to speed. Skid resistance is primarily measured in South Africa using a fixed slip wheel device (contact method) such as the Grip Tester, while the SCRIM (sideways wheel) and ASTM (locked wheel) equipment are used in the UK and US. The results of the surveys are reported in units that identify the different machines, such as SFC(50) for the SCRIM friction coefficient at 50 km/h and Grip Number for the Griptester. These values can be converted to CoF. It is not the purpose of this thesis to explore the measuring methods. The skid resistance will be presented as CoF, assuming the values proposed are converted from the various surveys. See the Guidance for the Development of Policy to Manage Skid Resistance AP-R374/11 for a description of available technologies (Austroads, 2011).

Transportation agencies monitor skid resistance because reduced wet-pavement friction increases wet-pavement crashes (Flintsch & McGhee, 2009). The Austroads report on Road Safety Engineering Risk Assessment Part 11: Road Safety and Maintenance adopted research of Davies, Cenek and Henderson to show a graphical illustration of how the crash rate increases for CoF lower than 0.4, see Figure 5-3 (Figure 2.1, Austroads 2010b:5).

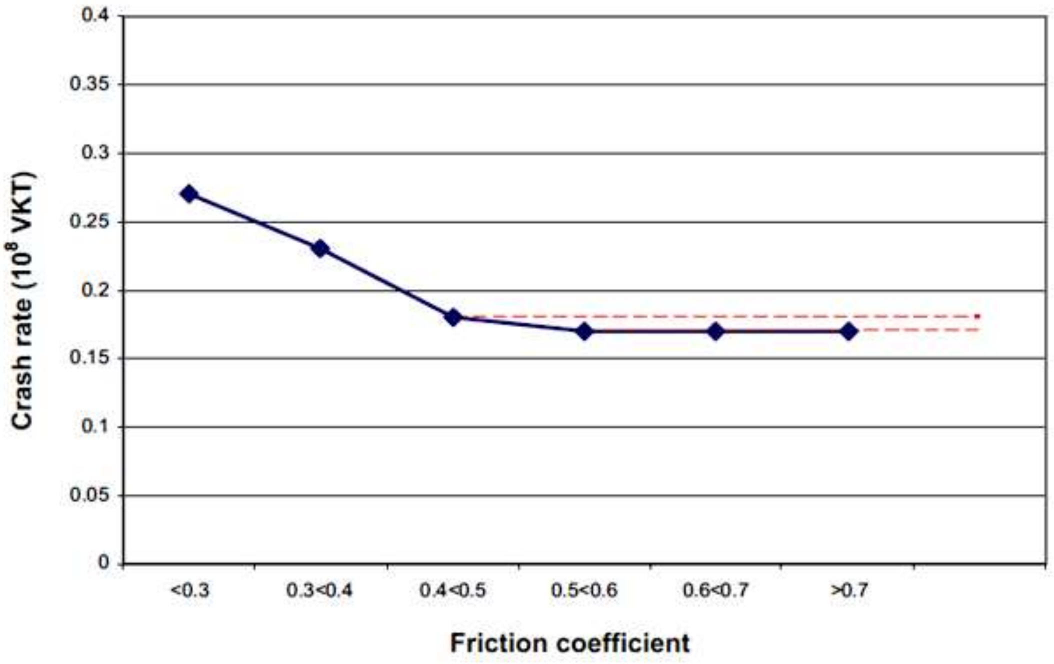


Figure 5- 3: Relationship between friction and crash rate

Relationship between friction and crash rate

It is generally recognised that skid resistance is speed-related and that the required demand is dependent on the site and traffic operations. The Austroads *Guidance for the Development of Policy to Manage Skid Resistance* (Austroads, 2011) lay down principles for road authorities to follow in developing a skid resistance strategy that is consistently achievable, robust enough to be defensible, and for the implementation of the strategy to be demonstrable. The methodology to measure skid resistance is for the jurisdiction to decide. It recommends site categories with appropriate skid resistance demand as shown in the Table 5- 5:

Table 5- 5: Recommended site categories for skid resistance demand

Site category	Skid resistance demand	Site description
1	High	Pedestrian/school crossing Traffic light controlled intersections Rail level crossings Roundabout approaches Roundabouts Curves with radius ≤ 100m
2	Intermediate	Curves with 100m ≤ radius < 250m Gradients ≥ 5% and ≥ 50m long Freeway and highway on/off ramps
3	Intermediate	Intersections
4	Normal	Manoeuvre-free areas of undivided roads
5	Normal	Manoeuvre-free areas of divided roads

The UK Highways Agency (Stationary Office, 2004) gives extensive guidance for the management of skid resistance in their Design Manual for Roads and Bridges (DMRB) Volume 7. Skid Resistance Section 3 Part 1 HD 28/04. Its objective is to manage the risk of skidding accidents in wet conditions by providing a level of skid resistance that is appropriate to the nature of the road environment at each location on the network. The investigatory levels of skid resistance are given in Figure 5-4 (Table 4.1) (Stationary Office, 2004).

Site category and definition		Investigatory Level at 50km/h							
		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65
A	Motorway								
B	Dual carriageway non-event								
C	Single carriageway non-event								
Q	Approaches to and across minor and major junctions, approaches to roundabouts								
K	Approaches to pedestrian crossings and other high risk situations								
R	Roundabout								
G1	Gradient 5-10% longer than 50m								
G2	Gradient >10% longer than 50m								
S1	Bend radius <500m – dual carriageway								
S2	Bend radius <500m – single carriageway								

Figure 5- 4: Site categories and investigatory levels of skid resistance in UK

Source: Stationary Office, 2004

Fernandes and Neves proposed two moments for intervention to provide skid resistance and macro-texture: preventative and limit. The preventative value M1 is still safe but slightly above the minimum limit and will result in less frequent interventions and reduced cost. The limit value M2 is a minimum value, below which there is a higher risk of accident. The skid resistance is reported as CAT = CoF * 100. It is converted to CoF in Table 5-6 below. The limits proposed by them are related to road environments E1 to E3 as described below:

- E1: Rural environment with a heavy presence of urban characteristics (e.g. urban crossings and intersections);
- E2: Environment characterised by a considerable predominance of intersections in a rural environment; and
- E3: Environment with curved segments, high longitudinal gradients and average speed higher than the tolerable speed (Fernandes & Neves, 2010).

Table 5- 6: Friction preventative and limit values proposed by Fernandes and Neves

Road Environment	CoF M1: Preventative limit	CoF M2: Safety limit
E1: Urban intersections	0.5	0.4
E2: Rural intersections	0.55	0.45
E3: Curved and hilly alignment	0.6	0.5

The Australian State of Queensland compiled an Addendum to 2006 Skid Resistance Management Plan (Queensland Government, 2010) citing seven categories of sites and two categories of traffic volumes with different CoF values for each of the 14 groups.

Table 5- 7: Queensland CoF values for categories of sites

Site category	Site description	Traffic > 2500 vpdpl*	Traffic < 2500 vpdpl
1	Traffic light controlled intersections Pedestrian / school crossings Railway level crossings Roundabout approaches	0.55	0.50
2	Curve with radii < 251 m Gradients > 5% and longer than 50 m On and off ramps	0.50	0.45
3	Intersections	0.45	0.40
4	Manoeuvre free areas of undivided roads	0.40	0.35
5	Manoeuvre free areas of divided roads	0.35	0.30
6	Curves with radii <101m	0.60	0.55
7	Roundabout circulatory lanes	0.55	0.50

Note: Categories 1 - 5 based on SCRIM SFC50 and categories 6 - 7 on SFC20 values
* vpdpl is "vehicles per day per lane"

Skid resistance measurement can be used on roads with operating speeds of less than 80 km/h, which is typically the urban network. Guidelines from various countries correctly point out that skid risk is dependent on various factors such as site and traffic. Ranges of values for investigation or preventative maintenance, as well as minimum or limit conditions, are proposed in various publications. Researchers and road authorities sponsoring the research and compilation of guidelines avoid setting standards to which they can be held to in claims.

The skid resistance capability is lost when micro-texture is lost due to the polishing of aggregate or when aggregate becomes covered with bitumen, road paint and contaminants. Total loss of aggregate, such as when stripping occurs, will also lead to loss of skid resistance. These conditions are readily observable in visual condition assessment and can be defined for triggers to do skid resistance investigations.

The measurement of skid resistance is costly in terms of expensive equipment, high operating cost and disruption of traffic. The local availability of the survey equipment is also low: currently only one Griptester is commercially operational (Walstrand, 2015).

Conclusions on standards for skid resistance

The values for investigatory or limit skid resistance numbers as compiled by researchers and contained in maintenance guidelines or manuals are mostly trigger values to focus attention and investigate further analysis of crash risk at the sites. The differentiation of values for different sites is rational and allows appropriate priorities to be set. However, this is a complicated process during which specific standards are not set.

South African road authorities should take note of these investigatory values and trigger values of visual condition assessment to identify sites for monitoring.

It is, however, proposed that a skid resistance standard for South Africa be based on requirements of the NRTA Regulations for braking performance for vehicles capable of travelling in excess of 40 km/h. The single value of 0.45 (based on minimum deceleration of 4.4 m/s^2) aligns with the typical minimum values or 0.05 below investigatory values proposed for high-risk sites.

5.3.3 Rutting and ponding

Rutting is a surface depression within the wheel path and is one of the most visible and common pavement failures. It results from compaction, consolidation or sheer failure and lateral movement in layers, leading to permanent deformation of the pavement or subgrade. The accumulation of permanent deformation is visible at the surface of the pavement. This condition is normally caused by heavy loads on roads lacking sufficient strength to support the loading.

Rutting is mainly researched from the structural perspective, as it relates to the strength of layers. Pavement design strives to attain a balance between the properties of each layer and its cost. Research such as the Contributions of Pavement Structural Layers to Rutting of Hot Mix Asphalt Pavements (White, Haddock, Hand, & Fang, 2002) is typical.

Wide and even shaped ruts indicate failure in the deeper layers, while narrow and sharp-edged ruts indicate upper layer failures (California Department of Transportation, 2014b; Simpson, 2003). These failure modes are illustrated in Figure 5-5.

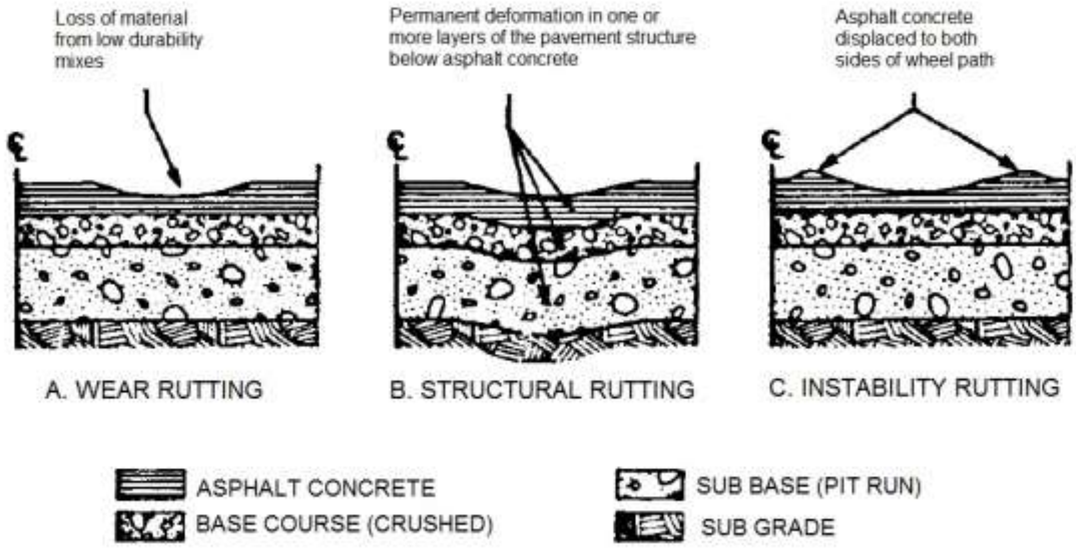


Figure 5- 5: Illustration of rutting modes

Source: (White, *et al*, 2002)

Research on the effect of rutting on safety, done in Sweden (Ihs, Gustafsson, Eriksson, & Wiklund, 2011) yielded little guidance for maintenance of rutting for safety. The research did not show that deeper ruts increased the accident risk or that ruts have the same influence on the accident risk for different AADT classes at a given speed. It should be noted that 95% of the 20 m sections in the Swedish analysis had a rut depth less than 15 mm and mainly represent conditions with a good road surface standard.

A study in New Zealand on the relationship between crash rates and rutting (Cenek, Henderson, Forbes, Davies, & Tait, 2014) came to similar conclusions. Very little of the New Zealand highway network had rut depths in the 10mm – 30mm range. The study proposed that the safety risk of rutting lies in the ponding of water in the ruts that could lead to hydroplaning. It concludes that there was an indication of an increase in crash rates where rut depth was greater than 10mm.

The South African Pavement Engineering Manual (SANRAL, 2013b) is directed at designing of pavements, which are assumed to be maintained throughout their lifetimes. It notes that failures can result in unsafe conditions, but does not quantify such conditions. Rutting is quantified as the most important indicator of terminal structural failure or terminal condition. In Table 2 in the manual; the value of 10 mm is given as a warning level and 20 mm as the terminal condition.

> A terminal structural condition is reached when the level of distress reaches a predefined, unacceptable level. Examples of terminal conditions are 20 mm of rutting for flexible pavements and 5 mm of faulting for rigid pavements. Although a terminal (unacceptable) level of distress is reached, the pavement has not necessarily failed in the strict sense of the word. For example, the rut may be rectified with a levelling course and the pavement may continue to provide years of excellent service (SANRAL, 2013b:2).

Conclusions on standard for rutting and ponding

Research on rutting in First World countries is constrained by the absence of such failures beyond a depth of 15 mm. While no significant relationships could be found in the latest research, it is acknowledged that crash rates seem to increase with rut depth beyond 10 mm.

In absence of appropriate research, the proposed standard for rutting and ponding is based on an avoidance of conditions that have not occurred. Rutting often manifests with other severe failures such as potholes and shoving. The standard for rutting is thus proposed as 20 mm, which will be in line with the proposed standard for shoving discussed next.

5.3.4 Potholes

> While SCOTS considers the latest roads condition results to be a significant achievement, council payments to compensate drivers for pothole damage have risen, from around £340,000 in 2007/08 to £1.2 million in 2011/12. (Audit Scotland 2013: 9)

Potholes are road failures that manifest as rounded or oblong openings in the road surfacing and the underlying layers. Potholes are induced on weak spots in the roadway by traffic action and typically start in the left-hand wheel track where the highest wheel loads impact on the pavement and water ingress from the shoulder is most prevalent. They can also develop on the centre line of the road if the overlap of the lane seal during construction was poor and allows water ingress. This is mostly seen on curves where the right-hand side wheels drive over the centre line when drivers cut corners. Potholes can develop in isolated locations due to local failures caused by subsidence over culverts or next to structures due to differential settlement. The development of potholes is preceded by failures such as rutting, crocodile cracking and aged seals.

Surface potholes are shallow areas where the seal or asphalt surface disintegrated. This can lead to structural potholes which are deep as the ingress of moisture weakens the base layer and leads to subsidence or washing out of fine materials (pumping) under traffic action and further allows the gravel base layer to loosen, erode and disperse. The TMH 9 Pavement Management Systems: Standard Visual Assessment Manual for Flexible Pavements (CSRA, 1992), which is the industry-standard for identifying and classifying road pavement failures, states:

> Structural failures are manifested as potholes, which are generally a secondary form of distress that develops from cracking or extreme loss of aggregate. They are traffic induced and normally develop from structural cracking in the wheel paths. Moisture ingress into the pavement layers can result in the total loss of the structural capacity of the pavement and in the formation of potholes. Failures occur when materials in weak pavement layers are displaced laterally through shear forces induced by traffic, resulting in mounds adjacent to depressions (CSRA, 1992:55).

The trend toward vehicle wheel rims of 17 to 20 inch is fashionable, especially on sport cars and sport utility vehicles. Such modern rims shod with low-profile tyres with ground clearance of less than 75 mm are more susceptible to damage and blow-outs due to interaction with holes, bumps, and edges (Wambold, Ivey, Zimmer, & Sicking, 2009).

The authors are of the opinion that holes in highway surfaces should be tolerated. “The many disadvantages of these flaws dictate their elimination within the bounds of financial constraints”. In their opinion, it is unlikely that the public will choose to fund the maintenance required to eliminate potholes. The purpose of their paper is to put the influence of potholes on safety into perspective so that maintenance activities can be appropriately prioritised” (Wambold, *et al*, 2009).

The threshold for damage to rims was closely approximated by hole depth or bump height equal to or greater than the rim ground clearance (RGC). Wambold, *et al* (2009) build on work by Zimmer and Ivey to relate pothole length, continuous depth and combinations of vehicle types and travel speeds. They concluded that a depth of 25 mm and length of 500 mm would be reasonably safe for small vehicles at low speeds. At the other high end of their scale, a pickup truck would experience unsafe conditions when the pothole is 140 mm deep and 2 500 mm long. The finding that for potholes of a specific dimension it becomes relatively safer at higher speeds is interesting, but of no importance from a safety point of view: the pothole sizes on a failed road will vary in length and the hazard will be dictated by the critical combination of speed, depth and length. The threshold for damage to rims was closely approximated by hole depth or bump height equal to or greater than the rim ground clearance (RGC). The critical combination of low-profile tyre at 100 km/h would be unsafe with pothole length of 400 mm and depth of 40 mm as illustrated in Figure 5-6 below. The shallow critical pothole depth for low-profile tyres is also true for motorcycles tyres at speed.

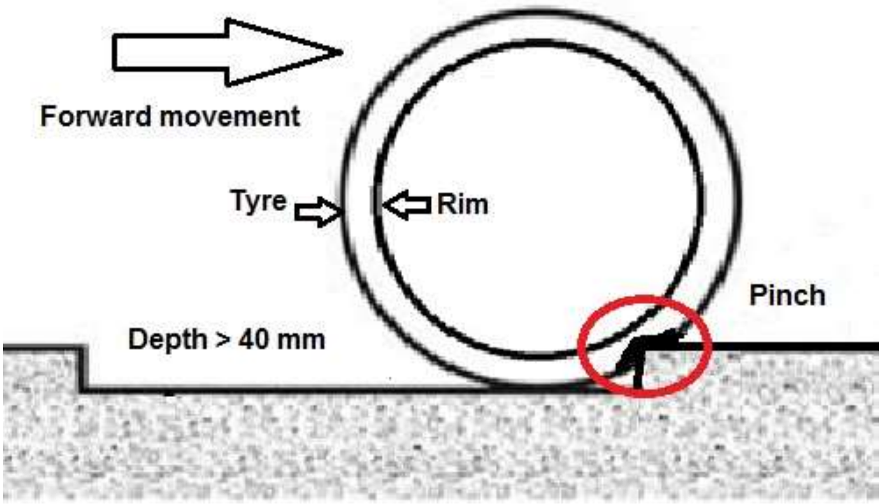


Figure 5- 6: Critical pothole for low profile tyre

Adapted from (Zimmer & Ivey, 1983)

The California Department of Transportation corrects for surface irregularities when surface deviations reach 1½ inches (40 mm) in a length of 50 feet (15 m), or when the ride quality is objectionable (California Department of Transportation, 2014a). This approach is for longitudinal deformations. Local deformations should be treated with the same urgency as potholes, as the effect of a local high point, especially on two-wheeled vehicles such as bicycles and motorcycles, is comparable.

Potholes of the pavement are road characteristics that road authorities should avoid through planned maintenance. Potholes are indicators of severe deterioration of the surface seal and road structure that will result in high cost of rehabilitation. Potholes expose the layers to ingress of water and pumping out of fine material under traffic. As such, the dimensions of potholes should be irrelevant: the road surface should be sealed when visual condition assessment indicates that the surfacing is dry, cracked or stripped. Deep layer failures that also cause potholes are the result of overloading or terminal life of the pavement and should ideally be avoided by programming of rehabilitation or special maintenance.

The reality is that maintenance is underfunded as new projects buy more votes in the democratic public government system that allocates resources in a political framework.

The TMH9 Visual condition assessment guide for flexible pavement describes the degree of severity for potholes and surface failures in its Table B17. Degree 3 severity is defined as the start of surface distress and shoving with minor depressions less than 30 mm. Degree 3 potholes are less than 200 mm in diameter and less than 25 mm deep. Such failures are not unsafe for motorised vehicles as shown in research and this seems to lull road authorities into a false comfort zone. The problem is that once a pothole of this size have developed and is filled with water during rain, the rate that the pothole can deteriorate can be rapid, especially under heavy truck traffic. Degree 5 severity is described as loss of surfacing and base material or severe depression of more than 50 mm and shoving. Potholes of Degree 5 severity are more than 300 mm in diameter, of serious depth (which is greater than 50 mm) and present severe secondary defects (CSRA, 1992).

The research for this dissertation is mostly directed at the road characteristics that influence four- and more-wheeled vehicles. There is, however, currently strong emphasis on non-motorised transport such as walking and cycling. Cycling is promoted for commuting and recreation. Two of the court cases discussed in Chapter 7 involve cyclists. Two-wheeled vehicles, such as bicycles and motorcycles, are very susceptible to potholes. The effect of potholes is therefore included in the research.

The influence of potholes and bumps on bicycles is by nature of the thin width of the cycle wheel and shallow depth of the tyre dramatic. These tyres develop what is termed a snake bit blow out when hitting a relatively sharp edge that is higher than the depth of the tyres. The depth of a bicycle tyre is nearly the same as its width. Width varies from 18 mm for a road race bike to 57 mm for off-road or mountain bike. The thin rims of road racing wheels can also buckle under severe impact.

Stutts and Hunter obtained data on bicyclists' injuries from hospital emergency departments in the US and compared the data with state-wide crash files, which are primarily events that involve a motor vehicle and those that occur on the pubic roadway. They estimated that the data are likely to capture less than a third of bicyclist injury cases serious enough to require emergency department treatment. In reality, they may capture far fewer, as from 40 to 60% of the bicycle – motor vehicle cases not reported in official state files (Stutts & Hunter, 1999).

The RTMC Road Traffic Report 2009 reported 258 bicycle fatalities out of a total of 13 768 fatalities (1.9%). The primary cause of these fatalities was collisions with vehicles. The accident data do not indicate the role of road conditions. Accident statistics on severe or slight injuries to bicyclists are not distinguished. From international research it can be assumed that local statistics are also underreported (RTMC, 2009).

The lack of data on cycling accidents cannot be interpreted as that road maintenance does not play a role in such accidents. The case study of Devonport v MEC for Roads and Transport Free State Province in Chapter 7 concerns a local shoving of the road of approximately 50 mm that caused a bicyclist to summersault. The acknowledgement of the importance of non-motorised transport and need for protection of these vulnerable road users should lead to a special interest in road maintenance of potholes and bumps, as they are high-risk road failures for cyclists on roads used for commuter and recreational cycling.

The notable difference in the risk for bicycles and motorised vehicles calls for different considerations of roads on which the use by bicycles could be reasonably foreseen, albeit for commuting or recreational purposes. Such roads should be free of potholes and shoving at least in the left-hand side shoulder or within the left-hand side of the lane where bicycles will ride. The width must allow for bicycles to overtake one another. The NRTA, Regulation s 311 states that

> (2) Persons riding pedal cycles on a public road shall ride in single file except in the course of overtaking another pedal cycle, and two or more persons riding pedal cycles shall not overtake another vehicle at the same time.

The design envelope of a cyclist is defined in Australia as 1 m wide. An additional 200 mm should be allowed if a kerb is present. The design envelope of two cyclists abreast would overlap to an extent and 1.8 m would be appropriate. The road width to be maintained for cycling should be minimally 1 m and where higher volumes of cyclists are expected, 1.8 m measured from the edge of the roadway. If the road is provided with shoulders of 1 m or more, the shoulder can be considered a cycle lane (Austroads, 1999).

Conclusions on standards for potholes

Potholes should be fixed before reaching Degree 3 dimension from a pavement protection point of view. Maintenance for safety becomes critical if the dimensions of the pothole are wider and longer than the footprint of a small tyre: approximately 200 mm wide by 300 mm long. The depth of the pothole should not exceed 50 mm.

Cycling routes must be defined taking into account the foreseeable usage. These routes must be maintained free of potholes at least 1 m wide from the edge of the roadway where low cycling volumes are foreseen and 1.8 m where frequent overtaking of cyclists is foreseen.

5.3.5 Shoving

Shoving is localised displacement or bulging of pavement material in the direction of loading pressure. Shoving can be associated with ruts or potholes, where the material compressed and depressed in the wheel track is displaced to the side and bulges above the roadway level. This is illustrated in Figure 5-7 as the areas of positive surface deformation.

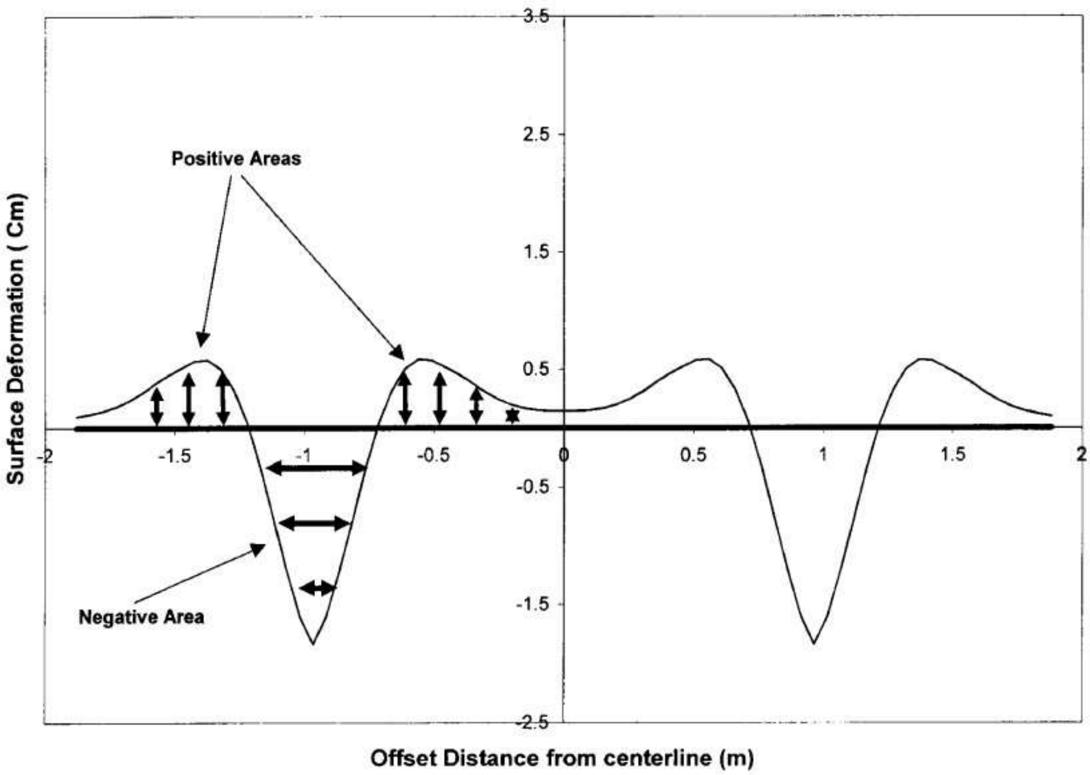


Figure 5- 7: Surface deformation illustrating shoving

Source: Figure 2 in White, *et al*, 2002

Shoving can also manifest in the longitudinal direction. This is mostly visible at stop lines at signs or signals, where a thick asphalt surfacing layer with inadequate shear resistance was used. In those situations it can be associated with rutting. Longitudinal shoving was not cited in cases as being the cause of an accident, as other failures such as rutting and potholing in the same area are cited as the causes.

In South Africa the typical rural pavement design is a cemented crushed aggregate base layer with a thin asphalt or chip seal surfacing. Rutting and bleeding in the surfacing layer are thus shallow. Shoving observed on such roads is often associated with potholes in the wheel track, where water ingress reduces the shear strength of the base, pushing material to the side. The extent to which the material can lift vertically has been measured in excess of 100 mm. Shoving is typically of a rounded shape and the lack of sharp edges hides the protrusion from sight. The bump on the road can therefore surprise the driver more than a potholes that can be detected due to sharp edges and contrasting colours.

Shoving is often associated with bleeding or over-rich asphalt mix (California Department of Transportation, 2014b). Bleeding and over-rich asphalt imply that the excess bitumen binder lubricates the surfaces between aggregate and aggregate interlock is lost, resulting in reduced shear strength. The US pavement designs are typically deep layered asphalt on bitumen-treated bases (BTB).

Literature of shoving is limited, as is the associated failures such as rutting and potholes.

Conclusions on standards for shoving

Shoving in excess of 25 mm can destabilise a two wheeled vehicle and in line with the proposed standard for rutting, being the negative version of shoving, 20 mm is proposed as the maximum vertical lift for shoving.

5.3.6 Loose material on roadway

Loose material that has a safety implication can range from large objects such as rocks from a rock fall to fine sand that washed on the road from a blocked side drain. Specific hazards are strips of tyre tread shed when a truck tyre blows out and disintegrates. Other hazards are goods and animal carcasses that have fallen or material that spilt from vehicles.

Loose material falling from vehicles on the roadway is unacceptable: Section 246 of the Regulations of the NRTA 1996 states the following:

> No person shall operate on a public road a motor vehicle carrying any goods -
>
> (c) which are not
>
> (ii) securely fastened to such vehicle, and which are not properly protected from being dislodged or spilled from such vehicle.

The standard for loose objects on the roadway is simply that there should be none. The cleaning of the roadway as part of maintenance is an operational or procedural specification addressed in Chapter 6. The presence of material such as sand, gravel and aggregate is, however, not as straightforward. This analysis focuses on the effects of such contaminants and proposes standards for these materials only.

The focus of the standards to be developed is on surfaced roads. Gravel roads were investigated as surfaced road contaminated with loose material can be viewed as similar to the loose material on a gravel (unpaved) road.

Lea and Jones (2007) studied the mechanisms of skid resistance of unpaved road and found that:

> Unpaved roads have a dynamic surface, which can make it difficult to predict the skid resistance of a section for use in geometric design and gravel selection and to schedule maintenance. This investigation showed that there are three mechanisms for skidding on unpaved roads: intersurface friction, sliding on a thin layer of loose material, and plowing through a thick layer of loose material. The main surface and material properties affecting skid resistance are the stoniness severity and extent, the severity and extent of ravelling, and the amount of loose material in the 0.850-mm to 2.00-mm range on the surface. The range of coefficients of friction for unpaved roads is from 0.40 to 0.85, with the lower value being conservative (Lea & Jones, 2007).

Their experiments revealed the average skid resistance on dry gravel road with an initial speed of 50 km/h as 0.67 and from 80 km/h 0.62 from samples sizes of 16 and 7 respectively.

Paige-Green in his unpublished PhD thesis, produced values from a large sample. He found an average skid resistance value of 0.6 (deceleration 5.9 m/s^2) on dry roads for an initial speed of 50 km/h (Paige-Green, 1989).

Resealing (chip and spray) of roads could cause loose aggregate on the roadway after opening to traffic if the bitumen binder application was too light, the aggregate was not properly rolled in and excess aggregate was not properly swept off. Loose aggregate is also a problem as individual stones are thrown up by tyre action and chip the paintwork or glass of passing vehicles. This is a frequent source of claims against road authorities and contractors which are mostly paid by either the vehicle or contractor’s insurance. The extent of the damages is not reported and no research could be found.

A claim was made against a road authority following the resealing of a road, when the excess aggregate caused the vehicle to skid. It was investigated by Roodt who conducted a number of braking tests on dry gravel roads and roads contaminated with sand and aggregate used for seals (6.7 mm and 13.2 mm grading). The average skid resistances found were 0.56 on dry gravel, 0.39, 0.39 and 0.44 on roads contaminated with sand, 6.7 mm and 13.2 mm surfacing aggregate respectively (Roodt, 2013) .

Surfaced roads that are contaminated with fine or coarse gravel have average skid resistance in the order of 0.4. This is still in excess of the design value of 0.35 but is not legal. The braking performance of vehicles as required in the NRTA is 4.4 m/s^2.

The dynamic surface caused by loose material on the road can be tolerated better with a four-wheeled or more-wheeled vehicle than a two-wheel vehicle. Local slips or skidding of individual wheels do not lead to instability of the four-wheeled vehicle but a slight slip of the front wheel of a motorcycle can lead to loss of steering control and balance. (A motorcycle is an inverted pendulum and is kept in upright position by continuously and intuitively steering the wheels to keep the tyre contacts below the centre of gravity).

Conclusions on standards for loose material on roadway

Discrete objects that fall on the road must be removed in terms of the maintenance procedures that are discussed in Chapter 6. Loose material that forms a blanket on the road, such as mud, sand, gravel and loose aggregate must be similarly removed within the specified reaction time after complaints or prescribed inspections.

5.3.7 Edge drop-off

Edge drop-off is a condition that develops next to the sealed roadway surface (lane plus sealed shoulder) and the remainder of gravel shoulder provided in the road prism. It manifests as result of erosion of gravel material at the interface. Pavement edge drop-off is a vertical height difference between two adjacent roadway surfaces. The safety impacts of edge drop-off is not only in the depth and width of the drop-off, but also in the width of the sealed shoulder which determines the risk of a vehicle moving off the sealed road surface. The management of edge drop-off is influenced by the width of sealed shoulder as part of the recovery area. Edge drop-off must therefore be analysed in the context of the functions of road shoulders. Figure 5.8 illustrates the gravel shoulder conditions (White, *et al*, 2007).

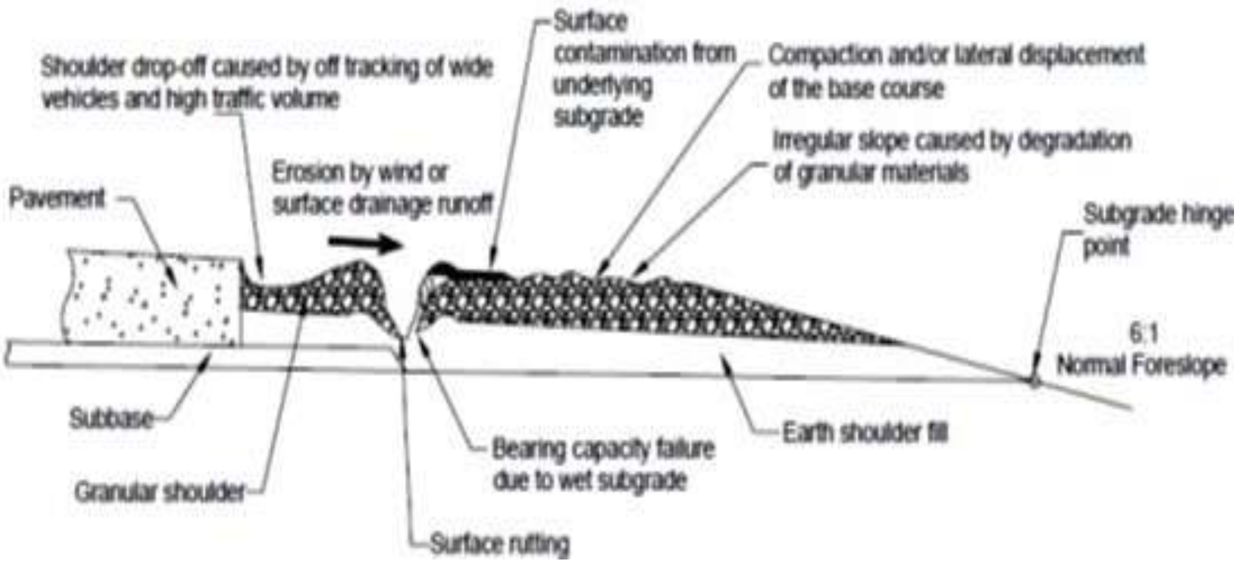


Figure 5- 8: Illustration of gravel shoulder conditions

Source: (White, *et al*, 2007)

The importance of a shoulder next to the paved road surface is recognised in road geometric design guides. The following functions are commonly listed, with the proviso that safety and traffic operations can be adversely affected if any are compromised:

- Shoulders provide space for emergency storage of disabled vehicles;
- shoulders provide space for enforcement activities;
- shoulders provide space for maintenance activities;
- shoulders provide an area for drivers to manoeuvre to avoid crashes;
- shoulders improve bicycle accommodation;
- shoulders increase safety by providing a stable, clear recovery area for drivers who have left the travel lane;
- shoulders improve stopping sight distance at horizontal curves by providing an offset to objects such as barrier and bridge piers;
- on highways with curb and enclosed drainage systems, shoulders store and carry water during storms, preventing water from spreading onto the travel lanes;
- on high-speed roadways, shoulders improve capacity by increasing driver comfort; and
- lateral support for layers (American Association of State Highway and Transportation Officials, 2004; Ministry of Works, Transport, and Communications, 2000; SANRAL, 2003).

The maintenance of the interface between the roadway surface and the shoulder must be done with these functions in mind. Gravel/unsealed shoulders are usually less costly to construct but require specific material and regular repairs, especially during the rainy seasons. Poor material and inadequate maintenance result in unsafe conditions when a drop-off develops.

Sealed shoulders are initially more costly to construct but have the advantage of reducing water access into the structural layers of the pavement and providing safer conditions for the motorist. From a structural point of view, the road shoulders adjacent to the carriageway provide edge support to the layers and prevent water ponding and seeping into the layers. This can minimise the risk of pavement failures that result from weakening of pavement layers, such as potholing, shoving and rutting.

Shoulders not only benefit the preservation of the road pavement, but enhance operations by improving safety (through increased recovery area) and more stable speeds. If a driver inadvertently leaves the lane or avoids a crash or an object in the lane ahead, a drivable shoulder greatly increases the chance of safe recovery. Ogden (1996) predicted crash reduction in the range of 20% to 60% on roads after construction of sealed shoulders. He found the benefit on straight sections to be approximately 50% higher than on curves. This may be due to drivers concentrating more on curves than on straight sections leading to highway hypnosis (the mental state in which a person can drive a vehicle while responding to external events in the expected and correct manner with no recollection of having consciously done so).

The impact of shoulder width on the priority of edge drop-off can be seen in the effect of shoulder width on crash reduction. The crash reduction benefits vary with shoulder width and the crash reduction values shown in Table 5-8 were developed at the Texas Transport institute (Fitzpatrick, Schneider, & Park, 2006).

Table 5- 8: Effect of shoulder width on crash rate reduction rate

Shoulder width	% Crash reduction
0	0
300mm	6
600mm	12
900mm	18
1200mm	21
1500mm	26
1800mm	30
2100mm	35
2400mm	38
2700mm	42
3000mm	45

The crash risk for wide-sealed shoulders is less than for narrow shoulders because the driver has the opportunity to correct his /her errand driving. The risk of encountering edge drop-off is therefore less. The priority for maintenance on roads with narrow shoulders is therefore higher.

The edge of a wide-sealed shoulder will be less prone to wind erosion as vehicles travel further away. The effects of eddies created by the wheels and undercarriage of a heavy vehicle are primarily in the first 1 m from the vehicle.

A gravel shoulder becomes un-trafficable and hazardous either through the accumulation of loose material on the surface, or through the shoulder becoming soft with an increase in the risk of loss of control. Austroads states that there is no physical measure of unsealed shoulder condition which defines “un-trafficable” and this must be a matter of judgment (Austroads, 2010a). Edge drop-offs do provide a measurable attribute that relate to safety.

Austroads refer to Glennon (1996) and Ogden (1996) to state that edge drop-offs appear to be associated with only 1% to 1.5% of crashes and proposes that it is unrealistic to expect significant safety benefits from edge wear treatments (Austroads, 2010b). This argument must, however, be viewed against the claims that can arise, as the reasonably road authority can foresee that this condition is dangerous.

Drop-offs are among the top accident-related conditions and a common source for tort claims against agencies that maintain roadways (Iowa Department of Transport, n.d.). Even if drop-offs constitute such a low percentage of crashes it is a significant cause cited in claims. Low shoulder / elevation difference is the 8th most frequently cited ground for claims against the South Carolina Department of Transport (Chowdhury, *et al*, 2011).

Roadways slope to the side for cross drainage to shed rain water. The water should continue its transverse path over the shoulder if it is an extension of the roadway. The combination of a longitudinal gradient and cross fall, however, creates a flow path along the contact between the roadway and shoulder if the transverse flow is obstructed or cut off. Obstructions originate from grass growing on the shoulders to a level above the roadway surface. Flow is cut off when the adjacent shoulder material becomes eroded due to wind action of vehicles travelling close to the edge of the roadway, and through the action of storm water runoff. Once an erosion channel is defined, it can rapidly erode with subsequent rain storms, especially in the summer rainfall regions of South Africa with thunder storms of high intensity. Edge drop-off then develops. Edge drop-offs are safety hazards because vertical differences between surfaces can reduce vehicle stability and drivability. The drop-off can contribute to a loss of control as the driver tries to bring the vehicle back onto the roadway, especially if the driver does not reduce speed before attempting to recover.

A pavement edge drop-off-related crash occurs when the driver, after running off the surfaced roadway, with the left-hand side tyres on the shoulder (South Africa left-hand rule of the road), attempts an immediate return to the roadway. The tyres running parallel to the edge scrub against the vertical pavement edge, resulting in friction between the tyre and pavement, as well as resistance to steering input. If the driver compensates for scrubbing by increasing the steering angle, the leading front tyre finally remounts the pavement with a sudden loss in resistance between the tyre and the surface of the pavement edge, as well as with an over-steering angle. The vehicle then suddenly steers to the right, pivoting around the left rear tyre. When the rear tyre also jumps over the edge drop-off, the driver either continues turning to the right and the driver may enter the adjacent lane. The driver could then possibly overcorrect to the left and then leave the road completely (Hallmark, Veneziano, McDonald, Graham, Bauer, & Patel, 2006; Ivey, Mak, Cooner, & Marek, 1988).

The risk of edge drop-off depends on the depth and geometry of the drop-off, driver ability, vehicle characteristics, and vehicle speed. Glennon and Hill suggest that a vertical or near-vertical edge drops of 50 mm or more could cause slingshot accidents at speeds less than 88 km/h and edge drop-offs of 150 mm or more will cause vehicle undercarriage contact, often resulting in rollover (Glennon & Hill, 1996).

A body of research was built up in the US in the period 1975 to 1990 on mitigating the effects of scrubbing by altering the shape of the drop-off. A 45º edge wedge was the shape mostly evaluated. Hallmark, *et al* discuss several studies that indicate that drop-offs with a vertical edge 75 to 125 mm could not be negotiated safely at speed in excess of 60 km/h (Hallmark *et al*, 2006, Klein, *et al,* 1977; Glennon 1985; Graham & Glennon 1984, and Olson, *et al,* 1986 in Hallmark, et al, 2006). Hallmark, et al, also quotes research by Ivey and Sicking (1986) that a vertical drop-off of 50 mm can only be negotiated up to 60 km/h and that Olson, *et al* (1986) indicated recovery was possible with a 45º wedge in the range of 125 to 150 mm up to 88 km/h (Hallmark, *et al*, 2006).

Delaigue simulated the recovery using different edge shapes and suggested that a passenger vehicle would be able to recover from up to a 125 mm drop-off at 10 km/h with an edge wedge 45° or flatter. This research is not considered of much value for South Africa, as most of the rural Class 1 to 3 roads carrying significant traffic are constructed with seals. Asphalt surfacing in excess of 50 mm is rare and mostly restricted to freeway construction (Delaigue, 2005).

The most authoritative design guide, A Policy on Geometric Design of Highways and Streets, commonly known as AASHTO's Green Book, does not provide guidance on a maximum allowable drop-off height. It stresses that regular maintenance is necessary to provide a shoulder that is flush with the pavement surface. It states that unstabilised shoulders consolidate with time, and the shoulder becomes lower than the roadway at the interface. It confirms that drop-off can adversely affect driver control when driving onto the shoulder at any appreciable speed (American Association of State Highway and Transportation Officials, 2004).

The Roadside Design Guide provides information and operating practices on roadside safety. Chapter 9 discusses safety features for work zones and drop-off under construction. It states that no vertical drop-off greater than 50 mm should occur. It further states that edge drop-off greater than 75 mm should not be left overnight unless measures to mitigate the hazard are taken (American Association of State Highway and Transportation Officials, 2011).

Standards or guidelines of selected states in the US for drop-offs were collated by Nordlin, *et al* in 1976 and reported by White, *et al* and are shown in Table 5.9 (White, *Mekkawy, Jahren,* Smith, & Muhannad, 2007).

Table 5- 9: AASHTO Policy for the Geometric Design of Highways and Streets

State	**Drop-off standard**
California	Repair drop-offs greater than 1.5 inch, or when edge failure becomes apparent
Illinois	• No published standards but attempts to keep shoulders flush with pavement • Posts warning signs to alert traffic to shoulder construction
New York	• 2 inch maximum drop-off on state highway (DHV=200) • 1.5 inch maximum drop-off on state highway (DHV=200-500) • 1 inch maximum drop-off on express ways (DHV>500)
Oregon	• Requires shoulders to be flush with travelled way • Considering change in standards to permit up to 2 inch drop-off

Texas	No published standards but try to limit drop-off to 2-3 inches
Washington	• Requires shoulders to be flush with travelled way • Drop-offs greater than 3 inches should be filled with stabilised material

Note: DHV = Design Hourly Volume

Conclusions on the standard for edge drop-off

The proposed standard in relation to edge drop is an elevation change of 75 mm, regardless of the shape of the drop-off.

5.3.8 Edge break

Edge break is a roadway failure in the horizontal plane as the roadway surface and base layers lose edge support and slip or break off. A jagged edge of road is more likely to cut the tyres on the wheels running onto the shoulder. Edge break follows edge drop-off and the combination of the two failures tends to hide the contribution of edge break, as the cause of an accident is mostly recorded as edge drop-off.

Austroads suggests that repairing edge wear is a maintenance action required to protect the integrity of the pavement rather than to directly improve the safety of users. It further explains that edge wear can result in loose material transported onto the road surface and can cause safety problems for motorcyclists and bicyclists if not swept off. It admits that there is no data available to support risk modelling in relation to these events (Austroads, 2010a).

Edge break can affect the stability of small cars and two-wheeled vehicles. The extent of the break into the roadway should be restricted.

The Transportation Research Circular E-C134: Influence of Roadway Surface Discontinuities on Safety (2009) mentions that preceding research into edge conditions was done when the federal speed limit was 55 mph (88 km/h). With speeds of 112 km/h now common, it was acknowledged that there needed to be more concern for edge failures (Wambold, *et al*, 2009).

Conclusions on standards for edge break

The standard for edge break is proposed as 100 mm, which relates to the typical offset from the roadway edge to the yellow edge line for roads with no or narrow-sealed shoulders. This width will allow a four-wheeled vehicle driving along the edge of the roadway surface from hitting an irregularity.

5.4 Traffic control

Traffic control incorporates all facets of operations from road infrastructure elements, law enforcement to regulation. The regulatory framework for South Africa is contained in the

NRTA and the Regulations promulgated in terms thereof. The cardinal rule of the road in Regulation 296 requires that the vehicle be driven on the left side of roadway. Control implies providing information to road users. When driving, the driver observes information provided by traffic control devices.

The South African Development Community Road Traffic Signs Manual (SADC RTSM) (Department of Transport, 2012) defines traffic control devices to include:

> all road traffic signs and other devices, including delineation devices, used to regulate, warn, guide or inform road users. Traffic control devices are thus used to achieve an acceptable level of road safety by providing for the orderly and predictable movement of all traffic, vehicular and pedestrian, throughout all levels of the road network (Department of Transport, 2012).

The Manual Uniform Traffic Control Devices for Streets and Highways (FHWA 2009:1A-1) states that

> The purpose of traffic control devices, as well as the principles for their use, is to promote highway safety and efficiency by providing for the orderly movement of all road users on streets and highways throughout the Nation. Traffic control devices notify road users of regulations and provide warning and guidance needed for the reasonably safe, uniform, and efficient operation of all elements of the traffic stream (US Department of Transportation Federal Highway Administration, 2009).

The SADC RTSM (Department of Transportation, 2012) gives the requirements for and functions of traffic control devices as the regulation of traffic by assigning right-of-way, by indicating regulations in force, warning road users of hazards, guiding by the indication of direction, distance, location and other navigational information and locally in the selection of the correct portion of the roadway. The driver needs information that is visible, readable, reliable, credible and understandable to minimise uncertainty in order to make sound decisions in relation to driving tasks.

The traffic control devices that require maintenance are road markings and traffic signs. Cases against road authorities are often based on absence or dysfunctionality of signs and markings.

5.4.1 Road markings

The SADC RTSM in its Volume 1 Chapter 7 Road Markings and Volume 2 Chapter 2 Road Marking Applications define road markings as a wide range of “devices which may be embedded in, or applied or attached to, the road surface, kerbing or objects within the roadway for the purpose of regulating, warning or guiding traffic”(Department of Transport, 2012).

Road markings can be of the following types:

- Transverse markings (e.g. STOP and YIELD lines);

- longitudinal markings (e.g. lane and edge markings);
- arrows;
- painted islands;
- symbols;
- words, letters and/or numerals;
- parking markings;
- roadstuds; and
- other delineation devices.

The importance of maintaining a road marking for safety will depend on its purpose: a regulatory marking such as a transverse stop line will be more important to maintain than a guidance line. A regulatory road marking must be in a functional condition to fulfil its function to control driving behaviour and to be enforceable. For example, a "STOP LINE regulatory marking RTM1 imposes a mandatory requirement upon drivers of vehicles, when combined with a STOP sign R1, a RED traffic signal indication, or the signal of a traffic officer, **that they shall stop their vehicle immediately behind such line,** AND such line shall have the significance assigned to STOP sign R1*"* (Department of Transport, 2012). To expect a driver to heed to the road marking and ensure safety the marking must be visible and identifiable.

In addition to regulating traffic, road markings also warn of hazardous conditions (railway crossing ahead and arrows for lane use) and guide the driver along the roadway. Longitudinal road markings delineate the limits of the roadway and all or portions of the travelled way and maintain the continuity of visual information. The provision of continuous road markings along a road is practical whereas the provision of continuous visual information by means of road signs is not. The advantages of road markings are that they can often be seen when a verge-mounted sign is obscured and they provide a continuing message (SANRAL, 2003). They improve safety, for example, by clearly defining the path to be followed through hazards, by separating conflicting movements, by delineating the road edge on unlit roads at night and by encouraging lane discipline. Grosskopf also mentions that even if the driver is not looking directly towards a road marking, it remains in his peripheral vision (Grosskopf, 2001).

In the COST 331 Requirements for Horizontal Road Marking, the authors conclude that road authorities and decision-makers should acknowledge road markings as one of the most effective low-cost engineering measures available for improving road safety (European Commission, 1999). Manuals and guidelines for remedial measures for hazardous locations and accident modification factors predict crash reductions of 25% to 40% for improved delineation (American Association of State Highway and Transportation Officials, 2010; Ogden, 1996). Elvik and Vaa cite injury crash reductions for all accidents of 3% for edge lines and 24% for edge lines and centre lines (Elvik & Vaa, 2004).

Centre and edge delineation advises the driver on his or her position on the road and about conditions ahead. Delineation is important where visibility become poor (for example, due to rain, fog or darkness) and on curved road alignments. From such crash modification factors it can be deduced that if road markings as designed become worn out and faded, the risk of crashes will increase in a similar manner.

Road markings can be made from different materials. These include thermoplastic material, epoxy resins, reflectorised tape, solvent-based and water-based paint. Thermoplastics are only used in highly trafficked urban areas for critical road markings such as STOP lines, due to the high cost. These markings can be three times the cost of paint but last five times longer (de Witt, Smith, & Visser, 2000). The other materials, excepting water-based paint, are not used in South Africa due to the high cost or environmentally harmful solvents.

The lowest cost is obtained using road paint to the SANS 731-2 specification of a paint layer of minimum 0.42 mm (South African Bureau of Standards, 2006). The disadvantages of painted markings are that heavy traffic wears the paint off the road surface and their conspicuity is impaired when wet or dirty. Conspicuity when wet is problematic as the paint is covered with water and at night the lights of the vehicles are reflected forward on the film of water with no backwards reflection (retroreflection). To improve the performance of road markings, glass beads are mixed into the paint or spread on the wet paint immediately after spraying. The tops of the glass beads are exposed and allow light to enter and a portion of the light is reflected back towards the driver as indicated in Figure 5-9.

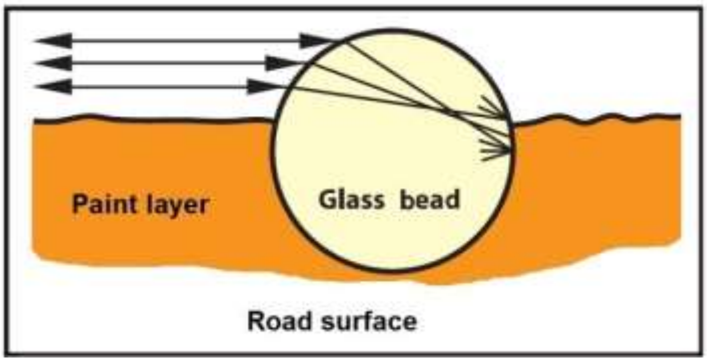


Figure 5- 9: Retroreflectivity provided by glass beads in road paint

Extensive literature is available on research into specifications and testing of retroreflectivity of road paint and its safety effects (Babic, Fiolic, & Prusa, 2014). The testing of retroreflectivity is a cumbersome process with complicated physics involved. The specific angles of the light source and the observation position are prescribed as shown in Figure 5-10. Compact testing apparatus to test retroreflectivity on the road has been developed for handheld and vehicle-mounted applications (Austin & Schultz, 2009), but these are expensive to buy and operate.

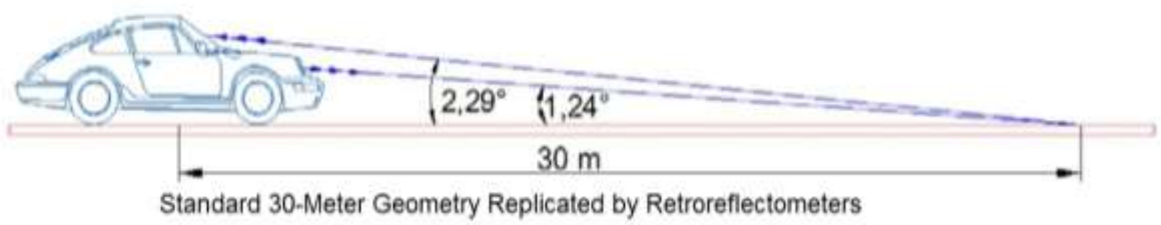


Figure 5- 10: Driver's view of road markings

As wet night-time conditions are accepted as the most dangerous, the maintenance of road markings are typically based on a minimum standard of retroreflectivity of 100 mcd/m^2/lux for white lines (Austroads, 2010b; Highways Agency, 2007). Newly-painted white lines have retroreflectivity of between 140 and 250 mcd/m^2/lux (Road Safety Markings Association, 2007).

The SADC RTSM (Department of Transport, 2012) notes that specifications for applying and testing road markings for compliance are not well-developed. The testing procedures (for example, for retroreflectivity) require expensive equipment and highly skilled operators and very few suitable items of equipment are available in Southern Africa. The South African Bureau of Standards (SABS) can only test retroreflectivity in their laboratories in Pretoria (Dhimmar, 2015). The SADC RTSM advises that detail on specifications and testing given in these sections on road marking are for guidance only. It expresses the hope (in the original version of 1999) that the suggested specifications then given would encourage the development of effective testing procedures and specifications. Since 1999 no significant local research into road signs and markings has been done and the relevant research section of the Council for Scientific and Industrial Research (CSIR) has closed down.

The revised project specifications have significant implications for the road marking industry as a whole. Under this specification the road authority no longer prescribes to the contractor which marking material has to be used, nor the application rate. In this specification the threshold values for the functional performance of the road marking are specified for respectively the new, 9-month and 18-month old conditions. The payment structure provides for payment to be done in instalments subject to compliance by the markings with the set thresholds. Penalties will be imposed should the markings not comply.

Grosskopf discusses the introduction of performance specifications for road marking contracts (Grosskopf, 2001). Instead of the previous process specification requiring the use of an SABS approved paint and method, values for retroreflectivity measured by an approved instrument are specified at three, nine and 18 months. The onus is put on the contractor, as an expert in this field, to use appropriate materials and at appropriate application rates to be able to guarantee the successful performance of the markings as specified. The contractor can follow market developments and use material and remarking frequencies that are the most economical and competitive in an open tender. The risk of substandard work that the road authority used to carry is now borne by the contractor. Performance-based contracting is now used on all SANRAL routine maintenance contracts and on some provincial road marking contracts. The typical threshold value is 100 mcd/m^2/lux.

An interesting study was done in 2006 on sections of road in California. This study examined the safety effect of retroreflectivity of longitudinal pavement markings and markers over time on non-intersection locations during non-daylight conditions. The study developed multipliers that represent the change in the expected number of crashes as a function of retroreflectivity. It focuses upon quantifying the relationship between retroreflectivity and safety over time, independent of marking or marker material type.

> Safety effect multipliers were solved for yellow and white pavement markings separately and in combination, and for pavement markers for different road types and crash severity, using the retroreflectivity models and California's data of over 118,000 non-intersection, non-daylight (night, dawn, and dusk) recorded crashes.
>
> In summary, this study found that there is no safety benefit of higher retroreflectivity for longitudinal markings on non-intersection locations during non-daylight conditions for roads that are maintained at the level implemented in California's state highways. California's level of maintenance appears to be frequent with pavement markings being installed on higher volume highways up to three times a year with waterborne paint, or every two years with thermoplastic markings. The findings of this research study allow agencies to recognize that resources to increase the retroreflectivity of longitudinal markings, beyond normal maintenance activities, will not be cost effective and that those resources could instead be allocated towards other safety measures (Bahar, Masliah, Erwin, Tan & Hauer, 2006).

Although this study only looked at longitudinal markings, these markings represent the biggest portion of the road marking area of a road authority. Longitudinal markings are of great importance in rural areas where retroreflectivity has historically been seen as important, compared to urban areas where low speeds and street lighting mitigate the lack of retroreflectivity. The important insight from this study is that road markings maintained to adequate visible standards (thus limited wear and fade) are reasonably safe. A strategy to focus on wear would be more cost-effective.

The Highways Agency in the UK proposes thresholds for maintenance of road markings for four characteristics: retroreflectivity, luminance factor, skid resistance and wear. The first three are tested to British Standards specifications (BS EN 1436). Wear is, however, determined by visual assessment (Highways Agency, 2007). In line with the findings of Bahar, *et al* (2006), a simple assessment of wear would be a reasonable strategy to ensure safety. Table 5-10 shows the "score" of the road marking based on observing the markings that should be compared with a guideline as shown in Figure 5-11.

Table 5- 10: Visual assessment of road markings

Assessment	Score
Non-existent	0
Barely visible	1
Visible, but has bare spots and low night time conspicuity characteristics	2
Marginal – some visible wear and/or fair night time conspicuity characteristics	3
Good night time conspicuity and very little wear	4
Good night time conspicuity and no wear	5

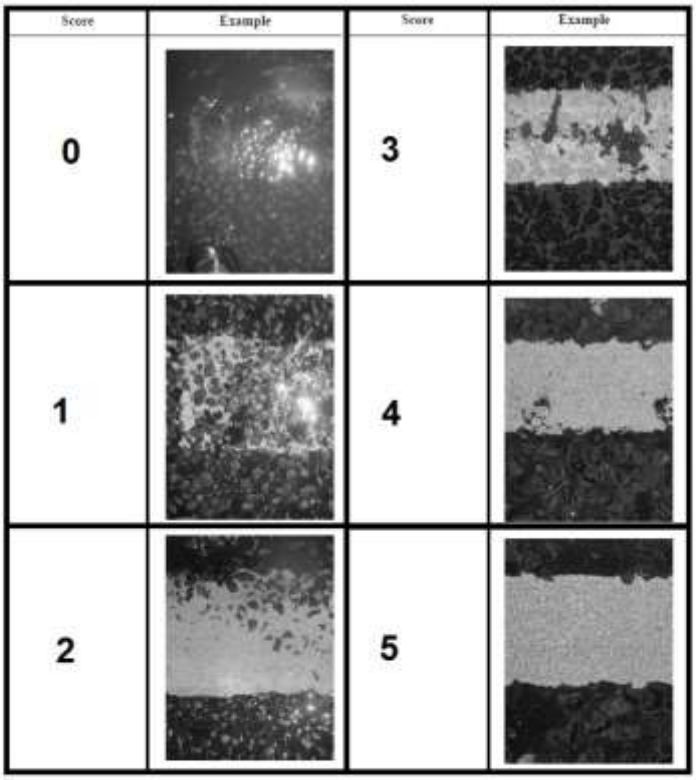


Figure 5- 11: Images for visual assessment of road markings

Source: (The Highways Agency, 2007)

The UK Highways Agency visual assessment method for wear is done on 50% of the markings in each location or every 20 m for continuous markings. The threshold level is set as less than 70% of the road marking remaining.

SABS 731-2 imposes a traffic wear requirement that is tested as per SANS 6248:2007. The traffic wear index estimates the extent to which a 500 mm by 100 mm transverse road marking placed 500 mm from the road edge (in the left-wheel path) has been worn away. The paint film applied to the road surface is examined for percentage substrate still covered in paint, after a known number of vehicle passed in a 12-month period. It gives an indication of the daytime visibility of the road marking. The wear index is calculated based on a prescribed rating system. The 500 mm by 100 mm test mark is divided into twenty 50 mm by

50 mm squares and each square is classified into a grade of coverage. After the application of a rating and weighting procedure, the tester is left with an aggregate value called the Traffic Wear Index. A large index indicates a greater the degree of wear. The SANS standard for road paint requires that the wear index be 35 or smaller for the paint to be acceptable. A newly-painted test mark will have a Wear Index of 20. To pass the SANS standard, 14 squares can be of Grade B and 5 of Grade A. Table 5-11 shows such a calculation for a test sample showing extensive wear (Grade C) in the central 200 mm of the wheel track with reduced wear towards the outsides (South African Bureau of Standards, 2007).

Table 5- 11: Application of wear index

Grade	Area of substrate still covered by paint	Factor	Number of squares	Wear index
A	Exceeding or equal to 75%	1	4	4
B	Exceeding or equal to 50% and less than 75%	2	8	16
C	Exceeding or equal to 50% and less than 75%	3	8	24
D	Less than 25%	4	0	0
Total			**20**	**44**

A longitudinal road marking, such as centre, lane or edge line, will be exposed to less concentrated traffic than the transverse test marking. The line will thus have a longer life until a representative sample of longitudinal test areas will have a Wear Index of 35 or more. A Wear Index of less than 35 can be construed as that more than 75% of the area of the road marking under review has less than 75% of the substrate covered by paint.

Conclusions on standards for road marking

The ideal measure for the adequacy of road markings is retroreflectivity, as this would ensure night-time safety. If retroreflectivity is up to standard, the functionality of wear and luminance will be provided as well. Historically the availability of equipment and cost associated with measuring retroreflectivity restricted this option. The cost of equipment has reduced and vehicle-mounted systems are now generally available.

National, provincial and metropolitan municipal road authorities that maintain road markings through performance-based contracts have shifted the onus of measurement to the contractors.

Retroreflectivity as standard for higher order roads (Classes 1 and 2) is thus proposed with 100 mcd/m^2/lux as the minimum for white road markings.

Provincial and local municipal road authorities who lack capacity and funding can make use of visual assessment to be done at a lower level of sophistication by supervising staff, guided by aids such as standardised pictures of grades of failure or scores. The proposed standard for maintenance to be undertaken is when more than 75% of the road marking area has less than 70% of remaining marking.

Longitudinal markings are assessed in 20m sections and transverse markings in test sections as per SANS 6248:2007 .

5.4.2 Road signs

1 The primary objective for road traffic sign maintenance is to ensure that the signs displayed on the road satisfy criteria like conspicuity, legibility, comprehensibility, credibility and uniformity in a cost-effective way so that information can be clearly transferred to the motorist.

2 Because the physical appearance of signs is apparent to all road users, the quality of this appearance has a high profile in crediting or discrediting the authority or authorities responsible for the provision and/or maintenance of signs (Department of Transport, 2012).

Road traffic signs perform the same functions as road markings, which are to regulate, warn, guide and inform the road user. Road signs are discrete infrastructure assets and were among the first classes of assets that were incorporated in road infrastructure asset management systems. Quality sign maintenance should be based on a comprehensive sign management system. The elements of a sign management system include:

- Inventory – a manual or computer-based database of signs installed on your roads;
- inspection – a programme for scheduled inspection of signs;
- preventive maintenance – activities that will ensure that signs will attain their full service life;
- repair and replacement – a programme and process for either repairing or replacing non-functional signs; and
- reporting and record-keeping – a process for keeping record of all maintenance activities (McGee, 2010).

Signs are erected in accordance with design conditions with respect to the need to regulate, warn, guide or inform. Again, the regulation and warning signs have priority over other signs to ensure safe traffic operations. The signs must be erected to the SADC RTSM and the NRTA and its regulations. As example; a Stop sign must be erected on the left-hand side of the road, preferably 1.5 m and not more than 15 m to operating (effective approach) speed as set out in Volume 1 Chapter 2 Table 2.5. Experienced maintenance staff may be in a good position to advise the designers of conditions that affect the placement and should refer incorrectly placed signs to the design office for confirmation or rectification.

Austroads states that there are two different grounds for intervention – missing, damaged or poorly positioned signs and low retro-reflectivity. Damaged, missing or poorly placed signs will increase crashes at all times. Reinstating retroreflectivity will reduce night-time crashes. They suggest that it is possible to specify from past work levels of retroreflectivity which are reasonable estimates of the lowest levels likely to be effective for typical approach angles, and to relate these with some confidence to both the appearance of the sign and to its age. The intervention level can then be specified in terms of the appearance and/or age of the sign (Austroads, 2010b).

New signs are supplied to minimum standards for reflective material and colour to ensure visibility. The standards for new signs are contained in SANS 1519-1:2014 Road Signs Part 1: Retro reflective sheeting material (South African Bureau of Standards, 2014). Five classes of reflective material are defined, based on the coefficient of retroreflection. SANS 1519-1 then specifies values for reflectivity, colour and durability per class. The values for the coefficient of reflectivity are shown in Table 5-12 (SANS 1519-1:2014 Table 1). The residual values after the prescribed weathering test (test period ranging from two to three years for outside test) must be more than 80% of the prescribed values. These values do not constitute minimum standards, but serve as indication of durability that can be projected to the claimed life of the sheet. The 80% value gives no guidance on what the minimum standard for visibility for safety would be.

Table 5- 12: Minimum coefficients of retroreflectivity (new materials)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Class	Observation angle	Entrance angle	Minimum coefficient of retro-reflection for different colours of material, when measured with standard illuminant A 1) in cd/(lx.m^2)											
	degrees	degrees	Red	Orange	Yellow	Green	Blue	Purple	White	Brown	Grey	Fluorescent orange	Fluorescent yellow	Fluorescent yellow/green
I	0.33	5	10.0	20.0	35.0	7.0	2.0	2.0	50.0	0.6	30.0	-	-	-
	1.5	30	0.5	0.5	1.5	0.3	0.1	0.1	2.5	0.1	1.5	-	-	-
II	0.33	5	20.0	40.0	70.0	14.0	6.0	4.0	100.0	0.6	60.0	-	-	-
	1.5	30	0.5	0.5	1.5	0.3	0.1	0.1	2.5	0.1	1.5	-	-	-
III	0.33	5	25.0	65.0	120.0	21.0	14.0	6.0	180.0	8.0	90.0	-	-	-
	1.5	30	0.4	1.0	1.5	0.3	0.1	0.1	2.5	0.1	1.2	-	-	-
	0.33	40	13.0	20.0	60.0	11.0	7.0	3.2	95.0	3.0	47.0	-	-	-
IV/A	0.2	5	100	250.0	360.0	55.0	31.0	-	600.0	18.0	-	180.0	340.0	435.0
	0.2	30	51.0	130.0	200.0	28.0	16.0	-	325.0	10.0	-	90.0	200.0	225.0
	0.33	5	78.0	190.0	250.0	36.0	25.0	-	390.0	12.0	-	115.0	225.0	310.0
	0.33	30	40.0	100.0	130.0	18.0	11.0	-	205.0	6.0	-	65.0	125.0	158.0
	0.5	5	36.0	94.0	128.0	14.0	8.0	-	165.0	5.0	-	45.0	95.0	130.0
	0.5	30	20.0	45.0	70.0	8.0	3.0	-	80.0	2.0	-	23.0	45.0	65.0
IV/B	0.33	5	75.0	90.0	250.0	35.0	17.0	-	300.0	15.0	-	90.0	180.0	240.0
	0.33	30	35.0	45.0	130.0	18.0	7.0	-	150.0	7.0	-	45.0	90.0	120.0
	0.33	40	7.0	9.0	25.0	4.0	2.0	-	30.0	1.0	-	9.0	18.0	24.0

	1.0	5	20.0	24.0	65.0	10.0	5.0	-	80.0	4.0	-	24.0	45.0	65.0
	1.0	30	13.0	15.0	40.0	5.0	2.5	-	50.0	2.0	-	15.0	30.0	40.0
	1.0	40	5.0	4.5	13.0	2.0	1.0	-	15.0	0.5	-	4.5	9.0	12.0

The UK Highways Agency in Technical Directive 25/15 Inspection and Maintenance of Traffic Signs on Motorway and All-Purpose Trunk Roads uses the same values for Class RA1 as the lowest standard, but indicates the 80% of new retroreflection values as intervention levels as indicated in Table 5-13. It also provides three other tables for intervention levels for the Classes RA2, R1 and R3B (Highways Agency, 2015).

Table 5- 13: Coefficient of retroreflectivity intervention levels

Geometry of measurements		**Coefficient of Retroreflection Invention Level by Colour (cd.lx^{-1}.m^{-2})**							
Observation angle	Entrance angle	White	Yellow	Red	Green	Blue	Brown	Orange	Grey
20’	+5°	*50*	*35*	*10*	*7*	*2*	*0.6*	*20*	*30*
		40	**28**	**8**	**5.6**	**1.6**	**0.5**	**16**	**24**
		N/A	**(19.6)**	**(5.6)**	**(3.9)**	**(1.1)**	**(0.3)**	**(11.2)**	**(16.8)**

NOTES
- Reference should be made to BS EN 12899-1:2007 for supplementary details of the procedure to be followed in measuring the coefficient of retroreflection, including definitions of the observation angle and entrance angle.
- The minimum coefficient of retroreflection for each colour of a new sign is shown for information only in italics in the shaded area of the table.
- Intervention levels shown in bold represent 80% of the minimum coefficient of retroreflection for a new sign; the reduced intervention level in brackets is applicable to coloured areas of signs created by digital or screen printing, or using overlay film.
- Values derived from Table 3 of BS EN 12899-1:2007.

Table 5-14 gives the minimum retroreflectivity values for the US as adapted by Austin and Schultz from the 2009 Manual for Uniform Traffic Control Devices relative to the category of signs (Austin & Schultz, 2009). The values are comparable to Class II in the SANS specification. The Manual on Uniform Traffic Control Devices (MUTCD) is a regulatory instrument in the US (US Department of Transportation Federal Highway Administration, 2009). In the 2009 version a standard was imposed that required that all agencies had a maintenance programme in place by 2012 to maintain minimum levels of traffic sign retroreflectivity. By January 2015 agencies were required to replace regulatory, warning and ground-mounted guide signs (except street name signs) that fall below the minimum requirements. By January 2018 the replacement requirement extends to street name signs and overhead guide signs (McGee, 2010).

Table 5- 14: Minimum maintained retroreflectivity levels for specified signs

<table>
<tr><th rowspan="2">Sign class</th><th colspan="2">Sign colour</th><th colspan="2">Beaded sheeting</th><th>Prismatic sheeting</th></tr>
<tr><th></th><th></th><th>I</th><th>II, III</th><th>III, IV, VIII, IX, XI</th></tr>
<tr><td rowspan="2">Guide</td><td rowspan="2">White on green (ground mount only)</td><td>White</td><td>Do not use</td><td colspan="2">≥ 120</td></tr>
<tr><td>Green</td><td>≥ 7</td><td colspan="2">≥ 15</td></tr>
<tr><td rowspan="2">Warning</td><td rowspan="2">Yellow</td><td>≥ 48 in. or bold symbol</td><td>Do not use</td><td colspan="2">≥ 50</td></tr>
<tr><td>< 48 in.</td><td>Do not use</td><td colspan="2">≥ 75</td></tr>
<tr><td rowspan="3">Regulatory</td><td rowspan="2">White on Red *</td><td>White</td><td colspan="3">≥ 35</td></tr>
<tr><td>Red</td><td colspan="3">≥ 7</td></tr>
<tr><td>Black on White</td><td>White</td><td colspan="3">≥ 50</td></tr>
</table>

*White to red contrast ratio shall be at least 3:1.

Comparison with Australian standards (Standards Australia, 2007) indicates that these standards are common. This can be explained to a great extent by the dominance of the 3M Company as suppliers of reflective sheeting and that standards actually followed product development.

To understand retroreflectivity of road traffic signs, Figure 5-12 shows the way in which round glass beads with reflective coating at the rear or microprisms reflect incoming light in a diffuse manner. The light returning towards the observer, close to the source of illumination, is regarded as the retroreflected light. The microprisms are more effective than glass beads.

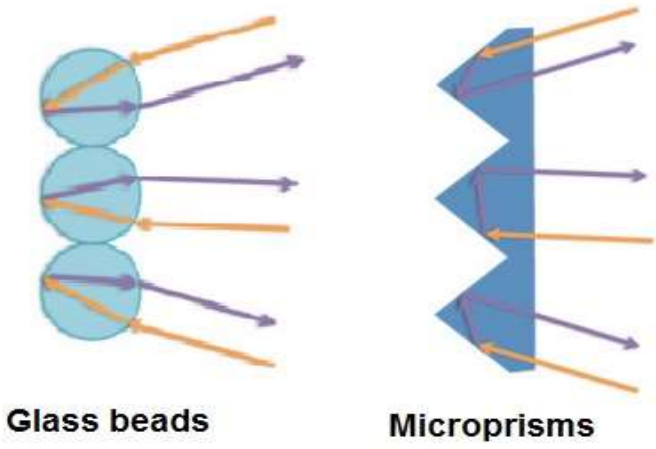


Figure 5- 12: Retroreflection by glass beads and microprisms

Retroreflection can also be illustrated by considering the luminance (the total amount of light a driver receive from a sign or marking, directly proportional to the amount of light energy that is directed back towards the driver's eyes) and the luminance factor (the ratio of the luminance of the material to that of a perfect reflecting diffuser when the material and the diffuser are identically illuminated) as indicated in Table 5-15 (Austin and Schultz, 2009; SANS 1519-1 2014)

Table 5- 15: Minimum luminance factor

1	2	3	4	5
Colour	Retro-reflective class			
	I	II	III	IV A & IV B
Red	0.05	0.04	0.03	0.03
Orange	0.17	0.15	0.14	0.14
Yellow	0.27	0.21	0.16	0.16
Green	0.04	0.03	0.03	0.03
Blue	0.01	0.01	0.01	0.01
Purple	0.03	0.02	0.02	0.02
White	0.35	0.31	0.27	0.27
Grey	0.12	-	0.18	0.18
Brown	0.03 to 0.09			
Fluorescent orange	-	-	-	≥0.22
Fluorescent yellow	-	-	-	≥0.35
Fluorescent yellow/green	-	-	-	≥0.55
Note: The luminance factor for black non-retro-reflective sheeting shall not exceed 0.03.				

Deterioration or failure of road signs can be ascribed to various factors (Department of Transportation, 2012).These may include:

- Normal deterioration as a result of age or weathering;
- vandalism;
- signs damaged in vehicle accidents;
- accidental damage to signs during other maintenance operations like grading or mowing of grass; and
- veld fires.

Road sign maintenance is necessary to ensure an effective road sign. This includes:

- Periodic cleansing of the signface;
- repair of vehicle accident damage;
- repair of acts of vandalism or other accidental damage;
- cyclic painting of frames, support structures and posts;
- inspection of slip base torque where steel break- away posts have been installed;
- control of vegetation or parking that might influence the visibility of signs;
- structural examination of sign gantries and cantilevers;
- replacement of lighting components;
- identification and removal of unnecessary signs; and

- checking for interference from advertising signs.

Preventative maintenance, repair and replacement must be informed by standards. Standards with respect to frequency of inspections and response times for different classes of roads are discussed in Chapter 6. It is accepted that the road traffic signs were initially erected in the correct position, orientation and with appropriate supports. The primary maintenance concern to be addressed in this chapter is visibility; specifically at night. The retroreflectivity is the characteristic that defines visibility and if adequate at night it will be adequate for the daytime. The primary maintenance standard will thus be retroreflectivity.

Alternative methods for inspecting signs for adequate retroreflectivity levels are:

- Measuring the sign's retroreflectivity level with a retroreflectometer;
- visually comparing the sign with a test panel that has a retroreflectivity level set at the minimum requirement; and
- visually inspecting the sign and making a subjective judgment by a trained inspector as to its adequacy (McGee, 2010).

Other assessment methods are shown in Table 5-16 (3M US, n.d.):

Table 5- 16: Assessment methods

Method	**Process**
Visual night-time inspection	Trained sign inspector, moving vehicle
Measured retroreflectivity	Measure signs with a retroreflectometer
Expected life	Determine expected life, replace at end of service life
Blanket replacement	All signs in a corridor or of a specific type are replaced at specific intervals
Control signs	Replacement based on performance of control signs
Other engineering-based methods	Varies with method

Direct measurement is the most accurate, but it is time-consuming. Retroreflectometers are not commonly available in South Africa. Visual methods can be effective using well-trained staff. The inspection should be done at night. The road authorities should have test panels of critical signs which are calibrated with instruments and kept within conditions where they do not deteriorate. For inspections, the surveyors first harmonise their vision with the standard sign retroreflectivity under the conditions that they will observe the signs and then go out to inspect and assess the condition of the signs. In the last method, a single inspector assesses all the critical signs to ensure uniformity. To be effective, the asset register should be able to identify the critical signs as well as the age and orientation of all signs.

Conclusions on standards for road traffic signs

Signs must be in position and correctly oriented to be visible at the distances prescribed in the SADC RTSM. The standard to assess these design attributes are simply right or wrong and the latter must be fixed within the time as discussed in Chapter 6. The maintenance responsibility towards these characteristics is to inspect and reinstate.

Routine replacement of signs based on a strategy of age is not an efficient way to manage the assets. The weathering of signs is not the same for all as various factors, such as orientation to the north – implying intense exposure to fading by the sunrays, play a role.

The standard for visibility of road traffic sign maintenance is proposed to be based on the minimum coefficients of retroreflectivity per class of new materials in SANS 1519-1:2006 Table 1. The international norm for intervention is 80%. Intervention is not construed that the sign is to be replaced immediately, but that it be put on the priority list for monitoring. The standard proposed for legal duty is proposed as 75% of new values per class, which is lower, as intervention levels guide the road authorities to develop asset management strategies and improve over time. The proposed standard of 75% can be adjusted in the future.

The implementation of inspections will differ from the more competent road authorities to the less competent. The national roads that are under routine road maintenance and performance-based contracts are normally monitored with retroreflectometers. The smaller road authorities must compile test boards for the calibration of visual inspections and have monitoring performed by either a dedicated inspector or teams of inspectors. With timely replacement of signs based on visual assessment, the standard for retroreflectivity should be achieved.

The proposed standard for the presence of regulatory, warning and guidance signs is 100%, with the only exception being signs that were run over within the response time discussed in Chapter 6.

5.5 Drainage

The safety implications of drainage lies in a river bridge or a culvert wash-away, erosion of the side drains and drainage channels undermining or breaking the road surface and surface water in the form of ponding and sheet flow. The features of drainage selected for proposed maintenance standards for safety are the side drains, cross drainage and roadway drainage. The inspection and monitoring of these features have the same pattern and will be discussed together.

5.5.1 Design floods and road classes

Bridges and culverts are designed for 5, 10, 20, 50 and 100 year flood frequencies, depending on the class of road. Figure 5-13 shows the design flood frequency in years for road classes 1 to 6 as a function of the estimated 1:20 year flood size (SANRAL, 2013a).The design flood frequencies for Class 1 and 2 roads, which form the strategic national and provincial network, start at 50 and 20 years respectively for 1:20 year floods less than 20 m^3/s, increasing to 100 and 50 years respectively at the 1:20 year floods of 150 m^3/s.

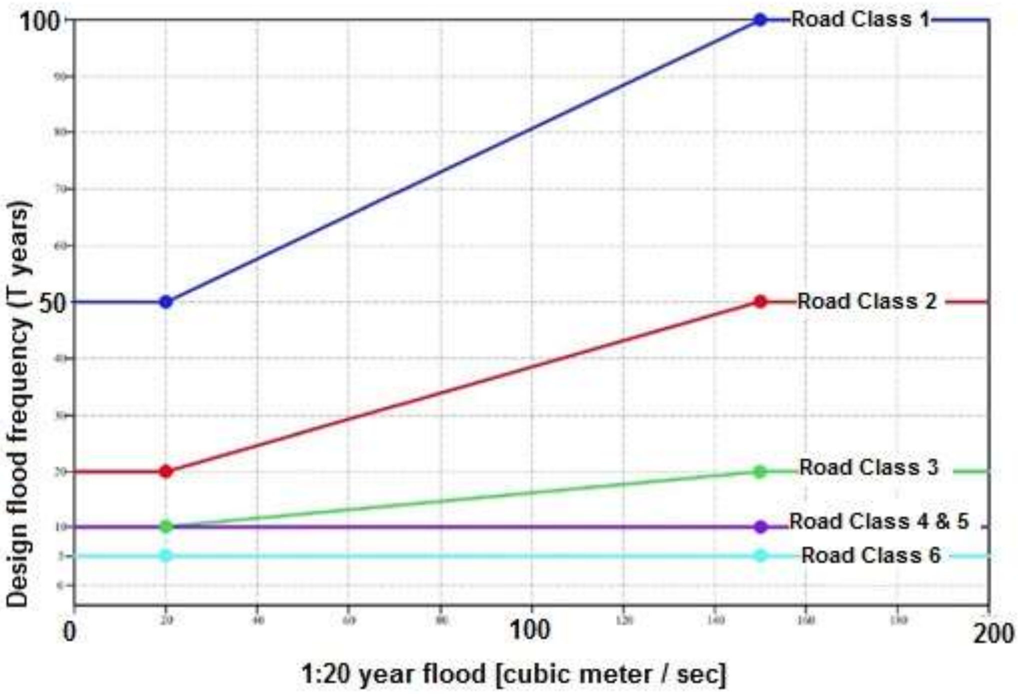


Figure 5- 13: Design flood frequency estimate

Source: (SANRAL, 2013a)

Overtopping of the bridge is normally not allowed with bridges with abutments and decks, but culvert-type bridges and culverts are often designed to form a dam on the inlet side to increase the energy available to force the water through the culvert. This normally happens where there is substantial cover over the structure. The design flood should, however, not overtop the road and the damming should not encroach on the shoulder of the road. On low-volume roads overtopping of the road may be tolerated in order to save cost, but the overtopping frequency must be in relation to the traffic volume. Very low-volume roads are typically used by local communities that know when to drive with care. An example of the Minnesota design approach is shown in Table 5.17 (Minnesota Department of Transportation, 2000).

Table 5- 17: Minimum overtopping frequencies for low-volume roads

Average daily traffic (ADT)	Minimum overtopping frequency
0 – 149	10
150 – 499	25
500 – 1499	50

The implications of the design flood frequency approach to design of water crossings are:

- The rainfall and flooding must be monitored by the road authorities to anticipate overtopping of bridges and culverts.
- Under conditions that can result in design extremes occurring, high-risk crossing of major rivers and culverts must be monitored and roads closed when flood levels encroach on the safety margins of clearance or damming levels.
- Cross drainage structures must be maintained to the design conditions of opening size, entry and exit conditions and risk of blockage.

5.5.2 Bridge maintenance

The definition of a bridge is based on a number of criteria, the most important being that the structure measured along the road centre line should be longer than 6 m. Bridge design and maintenance are specialised subjects. Bridge management is treated as a category of road infrastructure asset management on its own. The assessment of bridges involves the condition of the construction material, foundations, joints and balustrades, in conjunction with the structural load and bearing capacity. Foundation conditions are designed together with geotechnical engineers and geologists and must be assessed by a specialist. The hydraulic design of road over river bridges is done with river hydrologists to determine the design floods and size of bridge opening. River bridge inspections involve the condition of the drainage channel and vegetation to pre-empt the blocking of the openings with flood debris. Bridge openings rarely silt up as they are mostly designed to not alter the natural flow and streambed. Bridges are designed to not overtop and damming to increase the upstream energy is not normally considered in the design.

Bridge failures such as the wash-away of the bridge approach fill on the N2 approximately 100 km south of Durban in 1956 (see discussion on the case of Stanley Motors v Administrator of Natal in Chapter 6) are rare and coupled with extreme weather conditions such as cyclones.

The number of bridges is substantively less than the number of culverts. In view of the specialised nature and existing high-level of competence and control in bridge management, this category is excluded from the proposal for standards of maintenance in this thesis. The focus is on culverts, which are often overlooked in maintenance.

5.5.3 Culverts

Culverts are differentiated from bridges as being structures that are covered with earth (fill). Culverts more than 6 m long are classified as bridges for management purposes. They include water crossings in pipes or box structures. Culverts are designed for the same flood risks as bridges, but these structures carry much smaller flood volumes and can be designed for upstream damming to create higher energy. Culverts are often placed where the natural flow of water is changed and inlet designs such as drop inlets and berms are used to direct flow. The imposed positions of culverts make them susceptible to siltation or erosion.

Cross drainage by means of culverts is essential to allow water to follow the path of natural drainage. If the culvert gets blocked by vegetation or silt, the flow capacity is reduced and this leads to a risk of overtopping the road. Similarly, the flow channel leading to the inlet must be kept in the condition it was designed for. If the expected flow speed cannot be achieved the culvert may drown from the inlet side. If the outlet channel is overgrown, the flow is impeded and the culvert may drown from the outlet side. The design of culverts does not allow for reduction in the flow cross section and the maintenance must ensure this design condition is met at the onset of the rainy season.

Side drains along the edge of the road in cuttings or on kerbed roads can get blocked by vegetation and debris. Grid inlets can similarly be blocked by accumulated material.

Missing grid inlets are dangerous. The case study of Mothlapudi v SANRAL and others involved a missing grid inlet on a curved loop ramp on the N1 freeway. The driver panicked as she drove through the open manhole, 600 mm long, which allowed most of the wheel to fall into the hole. She overturned the vehicle and her son fell from the rear of the bakkie and sustained severe head injuries.

The flow path on the road is critical where the road rolls over in superelevation. The water on the edge of a down-sloping road at the start of the superelevation runoff will return to the opposite side of the road. If water running along the edge of the road is not drained from the road at the inflection point, the volume of water crossing the road is more than expected in the design. The film of water then becomes thick enough to cause hydroplaning, which occurs in the curve and causes the vehicle to veer out of the curve. The case study of de Beer v MEC Mpumalanga investigated such a hydroplaning. The maintenance issue is to keep the vegetation next to the road below the road surface so that the water can flow off the roadway and not along the edge.

In all of the situations where vegetation plays a role, the inspection frequency is dictated by natural growth and seasons. The growth of vegetation can be controlled between the start of spring and summer when shrubs and shoots emerge from the ground and can be cut back with little effort. Inspection in the second part of summer is needed to confirm that further growth has not occurred. These inspections must be done on foot by walking down to the culvert openings and flow channels.

Grass next to the road may need monthly inspections and openings to down chutes and grid inlets must be kept clear of vegetation. These inspections can be done from a vehicle.

Conclusions on drainage standards for maintenance

Cross drainage by means of culverts must be maintained to design conditions which imply no siltation and impedance of vegetation in the inlet and outlet channels. The proposed standard is 100% of culverts free of siltation and no shrubbery in the inlet and outlet channels.

Side drains must be kept clean of blockages of the channel and grid inlet over manholes. the grid inlets to manholes must be present. The proposed standard is 100% clean side drains and grid inlets with grids present.

Roadway surface drainage longitudinal to the road on a slope must be directed from the road surface to prevent accumulated water to crossing the road at a superelevated section of road. The vegetation next to the road and mouths of down chutes must thus be lower than the road surface. The standard is 100% compliance.

The above standards must be reinstated within response times as discussed in Chapter 6.

5.6 Roadside maintenance

The design of the roadside for safety was initiated by the acceptance of driver error in run-off-the-road accidents. Injury resulting from such accidents is preventable or can be mitigated. This gave birth to the forgiving roadside design approach (Wolhuter, 2015:340). Roadside design for safety is currently in the international focus with the International Road Federation coordinating conferences, workshops and research into ways of improving roadside safety. A recent Austroads publication titled Improving Roadside Safety: Summary Report (Austroads, 2014b) lists 109 publications in its references with contribution from Australia, New Zealand, UK, US and various European countries. In line with the need to keep things simple for implementation in South Africa, standards for characteristics of three sets of features are proposed.

5.6.1 Designed width of shoulder and clear zone

Based on US research, approximately 30% of all collisions involve a single vehicle running off the road. Rural high-speed roads contribute mostly to this situation.

The purpose of the design and maintenance of a forgiving roadside is to provide a roadside that either has a clear recovery area or, where such an area cannot be provided, a barrier.

Glennon proposed the following rule of thumb:

a. Remove, redesign, or protect roadside hazards within 30 feet (10 m) of the travelled way on freeways (interstates) or within 20 feet (6 m) on other roadways.

b. Hazards protected by traffic barriers should have more severe impact consequences than the traffic barrier.

Typical hazardous conditions identified by Glennon are steep side slopes, bridge structures, trees, service poles, drainage structures in the clear zone and non-crashworthy or ill-placed traffic barriers and bridge rails (Glennon & Hill, 1996; Glennon, 2005).

The design width of the shoulder is the primary part of the recovery area. It comprises the sealed shoulder and the gravel shoulder up to the shoulder break point, from where the side slopes downwards in the fill or the drainage channel (side drain) in cut starts. The sealed shoulder is separated from the travelled lane by the yellow edge-line marking, which is a safety feature in its own right.

The sealed shoulder can be used for safety features such as reflective roadstuds for improved guidance or for continuous shoulder rumble strips. Research for the NCHRP on Guidance for the Design and Application of Shoulder and Centerline Rumble Strips (Torbic et al., 2009) found that the provision of continuous shoulder rumble strips leads to reductions of 11% in single-vehicle run-off-the-road crashes on rural freeways and 15% on rural two-lane roads. Fatal and injury crashes are reduced by 16% and 29 % respectively.

The width of the clear zone is a function of road class, traffic volume and side slopes and is a design decision. The SANRAL Geometric Design Guidelines (2003) refers to the 1996 AASHTO Roadside Design Guide for the design width of the clear zone.

Conclusions on maintenance standards for shoulder and clear zone

The maintenance standard proposed for the designed width of the shoulder and clear zone is that the full width be trafficable. All safety features that were provided must be kept in operational condition and only roadside features included in the design may be allowed to be established in the clear zone.

5.6.2 Guardrail, guardrail terminals and transitions to balustrades

The concept of the clear zone as element in the forgiving roadside cannot be provided along the full length of the road. On a high fill, the width must be restricted from a cost point of view. It is necessary to erect road signs near to the edge of the road for visibility. Street lights must be placed near for effectiveness and bridges cannot be made uneconomically wide. Where a potential hazard cannot be removed, it must be shielded from vehicles in a manner that will be able to redirect or contain an errant vehicle without imposing intolerable vehicle occupant forces. It must cater for a large range of sizes, weights and designs of vehicles; over a range of impact speeds and impact angles (SANRAL, 2003).

The design, testing and certification of road-side barriers are complex issues in their own right and subject to numerous research reports and standards (Sicking, Lechtenberg, & Peterson, 2009). For the purposes of this thesis, the design of barriers and guardrail systems will not be analysed.

The provision of guardrails is typically based on warrants to ensure effective use of funds. The Gauteng Provincial Government 2001 Road Design Manual Volume I: Geometrics, gives the following general guidelines apply to the provision of guardrails:

- On a surfaced road guardrails are normally justified on a fill of 4.0 m or higher;
- a guardrail is normally justified on a fill for a gravel road which is 6.0m or higher;
- a guardrail should be provided where there is standing water deeper than 1.5m next to a road';
- where a vertical retaining wall higher than 1m is provided next to the road, the retaining wall must be designed in such a manner, on the carriageway side, to serve as a safety barrier, otherwise a guardrail must be provided;
- should any exceptional obstruction exists closer than 1 m from the shoulder breakpoint, on a road without barrier kerbing and/or with a design speed of 80km/h or more, a guardrail must be provided;
- guardrails must be provided at all approaches to bridges and fixed to the bridge balustrade;
- such guardrails should be double according to national standards;
- guardrails must be provided on the outside of curves that have a radius of less than 300 m and no recovery areas; and
- in medians as prescribed for median barriers (Gauteng Provincial Government, 2001).

The SANRAL Geometric Design Guidelines stresses that the designer should be aware of the needs and circumstances of the individual situation when deciding on installing guardrails (SANRAL, 2003). The maintenance responsibility is, however, to keep the systems that were provided in the initial construction in operational condition.

There are a range of barrier types: rigid (concrete), flexible (W-shaped steel) and cable. Rigid guardrails require little maintenance and cable systems can be repaired quickly. The most prevalent type of guardrail is the W-shaped steel profile guardrail on wooden poles. It is time-consuming to repair after a collision and the damaged sections cannot be re-used. These guardrails also deteriorate over time as the spacer blocks break, and the wooden poles dry out and become loose in the ground.

The installation of guardrails requires careful consideration of the site conditions, offset from the road, length of need and operational requirements such as deflection space, flares and transitions.

Guardrail terminals are vulnerable in collisions as it is difficult to design the start terminal to be as safe as the rest of the system. At the start, the guardrail is typically sloped (concrete and cable systems) or turned down and flared out. These terminals are thus hazardous in their own right. The hazard markers normally erected at the start and end must be maintained at all times.

The transition of flexible guardrail to a bridge balustrade creates a hazardous situation due to the relative stiffness of the two barriers types. The flexible guardrail is designed to deflect outwards, while the rigid balustrade remains fixed. This causes a pocket effect in the flexible barrier and the vehicle can hit the fixed balustrade head on. The maintenance implication is that the transition length as prescribed by the suppliers, where the stiffness is increased by adding more wooden poles, must be maintained particularly well. Older bridges where guardrails are added later and not fixed to the balustrades must be upgraded as a matter of urgency.

Damaged barriers shall be repaired to a standard not less than that existing before the damage occurred, or if they were incorrectly installed, they shall be repaired to the correct standard, in compliance with the standard determined by the responsible engineer, and be in accordance with the manufacturer's specification (Transit New Zealand, 2006).

Conclusions on maintenance standards for guardrails

The standard proposed for maintenance is that 100% of all the guardrail lengths, terminals and transitions must be functional; the only exceptions being sections to be repaired within the response times required.

5.6.3 Vegetation

Vegetation is defined as all plant life growing within the site including but not limited to grass, weeds, scrub, shrubs, trees and overhanging branches (Transit New Zealand, 1997).

Poor roadside vegetation management practices have ranged from blatant neglect to routine blanket applications of herbicides. In response to the development of Integrated Roadside Vegetation Management (IRVM) the NCHRP commissioned a synthesis document on IRVM, to report on the incorporation of integrated roadside vegetation management decision-making processes into highway project planning, design, construction, and maintenance. It also reported on existing research and practice by means of a questionnaire to the state road authorities (Berger, 2005).

Vegetation is controlled in areas for sight distance, on unsealed shoulders, traffic islands, medians, verges, surface water channels, side drains, batters and embankment side slopes, rest and landscaped areas (Transit New Zealand, 1997). The methods for vegetation control range from mechanical eradication by cutting down, chemical eradication by spraying with a suitable registered chemical to total physical eradication. SANRAL implements the requirements of the Conservation of Agricultural Resources Act 43 of 1983 (CARA), to eradicate declared invader species. It also eradicates species that are considered undesirable from a maintenance point of view (SANRAL 2009). The Eden District Municipality had a handbook compiled titled Road-verge Vegetation Management Guidelines that does consider road safety and gives excellent guidance on promoting indigenous regional flora (Milton-Dean, 2011).

The control of vegetation is also important on rural roads with a risk of veld fires. The amount of combustible organic material or biomass will determine the extent of the fire, while the moisture content can determine the heat of the fire and rate of spread. Smoke is a function of the type and density of vegetation and even debris next to the road. The National Veld and Forest Fire Act (NVFFA) 101 of 1998 may require that a fire break be cleared on either side of a fence separating a road servitude from private land that supports flammable vegetation (Milton-Dean, 2011).

5.6.3.1 Highway trees

A tree is a woody perennial plant, typically having a single stem or trunk growing to a considerable height and bearing lateral branches at some distance from the ground (Oxford Dictionaries, n.d.- b)

Though no scientific definition exists to separate trees and shrubs, a useful definition for a tree is a woody plant having one erect perennial stem (trunk) at least three inches (75 mm) in diameter at a point 4-1/2 feet (1.4 m) above the ground, a definitely formed crown of foliage, and a mature height of at least 13 feet (4 m). This definition works fine, though some trees may have more than one stem and young trees obviously don't meet the size criteria. A shrub can then be defined as a woody plant with several perennial stems that may be erect or may lie close to the ground. It will usually have a height less than 13 feet (4 m) and stems no more than about three inches (75 mm) in diameter (Kuhns, n.d.)

Trees occur in or next to road reserves. However, neither SANRAL nor the provincial road authorities in South Africa has formal policies on trees in or next to road reserves. Municipalities with road tree policies focus on landscaping and road safety as a secondary consideration. The United Kingdom has such a policy contained in the publication Well-maintained Highways: Code of Practice for Highway Maintenance Management (Roads Liaison Group, 2005). The salient points are:

> 9.6 SAFETY INSPECTION OF HIGHWAY TREES
>
> 9.6.1 Trees are important for amenity and nature conservation reasons and should be preserved but they can present risks to highway users and adjoining land users if they are allowed to become unstable. In England and Wales the highway authority is also responsible for ensuring that trees outside the highway boundary, but within falling distance, are safe. All trees within falling distance are collectively termed ‘highway trees’. Section 154 of the Highways Act 1980 empowers the authority to deal, by notice, with hedges, trees and shrubs growing on adjacent land which overhang the highway, and to recover costs.
>
> 9.6.2 Safety inspections should incorporate highway trees, including those outside but within falling distance of the highway. Inspectors should take note of any encroachment or visibility obstruction and any obvious damage, ill health or trip

> hazards. A separate programme of tree inspections, however, should be undertaken by arboricultural advisors.
>
> 9.6.3 Authorities should include some basic arboricultural guidance in training for inspectors but it is important that arboricultural advice is obtained to advise on the appropriate frequency of inspections and works required for each individual street or mature tree, based on assessment of respective risks (Roads Liaison Group, 2005).
>
> Trees are features along roads, planted for purposes such as rest areas, esthetical reasons, or grow naturally. Trees can be located at random or line the road reserve either inside or outside the road reserve. Trees also occur next to the road reserves where the road runs through natural or cultivated forest. A tree can be viewed as a non-essential element of the road furniture, whereas a road sign support or gantry is provided for the functioning of the road. The location of such a non-essential element must be evaluated from a functional and safety point of view.

The first consideration in the safety of roadside furniture is the distance from the roadway. The design of a road provides for a recovery area or clearance zone next to the roadway, as it is accepted in road design that drivers do encroach on the shoulders of a road due to inattention, emergency action and to rest. The clearance zone is typically 6 to 9 m wide with specifications for the side-slope. Where such clearance zones cannot be provided, crash barriers are provided to contain errant vehicles. Trees should therefore not be located within the clear zone.

SANRAL Geometric Design Guidelines (2003) states with respect to vegetation are the following:

> 8.2.5 Best practices in respect of roadside vegetation
>
> Single-vehicle collisions with trees account for a sizeable proportion of all fixed object collisions. Unlike typical roadside hardware, with the exception of landscaping, trees are not a design element over which the designers have direct control. While policies and approaches vary by agency, a number of best practices are presented here to assist the designer in dealing with this complex and important issue.
>
> Depending on their size, trees within the clear zone constitute a serious hazard. Generally, a tree with a trunk diameter greater than 150 mm is considered a fixed object. When trees or shrubs with multiple trunks, or groups of small trees are close together, because of their combined cross-sectional area, they may be considered as having the effect of a single tree.
>
> Typically, large trees should be removed from within the selected clear zone for new construction and reconstruction projects. Segments of a highway can be analysed to identify groups of trees or individual trees that are candidates for removal or shielding.
>
> While tree removal generally generates some public resistance, it will reduce the severity of any crashes. Tree removal often has adverse environmental impacts. It is important that this measure only be used when it is the only solution. For example, slopes of 1:3 or flatter may be traversable but a vehicle on a 1:3 slope will usually reach the bottom. If there are numerous trees at the toe of the slope, the removal of isolated trees on the slope will not significantly reduce the vehicle/ tree collision risk although some isolated trees may be candidates for removal if they are noticeably

> close to the roadway. If a tree or group of trees is in a vulnerable location but cannot be removed, traffic barriers can be used to shield them.
>
> Maintenance of the roadside plays an important role in helping to control vegetation and tree problems by mowing within the clear zone and eliminating seedlings before they create a hazard.

Trees within the road reserve and outside the clearance zone can still affect the safety of the road users if the height of the tree exceeds the distance from the roadway. In the event of the tree falling on to the roadway, this will become a hazard. The same applies to tall trees outside the road reserve. Trees that do occur in the road reserve or next to it must be assessed for safety risk. The risks that can be identified are: collision hazards, falling trees and broken branches that can fall on the road.

Although the South African Accident Report form does not specifically identify accidents involving trees, there is sufficient anecdotal evidence of accidents involving trees. Research in the US indicates that collisions between vehicles and trees are a major type of traffic fatality. The Fatal Accident Reporting System data for 1999 indicate 10,967 fatal crashes involved a fixed object. A total of 3 010 fatal crashes, or about 8% of all fatal crashes involved trees (Glennon & Hill, 1996; Neuman, Pfefer, Slack, Lacy, & Zeeger, 2003).

The maintenance specification should specify the “highway” trees that are approved of in the road reserve and the trees outside of the road reserve that could fall on the road. These trees should be inspected for disease (cankers and decay), dead branches, cracks, weak branch unions, root problems and poor tree architecture. Lonsdale advises that where people or property could be at risk from tree failure, routine inspections should be carried out frequently enough to detect any hazards that may have recently developed. Large old trees sometimes develop hazards quite rapidly and an inspection frequency of one year or more is generally advisable where such trees occur on high-usage sites. Inspections are also required after any severe weather events that might have caused damage to trees. Detailed inspections of particular trees that show signs of progressive deterioration in their condition may be required. The best time for inspection is during clear weather at the beginning of the autumn (Lonsdale, 2000).

The principle of a road authority being responsible for a tree that grew outside the road reserve and fell on the road during a storm was established in the Eastern Cape High Court in the case of Botha v MEC Roads and Transport Eastern Cape. This case is discussed in Chapter 7.

Trees should be trimmed and topped in a controlled manner to a height that prevents them from falling on the road. Trees next to the road need not be high to be attractive. This will prevent the need to close roads in times of high wind and rain that weaken the ground around the root system.

Conclusions on maintenance standards for trees

The proposed standard for trees in and bordering on the road reserve is an annual inspection in autumn by an appropriately qualified professional natural scientist and the removal of any trees or branches that may pose a risk to road users, including topping to contain the height of the trees.

5.6.3.2 Lines of sight

> Clear sight lines and adequate sight distances are provided to allow time for decision-making and, wherever possible, margins are allowed for error and recovery (SANRAL 2003:3-3).

Adequate sight distance is a basic design assumption. A design that does not provide and ensure its availability is negligent. Intervisibility is a term coined in the UK to describe the need for both parties (driver-driver, driver-pedestrian) to see each other in time to act appropriately. The greatest problems with lines of sight are at junctions, intersections and railway level crossings in observing conflicting vehicles on the crossing road. Typical hazardous conditions proposed by Glennon (2005) are hidden intersections, signs, horizontal and vertical curves and conflicting vehicles. The most severe accidents happen when the lines of sight to traffic signals and regulatory signs STOP and YIELD are obscured, as conflicting vehicles may both be travelling at high speeds.

Vegetation in sight triangles can restrict a driver's sight and thereby hamper safe travel ahead of or through intersections. Standards for stopping sight distance and intersection sight distance were developed to give drivers adequate time to see conflicting objects or vehicles, respond, and avoid collision as a function of operating speed.

Austroads indicated that no literature could be found that explicitly dealt with effects of overhead branches on traffic control devices. Some signs may remain legible with 20% of the sign face obscured. With more than 20% of the sign covered, some drivers may direct considerable attention to trying to read the sign, to the detriment of their performance on the driving task. The safety impact of the sign may be worse than if no sign was present. The researchers speculate on a suitable intervention level, as the impact of restoring sight distance to the required minimum depends on the speed. They suggest that once sight distance falls by 20%, action should be taken to restore it. It is further assumed that this action would reduce crashes by 33% (Austroads, 2010).

These assumptions by Austroads are nonsensical. To have a reduction of 33% implies that the presence of sight obstructions causes an increase in the number of crashes. This should not even be tolerated. To know that crashes will increase by not inspecting and maintaining is negligent. The test is what the reasonable person with skill in such matters would have done to prevent the problem from occurring. If there is knowledge of a recurring sight line problem, the cause should be removed (Austroads, 2010b).

Vegetation that grows higher than 1.05 m (the design eye height of a driver) (SANRAL, 2003) could obscure road traffic signs and signals, as well as interfere with sight lines between vehicles, pedestrian and animals. The case of Gerber v MEC Roads and Transport Western Province involved a pedestrian on the median of the N7 freeway, who walked in front of a motorcycle. The vegetation on the median was estimated by witnesses to be between 2 m and 4 m high and hid the pedestrian completely.

Conclusions on maintenance standards for vegetation in the road reserve

The standard for vegetation is to keep the height of shrubs and grass below 1 m where there is no risk of fire, and at an appropriate height of not less than 150 mm where fire is a risk.

Chapter 6: Road maintenance procedures

> The Team is required to inspect the site frequently so that problems are identified, the causes investigated and assessed and the actions required identified and carried out timeously. Obvious problems should be noted as soon as they become evident and serious situations should be reacted to and reported immediately. (SANRAL, 2009:2-2).

The types of maintenance, inspections, monitoring and reaction to events and incidents were reviewed in the literature review, Chapter 2, section 2.6. In this chapter the proposed procedures to ensure that the road remains in safe and functional condition are based on the road characteristics that impact on road safety for which standards were proposed in Chapter 5.

6.1 Reactive, *ad hoc* and special maintenance

Reactive and special maintenance takes place in response to complaints, emergencies and inspections. Actions can only be triggered by events that have happened or have been identified as imminent. The events are by their nature unplanned, but the response can be planned in advance. In terms of the Construction Regulations 2003 of the OHSA, risks assessments must be done for all activities as part of the method statements (Republic of South Africa, 2003).

Skilled maintenance staff can identify failures or high-risk of failures with greater exactness and precision than the general public. Such problems with a high safety risk must be attended to within a reasonable time, depending on the severity of the hazard and consequences of the failure. These response times are described in section 6.11.

Of the maintenance characteristics identified in Chapter 5, loose material or debris on the road should ideally be the only reactive maintenance, excluding emergencies such as slope failure, road washaway or trees that fall on the road. The procedures to deal with loose material on the road are linked to complaints and routine road inspections as appropriate for the class of road.

The first procedural problem is that the public very rarely know whom to contact with complaints or in connection with emergencies, excluding crime-related one for which the 10111 number is well-known. This leads to a *laissez-faire* culture about hazards identified on the road, as the observer feels that he/she has no control over the problem. SANRAL roads with routine maintenance contracts have contractors' boards typically at the start of each contract in the direction of approach. Some municipalities have signs on the major arterials giving contact details for complaints in general. Websites and social media have developed in response to potholes, but often observers are distracted by other matters and forget to report the failure by the time they reach their destination. The City of Johannesburg has a “report a pothole” service.

A single national road condition and emergency reporting number should be instituted by road authorities under the auspices of the national Department of Transport, linked to the national disaster management centre and its national disaster management information system that are required in terms of DMA and the Disaster Management Framework (Department of Local and Provincial Affairs, 2005). The road safety problem in South Africa can in fact be regarded as a national disaster with around 14 000 fatalities per year, which is more than the fatalities caused by all the natural disasters put together. This act is executed by the Department of Local Government and Traditional Affairs (Department of Local and Provincial Government, 2012).

The contact information with respect to road safety and maintenance problems should be displayed at prominent locations on rural roads, such as intersections and junctions, on direction signs and painted on the road outside of the wheel tracks.

Complaints and emergencies should be recorded, classified and directed to the appropriate section to plan and execute the remedial or mitigating actions. A close out report must be filed for every attended complaint.

Failures and emergency situations identified during inspections by road authority staff or contractors must also be formally recorded and treated in accordance with appropriate protocols for reaction time per class of road. A complete paper trail of the identified failure or emergency must be kept, as claims for damages only need to be submitted within six months of the incident. Life-threatening hazards must be reported to the client and if the scale and scope of remedial action is in excess of the discretion of the site staff, approval for variation orders must be sought.

Special maintenance in response to emergencies will typically involve an incident management phase, followed by a holding action to allow for the investigation of the problem and the design of an appropriate solution. This can be in response to a landslide or slope slip, where the slope has to be stabilised, followed by a permanent solution.

Special maintenance has in the past included the repair of accumulated failures beyond the typical routine maintenance scope. The ideal situation that needs to be created by adequate maintenance is that such a situation will be avoided. In the case study of Madonsela v SANRAL and others (settled), discussed in Chapter 7, potholes were recurring in a low-lying area with a high water table due to saturation of the pavement layers. Sequential patching with cold mix asphalt failed to the extent that a large pothole developed where patches became dislodged. Only after the accident involving Madonsela, layer works were excavated to subgrade level and properly built up over an extensive area.

6.2 Routine road maintenance

Routine road maintenance is the execution of maintenance activities to a regular schedule, such as cleaning and vegetation control. The appropriate inspection cycles are discussed in this section. If a road is at the end of its service life and programmed maintenance (see section 6.3) is not imminent, the regular patching of potholes as a holding action can become a routine maintenance activity. SANRAL in its Routine Road Maintenance Manual states

> SANRAL has various strategies for sections of the route based on its PMS. These will include planned reseal, rehabilitation or new construction projects. This must be known as it strongly influences possible routine maintenance measures. For example, where a road has widespread crocodile cracks together with some rutting, but is due for rehabilitation in the short term, a minimum action such as maintaining the road surface so that it is safe for public traffic (i.e. a holding operation) may be the right approach. Extensive patching and repairs would be wasted effort and money (SANRAL, 2009:2.2).

Cleaning of the road reserve is primarily an environmental matter. Prior to 2002, plastic shopping bags were a particularly bad litter problem in road reserves, to the extent that they were referred to as the national flower. Since 2002 shopping bags have to be paid for and the problem has reduced, but high-volume roads still have litter problems.

Depending on the road authority and road class, inspections are done at regular intervals and cleaning of the road reserve is scheduled to the observed need. The observations of road inspectors and the input from cleaners can also be used to identify safety hazards and failures that start on the verges of the road. This can be silting and erosion of side drains and culverts, growth of trees in the recovery/clear space next to the road and in drainage channels and obscuration of sight lines.

In addition to the short-interval routine inspections, a comprehensive survey of the road and road reserve should be done at appropriate intervals to compile route/strip plans. This can now be complemented with video surveys taken from a moving vehicle, as the cost of such equipment as well as the capacity to store data have reduced dramatically.

6.3 Programmed maintenance

Programmed maintenance follows from the Pavement Management System (PMS) and is primarily directed at resurfacing, reconditioning and reconstruction of roads. This aspect of road infrastructure maintenance is driven by functional parameters and is aimed at interventions before the condition of the road becomes hazardous. This study is not concerned with standards for programmed maintenance, but with standards for failures of characteristics that have a safety implication and occur due to inadequate programmed maintenance.

Procedures for programmed maintenance are based on the pavement life cycle. Long intervals between inspections would be appropriate for new roads. Annual inspection would be required for a road nearing the end of its design life, and its surface seals and bases. Many of the characteristics that are inspected as part of the PMS have a safety implication. There is common cause to prevent the attributes of these characteristics dropping below thresholds of safety and operational functionality.

Programmed maintenance can also be used for road traffic signs. The road authorities wait until the signs on a road section or route are generally in poor condition and then replace all the signs under a single contract. This is especially done with respect to direction signage. Such an approach could lead to sub-optimal performance as the differences in, for example, the fading of signs facing north versus those facing south are not taken into account.

6.4 Network inspection intervals

The condition assessment surveys that inform the PMS for the determination of planned maintenance can be based on a fixed cycle as recommended by most researchers. Different cycles can be used for various classes of road.

Safety condition assessments of features and characteristics beyond the pavement characteristics were typically not done in a formal manner during PMS assessments and the management of maintenance for safety was based on complaints and hazardous location investigations.

The Yarriambiack Shire Council in Victoria, Australia, in their Road Management Plan (Yarriambiack Shire Council, 2012) budgets for 20% of the length of the sealed and gravel roads and footpaths per year, which allows it to do condition assessments on new roads at longer intervals and on roads nearing critical decision points such as reseals or rehabilitation at shorter intervals. All street furniture, kerbs, channels, bridges and culverts are assessed in fixed three-year intervals.

The comprehensive approach taken by Vicroads in their Road Management Plan (State of Victoria, 2014), as discussed in Chapter 2 and shown in Tables 2-13 and 2-14, starts with the definition of Road Maintenance Categories (RMC). RMCs are based on risk assessments and coupled to road hierarchies, road classes, traffic volumes, and traffic types. The inspection intervals are specified for the RMCs ranging from daily to not exceeding six months for day-time inspections while night-time inspections are limited to six and 12 month intervals, as shown in Table 6-1 (State of Victoria, 2014).

Table 6- 1: Hazard inspection type and frequency by road maintenance category

Inspection type	RMC1	RMC2	RMC3	RMC4	RMC5	RMC6
Day-time	Each weekday	Twice per week	Weekly	Every second week	Monthly	Not exceeding 6 months
Night-time	Not exceeding 6 months	Not exceeding 6 months	Not exceeding 6 months	Not exceeding 1 year	Not exceeding 1 year	Not exceeding 1 year

6.5 Surfaced roadway procedures

The roadway maintenance procedures are concerned with the surfaced and unsurfaced areas of the road. The maintenance procedures for safety of the surfaced areas entail visual inspections, measurements and tests. The industry standard accepted in South Africa is the Pavement Management Systems: Standard Visual Assessment Manual for Flexible Pavements, Technical Methods for Highways 9 (CSRA, 1992). Unless otherwise indicated, the discussion is guided by this document.

The maintenance procedure with respect to inspection and monitoring will vary over the life of the seal. A good PMS will inform road officials of the expected deterioration, as it has functions to predict the life of each characteristic for types of surfacing, climate and traffic conditions. Often the PMS is not kept up to date as the cost of regular inspections is high and skilled assessors are not available. Initial strategies called for annual or bi-annual inspections of the complete network, which could not be sustained. The long-time horizon to benefit from a PMS was set back by short-term funding shortages.

6.5.1 Texture

The texture of a newly surfaced road is evaluated under the construction specifications after completion and inspected at the end of the contract guarantee (retention) period, which is typically one year. Texture failures of road surfacing are mostly related to substandard bitumen binder for both seals and asphalt, over application of bitumen for seals and soft mix design or inadequate compaction for asphalt. These failures normally manifest in the first year and are fixed under the retention guarantee.

The texture of roads after the first year of construction deteriorates as a function of traffic and time. The aggregate can polish and lose micro-texture, resulting in a shiny appearance. Macro-texture can reduce due to deeper embedding in the asphalt or loss of aggregate as the seal or asphalt dries out and becomes brittle.

The inspection and monitoring of texture start off with visual assessment, with skilled observers that calibrate their scales of observation prior to each inspection by means of assessing road sections with known texture depth. Areas of questionable texture depth identified must be recorded in the PMS and testing by means of the sand patch method must be scheduled. Texture depth must be monitored closely on approaches to stopping conditions and in curves with radii near the minimum design value.

Site staff and maintenance crews must be trained to observe deterioration of texture depth and advise the PMS officials of changes between formal assessments.

In absence of a PMS that advises when to inspect the road for texture deterioration, the proposed visual assessment interval standard is bi-annually, until the trigger value of 0.5 mm is reached. The visual assessment must then be augmented with sand patch tests and monitored on an annual basis.

Critical areas such as stopping distances and sharp curves should be resealed when the texture depth drop below the proposed standard, either as special maintenance of these critical areas or programmed maintenance for the route.

Where local areas of insufficient texture depth develop due to specific failures or traffic conditions, special maintenance must be planned within the reaction time proposed.

6.5.2 Skid resistance

The skid resistance of a new road surface is dependent on the macro-texture and micro-texture. The maintenance procedure for macro-texture is discussed above. Macro-texture is proposed as the safety standard for the interaction between the tyre and the road on rural roads where hydroplaning at speeds above 80 km/h is a primary consideration. Micro-texture is dependent on the aggregate properties and it is assumed that the polishing value specified for the new seal or asphalt was provided at construction. Skid resistance will deteriorate as the micro- and macro-texture is lost due to traffic and over time as the aggregate is polished and lost, and dirt and bitumen accumulate between the aggregate.

The control of skid resistance is proposed to be done primarily in urban areas with operating speeds below 80 km/h. The urban road network is more compact than the rural road network and the cost of doing skid resistance testing on high-volume arterials can be justified.

It is proposed that the urban arterial network of roads with operating speeds above 60 km/h be assessed for skid resistance on a bi-annual cycle until a pattern of deterioration is established for the critical routes and intersections. The assessment cycle can then be adapted to pattern and surveys can be directed at road sections approaching trigger values.

The remedial measures for substandard skid resistance should be implemented within the reaction time indicated and appropriate warning signs be erected until the skid resistance has been restored.

6.5.3 Rutting, shoving and ponding

Rutting, shoving and the associated ponding of water develop over time due to heavy wheel loads and hot climatic conditions. As with texture, the causes of early rutting are related to bitumen quality and mix design if located in the surfacing layers. Rutting will normally manifest within the construction retention period if these causes are present and can be rectified by replacing the sections of substandard surfacing. Rutting and shoving in the longer term is caused by shear failure in the base and sub-base layers due to water ingress or fatigue.

Rutting and shoving rarely come as a surprise or sudden emergency. Road inspectors and maintenance crews often identify these failures during their normal activities. A formal road inspection and visual assessment at network level is proposed bi-annually. Areas where rutting starts to manifest should be monitored annually.

The reaction time to respond to rutting and ponding will depend on the rate of deterioration and the depth. The trigger value proposed must not be exceeded by the time the remedial work is scheduled.

6.5.4 Potholes

As discussed, potholes are most likely preceded by other failures such as dry seals, cracks, delamination, aggregate loss, shoving and rutting. These early failures may not have direct safety implications and standards for maintenance for safety are not proposed for these characteristics. If road maintenance for structural integrity and functionality can be done, maintenance for safety with respect to potholes will be accounted for.

Potholes are dependent on more factors than texture deterioration or rutting: in addition to traffic and time, the influence of underlying layers (material types and thickness), the subgrade, moisture conditions in cuts and swampy conditions in fills all contribute to pavement failure of many kinds and potholes are the final symptoms of terminal failure and impending disintegration.

Procedures relating to the prevention of potholes are in line with the visual assessment of all pavement characteristics required in the PMS. Bi-annual network level visual assessment is proposed as the basis but weak areas or sections of road should be identified for more frequent monitoring.

Once a section of road has deteriorated to the extent that potholes develop, even Degree 3 potholes, base layers open up and allow water to enter. The development of larger potholes can happen very quickly. No research could be found on the rate of deterioration of potholes in sealed roadways, as this should not happen. In the case of Matshoge v MEC North West Province (2014) the potholes covered the roadway to the extent that vehicles were driven on the gravel shoulder where the undulations were at least relatively smooth compared to the sharp edges of the potholes. The visual assessment guides typically indicate a 300 mm diameter pothole as a Degree 5 (most severe and dangerous), but the potholes investigated in the North West Province were often more than 1 000 mm in diameter, sometimes over the width of the lane and meters long.

6.5.5 Loose material

Loose material and debris were discussed under reactive maintenance in section 6.1. Loose material and debris are unexpected and can only be identified through complaints or inspections. Loose material was, for example, transported on the road in the case study of van der Merwe v MEC PWRT Mpumalanga (investigation) from a steep access road to a forestry station by vehicles and rainwater runoff. Loose rocks and gravel can also wash from cut slopes in mountainous areas.

The inspection cycle will depend on the class of road and traffic volume, and the location of the road section. The inspection frequencies per road class are discussed in Table 6-1, but it is clear that for Class 1 and 2 roads, such inspections should be at least once a week.

6.6 Gravel shoulder procedures

The study focuses on sealed roads. The gravel shoulders next to the sealed roadway have great safety impact as the two surfaces have greatly different characteristics and the interface between them are subject to many factors that result in the development of hazardous conditions. The maintenance requirements are therefore high and complex.

The width of the sealed shoulder has a substantive role in the deterioration of the edge and the risk of hazard to the motorist. The standards for height of drop-off and width of edge break as proposed in Chapter 5 do not differentiate for different shoulder widths. The proposed height of drop-off and width of edge break are dangerous as such, irrespective of the width of sealed shoulder. The risk of the driver encountering the edge drop-off or break becomes lower with increased width of sealed shoulder. A wide paved shoulder, which is the primary recovery area, will also prevent wind erosion caused by trucks and reduce the probability of vehicles overrunning onto the gravel shoulder where the gravel can be splashed out.

The maintenance procedures proposed for edge drop-off and edge break are the same in terms of inspection frequencies and monitoring.

The edge condition between the sealed and gravel shoulder is affected by a number of factors as indicated above. In addition, the longitudinal slope of the road can play a role in the rate at which erosion will take place. If a channel develops on the interface, it will erode quickly due to the higher flow speeds that can be achieved in a narrow channel. The insides of curves are more prone to erosion due to truck trailers that off-track to the inside. More erosion occurs at accesses where vehicles travel over the edge. Failures develop faster where standing water occurs next to the roadway in depressions in the gravel surface.

The changes that can occur in the road edge condition, especially in the rainy season, can be dramatic and happen quickly. A regular inspection and monitoring frequency is appropriate and dependent on the road class and volume. The proposed standards are discussed in Chapter 8. A wide-sealed shoulder is normally found on high-volume roads and a high frequency of inspections is justified from other considerations. Narrow or no-paved shoulders that still occur on many rural high-speed roads also justify a high frequency of inspection.

6.7 Traffic control

The traffic control category has the road markings and road signs as features. In both cases the characteristic are to be maintained to an appropriate standard of visibility. Visibility in this sense implies an uninterrupted view, and line of sight is discussed under the roadside: vegetation.

6.7.1 Road markings

New road markings on seals or asphalt are affected by the volatile fractions of bitumen that are released when the bitumen is sprayed or laid and then exposed to the sun. The paint is stained brown when applied too soon. However, many high-volume roads cannot be left without road markings.

In performance-based contracts, the road markings are assessed directly after construction; a first inspection one to two months after application, a second inspection in the middle of the performance period and a final inspection one to two months before the end of the performance period. The performance period is typically three years. The criteria for performance are measured as night-time reflectivity (mcd/lx/m^2) per line colour. White lines must have night-time reflectivity of 250, 150 and 120 mcd/lx/m^2 at the first, second and final inspections respectively.

The proposed inspection frequency is annually. This is shorter than the interval between the first and second, as well as the second and final inspections of the performance-based contract. However, this is reasonable considering that contractors involved in performance-based contracts mostly use material more superior than specified for internal use by road authorities.

The criteria for night-time reflectivity must be measured with an approved reflectometer, which most road authorities do not have. The procedure of calibrating the eyes of the observers on lines of known reflectivity before doing their inspections can be used as proxy.

6.7.2 Road signs

The calibration of the observer's eyes for road signs is conveniently achieved by having a set of signs of known reflectivity to adjust to. Observers must travel at night with appropriate vehicles. A light-delivery vehicle is appropriate as the reflection angle from the road sign measured from the light source to the eye of the observer is larger than the angle in a sedan vehicle. The larger angle reflects less light and thus tests a worst-case scenario.

Road signs deteriorate at different rates depending on the type of reflective sheeting and the orientation of the signs. Fading is strongly influenced by direct sunlight. The life expectancy of a red sign (R1 STOP) is in the order of seven years and the life expectancy of directional signs with green background is ten years. As regulatory and warnings signs are replaced on a continual basis and the network is inspected as a whole, there is no advantage in having different sign inspection frequencies for different sign types.

Video recordings of the road signs and marking surveys provide a record of the signs, their locations and condition.

6.8 Drainage

The features of drainage selected for proposed maintenance standards for safety are the side drains, cross drainage and roadway drainage. The inspection and monitoring of these features have the same pattern and are discussed together.

Missing grid inlets are dangerous. The case study of Mothlapudi v SANRAL (see section 7.4.2), involved a missing grid inlet on a curved loop ramp on the N1 freeway. For maintenance inspections, grids in side drains next to the road are easy to observe from a vehicle and it is proposed that a weekly inspection frequency be maintained.

Side drains along the edge of the road in cuttings or on kerbed roads can get blocked by vegetation and debris. Grid inlets can similarly be blocked by accumulated material.

Cross drainage by means of culverts is essential to allow water to follow the path of natural drainage. If a culvert gets blocked by vegetation or silt, the flow capacity is reduced and leads to the risk of overtopping the road. Similarly, the flow channel leading to the inlet must be kept in the condition it was designed for. If the expected flow speed cannot be achieved the culvert may drown from the inlet side. If the outlet channel is overgrown, the flow is also impeded and the culvert may drown from the outlet side.

The flow path on the road is critical where the road rolls over in superelevation. The maintenance issue is to keep the vegetation next to the road below the road surface so that the water can flow off the roadway and not along the edge.

In all of the situations where vegetation plays a role, the inspection frequency is dictated by natural growth and seasons. The growth of vegetation can be controlled between the start of spring and the start of summer when shrubs and shoots emerge from the ground and can be cut back with little effort. Inspection in the second part of summer is needed to confirm that further growth has not occurred. These inspections must be done on foot by walking down to the culvert openings and flow channels.

Grass next to the road may need monthly inspections and openings to down chutes and grid inlets must be kept clear of vegetation. These inspections can be done from a vehicle as part of routine inspections and when teams are on their way to other work sites.

6.9 Roadside maintenance

The road side is important as the recovery area for errant vehicles. This is also referred to as the clear zone and supports the “forgiving” roadside design philosophy.

6.9.1 Clear zone / recovery area

The extent of the clear zone is a design consideration. Research has shown that the first 6 m is the most important. The roadside must be kept clear of any object that can pose a hazard to vehicles that runoff the road, or if it is not possible (for instance road signs and light masts), the hazards must be protected with barriers or the poles must be breakable to minimise the stopping forces. From a maintenance procedure point of view, the roadside must be inspected for loose material and debris at a set frequency as dictated by road class and traffic. The clear zone can then be assessed for non-essential features that can be removed.

6.9.2 Barriers

Longitudinal barriers are warranted as described in Chapter 5. Experience on routine road maintenance contracts prove that the barriers do get hit, confirming that they are justified. The pattern of accidents shows that most accidents happen on the weekend between the hours of 18:00 and 21:00. These accidents predominantly involve single vehicles that run off the road, for which longitudinal barriers will help to mitigate the severity.

Barriers, their terminals and connections to bridge balustrades should be inspected weekly. Accident patterns involving barriers must be monitored to detect whether road factors are responsible for the hazardous locations.

6.9.3 Vegetation

The safety impacts of vegetation, excluding the impact on drainage already discussed, revolve around highway trees and lines of sight, as discussed in Chapter 5.

Highway trees should be identified as part of the design of the road and the reasons for retaining a tree must be noted as a design exception. Trees that can fall on the roadway must be inspected on an annual basis by a registered tree expert. Diseased trees must be treated or removed. The inspection must include the shape and new growth since the previous inspection.

Lines of sight towards road signs as well as intervisibility between vehicles and pedestrians must be maintained to appropriate distances. Vegetation in sight triangles or in line with signs must primarily be evaluated for removal. Inspection of growth of vegetation retained must be done on a monthly frequency and trimming of vegetation be done in a manner that will accommodate a month's growth.

6.10 Pedestrian walkway

The importance of a pedestrian walkway will depend on the route function and the volume of traffic. As was pointed out in the case of Cape Town Municipality v Bakkerud, the law expects the reasonable pedestrian to walk with care and keep a lookout. It does not impose the requirement that all pedestrian walkways be in good condition. However, the expectations of the community are that the road authority should maintain the walkways for reasonable use.

The best standard for frequency of walkway inspection is found in the UK. It proposes that for prestige areas and on primary walking routes the inspections be done monthly, secondary walkways every three months, link footways every six months and local access footways once per year.

6.11 Response times

> Safety inspections are designed to identify all defects likely to create danger or serious inconvenience to users of the network or the wider community. Such defects should include those that will require urgent attention (within 24 hours) as well as those where the locations and sizes are such that longer periods of response would be acceptable (Roads Liaison Group, 2012:110).

Response times to react to hazardous conditions are reported in the literature in terms of highway class and trigger values for the characteristic. Some manuals do not commit to specific response times.

The SANRAL Routine Road Maintenance Manual (SANRAL, 2009) refrains from stating response times but states that situations that may result in accidents be treated as priority and be dealt with first. These situations can be failed road surfaces, guardrails protruding onto the road and even external situations like veldt fires resulting in impeded visibility. Pavement defects such as rutting are acknowledged as having safety impacts, but are considered secondary issues. The manual refers to a risk assessment to determine the priorities for fixing the issues.

The UK approach to response times is based on a risk assessment that determines the response times. High-risk issues having a high impact and high probability of injury or short-term pavement structural deterioration are placed in Category 1 response. Category 1 defects should be made safe at the time of inspection or warnings should be erected immediately and the site made safe by protecting the public from encountering the hazard. Repairs of temporary or permanent nature must be executed within 24 hours and permanently fixed within 28 days. It is noted that some road authorities specify two hours response time for particularly high-risk instances. The rest of the defects are placed in Category 2 and should be fixed under planned maintenance. Table 6-2 shows the risk matrix (Roads Liaison Group, 2012).

Table 6- 2: Risk matrix

Probability → Impact ↓	**Very low (1)**	**Low (2)**	**Medium (3)**	**High (4)**
Negligible (1)	1	2	3	4
Low (2)	2	4	6	8
Noticeable (3)	3	6	9	12
High (4)		8	1	16
Response category	Category 2(L) response	Category 2(M) response	Category 2(H) response	Category 1 response

The Ontario Regulations for Municipal Maintenance as discussed in Chapter 2 (State of Ontario, 2015) gives response times per failure and road class. The example in Table 2-15 for potholes has different trigger values and response times, ranging from four days for Class 1 to 30 days for Class 5 roads.

Response codes ranging from A to F for defects in road characteristics are linked to response times ranging from four hours to six months in the Vicroads Road Management Plan (State of Victoria, 2014). Hazards and defects are grouped into categories of obstructions and substances in traffic lanes, pavement or surface defects and drainage. Trigger values are given for most of the pavement or surface defects.

It is proposed that response times for road safety-related maintenance features and characteristics for South African conditions should be simple for a start and form a base line for performance. The lack of capacity, sophistication and systems in provincial and small municipal road authorities must be borne in mind. These standards can be improved over time. Road authorities can establish shorter reaction times and differentiate between classes of road or risks if they have the capacity to do so. Table 6-3 shows the proposed response times for the selected features and categories.

Table 6- 3: Response times for road safety characteristics

Feature	Characteristics	Maintenance type	Response time within
Lane and surfaced shoulder	Texture	Planned, taking cognisance of rainy season	6 months or before start of rainy season
	Skid resistance	Planned, taking cognisance of rainy season	6 months or before start of rainy season
	Rutting and ponding	Planned, taking cognisance of rainy season	6 months or before start of rainy season
	Potholes and shoving	Reactive	One week
	Loose material	Reactive	2 days
Gravel shoulder	Edge drop-off	Routine	6 months
	Edge break	Routine	6 months
Road markings	Visibility	Planned	12 months
Road signs	Visibility and readability	Planned	12 months
	Missing signs	Reactive	One week
Side drains	Blockages	Planned	6 months or before start of rainy season
	Grid inlet cover	Reactive	One day
Cross drainage	Culvert openings	Planned	6 months or before start of rainy season
	Flow channel	Planned	6 months or before start of rainy season
Roadway	Flow path texture	Planned, taking cognisance of rainy season d	6 months or before start of rainy season
	Edge drainage	Routine	One week
Clear zone/ Recovery area	Designed width	Routine	One month
Barrier	Guardrail damage	Reactive	One day
	Guardrail terminals	Reactive	One day
	Bridge balustrade	Routine	6 months for permanent repairs, one day for temporary repairs
Vegetation	Highway trees	Planned	12 months
	Lines of sight	Routine	One week
Walkway surface	Pothole	Reactive	One day
	Level difference	Reactive	One week

Chapter 7: Cases

7.1 Introduction

The analysis of cases provides insight into how technical standards or procedures have been viewed by the courts as measures for the reasonableness of the conduct of road authorities and their contractors. Court judgments rarely contain much or adequate technical detail to assign values to the characteristics that were considered, but the descriptions can be interpreted in degrees of failure or inadequacy. The judgments often confirm the critical issues that the engineer must consider and for which the appropriate measures and metrics must be developed. These case studies dealt with inform this research on the most pressing and problematic issues in road maintenance for safety.

Four categories of South African cases were analysed:

- Decided cases in which the researcher was not involved;
- decided cases in which the researcher was involved;
- settled case in which the researcher was involved; and
- cases investigated by the researcher that were not yet completed.

The cases were analysed in tabular format to ease the interpretation of the important issues. Detail such as the road number, classification and location were noted to give the context of the accident. These details are known because of the researcher's involvement in the cases and knowledge of the South African road network. It is proposed that the detail will be helpful in visualising the road setting and general conditions.

The cases are presented in chronological order of the judgement date within the category types.

7.2 Decided cases in South Africa (not involved)

The cases discussed are:

- Administrator, Natal v Stanley Motors Ltd and Others 1960;
- Cape Town Municipality v Bakkerud 2000 3 SA 1049 SCA;
- Graham v Cape Metropolitan Council 1999 (3) SA 356 (C) (Appeal 2001);
- Minister of Transport v du Toit 2006 40 SA SCA;
- McIntosh v Premier, KwaZulu-Natal 2008 6 SA 1 SCA;
- Gerber v Premier van die Wes Kaap Provinsie Case 5634 (2006) [8 July 2009];
- Crafford v South African National Roads Agency Limited, (215/2012) [2013] ZASCA 8 [14 March 2013]; and
- Lauwrens v MEC PWRT Limpopo Province 74388 2010 [01 February 2013]

7.2.1 Administrator, Natal v Stanley Motors Ltd and Others 1960

This case was included for the principle that was established in 1960 that the road authority, through the duty of the engineer it employs, was responsible for considering conditions of the weather, however rare, in design. This principle can be extended to rare conditions resulting from maintenance and therefore the need for inspections to detect such conditions must be taken into account in maintenance procedures. The case is summarised in Table 7-1.

Table 7- 1: Administrator, Natal v Stanley Motors Ltd and others 1960

Description	The plaintiff drove south along the N2 with his wife and two children. The approach fill to a bridge over the Ndombe River was washed away as a result of rain; subsequent flooding and scour occurred along the river. The vehicle hit the north abutment. The wife died from injuries sustained in the accident.
Attributes investigated	Drainage. The need to inspect and asses the condition of the drainage channels (river and lagoon) and flood effects over time.
Road authority, route number and class	Natal Province. N2 (now R102). Rural Class 1
Maintenance arrangements	Provincial road maintenance
Location, date and time, conditions	South Coast Road (old National Road 2) 31st October, 1956, between 22:30 and 22:45, night, rain
Pleadings on legal duty and negligence	Legal duty to maintain the road was not disputed. The denial of negligence was founded on the rare and unforeseen events that occurred. Design assumptions were based on the adjacent railway bridge that has stood for 55 years.
Outcome, citation if available	The Natal Province was found negligent. The apportionment is not known. Administrator, Natal v Stanley Motors Ltd and Others 1960 (1) SA 690 (A)
Finding 1 Category Drainage	The danger of scour should have been identified as a risk. It was raised by the structural engineer during construction. The bridge was on a national road and of high importance. Although the bridge had been standing since 1941 and the railway bridge between it and the sea since 1901, the lagoon and sandbank were not static features in the environment and changes to the flow channel did occur due to shifting sand/soil resulting from flooding. The scour around the bridge piers and abutments should therefore have been monitored and protection provided.
Finding 2 Maintenance inspection	There was no evidence led on the maintenance inspections of the bridge foundations, although it was known from construction that the piles were installed short of the design depth.
Conclusions	This case is a seminal case where the duty of the engineer was spelt out to the effect that design should take into account all violence of weather, however rare. The design decisions to reduce the depth of piling and scour were taken despite apprehensions of the structural engineer. Where the design is made on a set of constraints or assumptions, it is incumbent on maintenance to ensure that the design conditions are preserved. If changes happen, mitigation measures must be put in place.

Figure 7- 1: Stanley: Location of bridge over river with lagoon and railway bridge

7.2.2 Cape Town Municipality v Bakkerud (2000 3 SA 1049 (SCA))

The case involving an elderly pedestrian was originally heard in the magistrate's court for an insignificant amount of R 750. The Cape Town Municipality appealed to the Western Cape High Court in order to affirm the so-called municipal immunity that then existed for omissions such as maintenance that was not done. A bench of four judges in the Western Cape High Court reviewed the principles involved in the light of the then new Constitution and changes in public policy and found for Mrs Bakkerud. The municipality appealed to the Supreme Court of Appeal in fear of the floodgates of claims that may open on local authorities. The Supreme Court of Appeal confirmed the ruling of the High Court. The case is summarised in Table 7-2.

Table 7- 2: Cape Town Municipality v Bakkerud 2000 3 SA 1049 SCA (29 May 2000)

Description	Mrs Bakkerud walked on a paved sidewalk along Mount Nelson Drive in Sea Point where she lived. Two potholes were present at a point where the walking space narrowed between a light pole and a wall. Although she admitted that these holes were known to her, she "must have been thinking about other things" and tripped. The matter was heard in the magistrate's court, appealed to the full bench and then the Supreme Court of Appeal. The case was important as it reviewed the so-called ''municipal cases'' that conferred immunity to municipalities for acts of omission.
Attributes investigated	The size and location of the potholes on the sidewalk were assessed. The maintenance inspection frequency was questioned.
Road authority, route number	City of Cape Town Municipality, no route number, arterial.

and class	
Maintenance arrangements	Municipal maintenance
Location, date and time	Mount Nelson Road, Sea Point. Date and Time unknown.
Pleadings, legal duty, negligence	In the court of first hearing, the CoCTM relied on the old municipal cases doctrine that they were not liable for acts of omission. In the appeals, legal duty was left for the court to decide. The CoCTM denied negligence as the sidewalk was not in its opinion unsafe and the pedestrian did not keep a proper lookout.
Outcome, citation if available	The plaintiff was awarded 100% of damages by the magistrate's court and on appeal. It was reduced to 50% in the SCA. Cape Town Municipality v Bakkerud 2000 (3) SA 1049 (SCA)
Finding 1 Road environment	Two holes of approximately 150 mm in diameter and 100 mm deep were located in the tarred sidewalk pavement. These holes were assessed as hazardous and caused the plaintiff to fall.
Finding 2 Maintenance procedures and reaction times	The holes existed for more than 6 months and were fixed within a few days of the claim being filed. The court found that the sidewalk carried high volumes of pedestrians and the fact that the holes were not repaired after such a lapse of time was negligent.
Conclusions	This case led to the demise of immunity that municipalities enjoyed from claims based on omissions. It established a set of considerations for legal duty as well as wrongfulness (blameworthiness) that would prevent a blanket imposition upon municipalities generally of a legal duty to repair roads and pavements.

The following quotations highlight some of the important facets of the judgment:

> [4] Writing for the court *a quo,* Brand J opined that the relative immunity conferred upon local authorities in what have come to be known as "the municipality cases" in this court was inconsistent with the current "legal convictions of the community" which require "municipalities to keep streets and pavements in a safe condition". Having characterised failure to do so as wrongful, the learned judge proceeded to consider whether the failure was attended by fault *(culpa)* and concluded that it was.
>
> [5] He acknowledged that, in considering whether or not fault could be attributed to a municipality, account would have to be taken of all factors, including financial constraints, which have a bearing upon the reasonableness or otherwise of the omission. His conclusion was expressed thus:
>
>> It follows from the aforesaid legal principles that appellant's failure to repair the holes constitutes an unlawful act of omission. The only question is therefore whether appellant was negligent. The uncontested evidence of respondent was that the holes in question had been there for at least six months prior to the accident. The fact that the holes were repaired within two days after the accident, justifies the inference that such repairs did not impose an undue burden on appellant. In the absence of any explanation why the repairs to the pavement were not affected much earlier, I cannot criticise the learned magistrate's finding that the appellant was negligent.
>>
>> *33 Per contra*, it would, I think, be going too far to impose a legal duty upon all municipalities to maintain a billiard table-like surface upon all pavements, free of any subsidences or other irregularities which might cause an unwary pedestrian to stumble and possibly fall. It will be for a plaintiff to place before the court in any given case sufficient evidence to enable it to conclude that a legal duty to repair or to warn should be held to have existed. It will also be for a plaintiff to prove that the failure to repair or to warn was blameworthy (attributable to *culpa*). It is so that some (but not all) of the factors relevant to

> the first enquiry will also be relevant to the second enquiry (if it be reached), but that does not mean that they must be excluded from the first enquiry. Having to discharge the onus of proving both the existence of the legal duty and blameworthiness in failing to fulfil it will, I think, go a long way to prevent the opening of the floodgates to claims of this type of which municipalities are so fearful.

No illustrations are available.

7.2.3 Graham v Cape Metropolitan Council 1999 (Appeal 2001)

Appeal: Cape Metropolitan Council v Graham 2001 (1) SA 1197 SCA

Both the Western Cape High Court and the Supreme Court of Appeal judgments were used to compile the summary in Table 7-3. This case was, similarly and parallel to the Bakkerud case, pursued by the municipality right to the Supreme Court of Appeal to try and retain the old municipal immunity for omissions.

Table 7- 3: Graham v Cape Metropolitan Council 1999

Description	A rock fell on the vehicle of the plaintiff while driving on a mountain pass, rendering the driver paralysed. Rock falls were known to occur especially after fires that reduced the binding effects of vegetation and rain.
Attributes investigated	Maintenance of road reserve and monitoring of adjacent property for hazards. Duty to close a road when conditions are hazardous. Warning signs.
Road authority, route number and class	City of Cape Town Metropolitan Municipality. Chapman's Peak Drive, Municipal route number M6, Rural Class 2.
Maintenance arrangements	Municipal maintenance.
Location, date and time	Chapman's Peak Drive between Noordhoek and Hout Bay, Sunday, 26 June 1994, at approximately 16:00/16:30.
Pleadings, legal duty, negligence	Legal duty was not in dispute. The CTMM denied negligence as the pass was not in its opinion unsafe.
Outcome, citation if available	The plaintiff was awarded 100% of damages. Graham v Cape Metropolitan Council 1999 (3) SA 356 (C) Cape Metropolitan Council v Graham 2001 (1) SA 1197 SCA
Finding 1 Road environment	As soon as an unusually high risk of slope failures is reasonably deducible in consequence of higher than average rainfall, the road should be closed to traffic.
Finding 2 Maintenance procedures and reaction times	If the defendant did not know this timeously, its ignorance would have been due to its failure to monitor local weather conditions from readily available reports and forecasts during the week and weekend before the accident happened.
Finding 3 Signage	The risk of slope failure in the form of rock and earth slides is considerably increased by moisture saturation during very rainy weather conditions. For this reason there should be special and effective warning signs at both entrances of the road apart from the commonplace and familiar W22 "Falling Rocks" signs.
Conclusions	This case imposed requirements for the roads authority to monitor the road and weather systems to assess risk for the motorists. Where the risk becomes high, the road must be closed. Effective warning that is in relation to the threat must be provided.

Figure 7- 2: Graham: Chapman's Peak Drive rock fall (for illustration only)

Photo: Louis Melis

7.2.4 Minister of Transport v du Toit [2006] SCA 40 (RSA)

The case is of great interest with respect to road sign maintenance and driver behaviour. Although the plaintiff was awarded only 20% (negligence on the part of the road authority), it needs to be seen against the award of 100% of damages suffered by the passenger, who had no contributory negligence. The case as summarised in Table 7-4 highlights the maintenance issues, but the judgment contained a statement that a driver cannot be expected to see each and every sign along a road section with many signs, such as on this off-ramp immediately after a toll plaza.

Table 7- 4: Minister of Transport v du Toit [2006] SCA 40 (RSA)

Description	The driver mistakenly left the N1 freeway at the Grasmere toll plaza and drove through a T intersection at the end of off-ramp due to inadequate road signs. The plaintiff was the wife of the driver of the vehicle. She was seriously injured.
Attributes investigated	Signage and maintenance procedures
Road authority, route number and class	SANRAL. (Toll concessionaire Tolcon was cited as third party), N1-19, Rural Class 1 freeway. The defendant was the Minister of Transport.
Maintenance arrangements	The toll concessionaire was responsible for all maintenance. Response times are specified in the RRMM. However, the problems were not identified.

Location, date and time	N1-19 off -amp to the R557 at Grasmere toll plaza, south of Johannesburg. 27 September 1995, late in the evening.
Pleadings, legal duty, negligence	The Minister of Transport accepted that it owed users of the road a legal duty to act without negligence in relation to road signs and other such facilities. The claim was opposed based on the assertion that the driver failed to drive as expected of a reasonably competent and cautious driver.
Outcome, citation	The road authority was found 20% negligent for the inadequate signs. Minister of Transport v du Toit [2006] SCA 40 (RSA)
Finding 1 Signs	The T-junction was a potential source of danger for motorists on the off-ramp, particularly at night, as they would come across it shortly after having emerged from an illuminated area and proceeded into an unlit stretch of the road. The T intersection chevron was inappropriately positioned. The sign was not properly aligned with the off-ramp. The probabilities were overwhelming that had the T intersection chevron been properly aligned with the off-ramp so that the plaintiff's husband would have found himself driving directly at it, he would have been alerted to the danger and would have reacted accordingly.
Finding 2 Maintenance procedures and reaction times	The stop sign itself was in a poor condition with its reflective paint badly faded and in places worn off entirely.
Finding 3 Maintenance duties	The placement of a chevron at a T-junction is normally designed as in line with the approach. Notwithstanding, these signs are vulnerable and often hit. Maintenance supervisors often then shift the sign sideways to allow an errant driver to drive past the sign. The misalignment of the chevron and directional information sign opposite the ramp was interpreted by the researcher as such an action. The maintenance contractor should not move signs without authorisation and reflection on its purpose. They should further evaluate the location of signs after opening the road to ensure safe operations. See further remarks on state of signs in 2010 below.
Conclusions	The faded stop sign indicated lack of inspection and response to fix out of specification signs.

Scott JA made very important observations with regards to the reasonable driver's behaviour and the assumption that all signs erected will be seen. It is quoted below for its impact on maintenance and the duty to evaluate signage under operational conditions. Care must be taken not to overfeed information, leading to shedding of information as the load exceeds the driver's processing capacity.

> 'On behalf of both appellants it was contended, however, that whether in any particular circumstances the steps taken by the first appellant were reasonable or not had to be determined with reference to the manner of driving of 'a reasonably competent and cautious driver'. If by this is meant that the authority responsible for erecting road signs and other warnings is entitled to assume that a driver will read and, if necessary, react to every sign regardless of its nature, size and positioning, I cannot agree. A driver of a motor vehicle is obliged to maintain a proper look-out. He (or she) must pay attention to what is happening around him; but most important of all, he must as far as possible keep his eyes on the road, particularly at night when his vision is limited. Depending on the state of the traffic, the nature of the road and the speed at which he is travelling, the opportunity which a motorist has to read and comprehend the import of each sign may be extremely limited. Indeed, it is not uncommon for even a competent and cautious driver to misread or fail to react to a road sign. For this reason it is imperative, particularly in unlit areas, for warning and

other signs to be clear, unambiguous and appropriately positioned so that if necessary they may be read and comprehended at a glance.

Figure 7- 3: du Toit: Location of freeway off ramp at Grassmere

Figure 7- 4: du Toit: STOP sign right obscured by No-Entry sign

Note: No STOP sign of left-hand side of right-turn lane

Figure 7- 5: du Toit: Hazard markers W401 and W402 missing on splitter island

7.2.5 McIntosh v Premier, KwaZulu-Natal 2008 6 SA 1 (SCA)

The McIntosh case is, in addition to the maintenance aspects, interesting from the fact that the cyclist did not hit (drove through) the pothole, but lost control in evading the pothole. The judge also rejected the province's defence that there was insufficient funding, as they were busy repairing the road at that stage. The summary in Table 7-5 focuses on the maintenance issues. A reading of the full judgments of the KwaZulu-Natal High Court and the Supreme Court of Appeal also illustrate the need for proper record keeping.

Table 7- 5: McIntosh v Premier, KwaZulu-Natal 2008

Description	The plaintiff went cycling with a group on a steep climb from Kamberg, Kwa-Zulu Natal. He sustained serious injuries when he fell from his bicycle while swerving to avoid a large pothole.
Attributes investigated	Pothole 400 mm wide by 750 mm long by 75 mm deep, warning signs
Road authority, route number and class	Province of Kwazulu-Natal, P164, Rural Class 3 two -lane single carriageway
Maintenance arrangements	Provincial road maintenance teams
Location, date and time	21 August 2004, time unknown
Pleadings, legal duty,	Legal duty admitted. Negligence denied: cyclist did not ride on the left-hand side of the road

negligence	
Outcome, citation	Plaintiff was awarded 60% of his damages om appeal. McIntosh v Premier, KwaZulu-Natal (632/07) [2008] ZASCA 62 (29 May 2008)
Finding 1 potholes	During this period it had been allowed to develop to a stage where it had attained the dimensions of a degree 3 (KZN) or degree 5 (CSRA, 1992) pothole depending on which code was applied.
Finding 2 Maintenance procedures and reaction times	It was common cause that the P164 was the subject of weekly routine inspections. The evidence revealed that the pothole in question had been in existence for more or less a year prior to the accident. No explanation was forthcoming as to why, notwithstanding the weekly inspections, it was not repaired.
Conclusions	The size of the pothole was deemed to make it a hazard in the road. It is interesting that the plaintiff did not actually ride through the pothole, but swerved to avoid it and lost traction in the process.

In the High Court KZNPD, Pietermaritzburg, Kruger J found that the plaintiff did not ride on the left-hand side of the road as required in the road traffic regulations and did not keep a proper lookout. The claim was dismissed.

The matter was taken on appeal where the road authority was found 60% liable.

The road was repaired in 2004 after the accident. In 2010 the road again showed potholes in the curve where the accident happened.

Figure 7- 6: McIntosh: 2010 Google Streetview of curve where accident happened

Figure 7- 7: McIntosh: Location of accident

7.2.6 Gerber v Premier van die Wes Kaap Provinsie Case 5634 (2006) [8 July 2009]

Although Gerber lost the case against the Western Cape Province, the facts of the matter such as the height of the shrubbery in the median point to hazardous conditions that could have been avoided. The summary in Table 7-6 does not elaborate on the issue of the driver having to keep a proper lookout, which was the crux of the judgement.

Table 7- 6: Gerber v Premier van die Wes Kaap Provinsie Case 5634 (2006) [8 July 2009]

Description	Gerber was riding his motorcycle on the N7 freeway southbound, south of Plattekloof Interchange at about 17:00 on 2 May 2004 when a pedestrian walked in front of the vehicle from the median. The shrubs in the median were claimed to have been more than 4 m high and hanging over the roadway. The rider did not see the pedestrian till too late to swerve or brake. The vehicle collided with and killed the pedestrian. The rider fell and was paralysed.
Attributes investigated	Maintenance of vegetation in the road reserve
Road authority, route number and class	Provincial Government Western Cape Department of Roads and Transport N7, Class 1 (Freeway)
Maintenance arrangements	Provincial maintenance teams
Location, date and time	N7 between Plattekloof and Montague Gardens interchanges 2 May 2004 17:00

Pleadings, legal duty, negligence	Legal duty to maintain the road was not in dispute. The PGWC denied that the overgrown vegetation was a cause in the accident.
Outcome, citation if available	The case was dismissed due to lack of causality. Gerber v Premier van die Wes Kaap Provinsie Case 5634 (2006) [8 July 2009] Unreported.
Finding 1 Road environment: Vegetation	The vegetation on the median of the freeway was allegedly in excess of 2 m high and encroached onto the roadway across the white-edge line. The purpose of vegetation on a median was listed by the Department's expert witness as preventing glare from vehicle lights in opposing flows at night, preventing U turns, acting as a buffer and landscaping. The finding was made that the pedestrian would have had sufficient opportunity to observe vehicles from the overgrown shrubs.
Finding 2 Maintenance procedures and reaction times	The expert witness of the Department claimed that the shrubs were trimmed to not encroach over the roadway, but no specification exists with respect to height and width. (Since the accident, the shrubs are kept to a height and the width less than 1 m.)
Conclusions	Arguments in this case involved the presence of pedestrians and persons sleeping in the shrubs. This clouded the issue that lies at the base of maintenance, which is that if the shrubs were trimmed to less than 1 m high, the primary function of preventing glare could still be fulfilled while illegal pedestrians could then be visible in the median.

Figure 7- 8: Gerber: Location plan

Figure 7- 9: Gerber: View of shrubs in median in 2014

7.2.7 Crafford v South African National Roads Agency Limited, (215/2012) [2013] ZASCA 8 [14 March 2013]

Although the plaintiff lost the case on the fact that it could not be proven where the kudu came from, the hazardous nature of tall grass in the road reserve as summarised in Table 7-7 must be noted by rural road authorities.

Table 7- 7: Crafford v South African National Roads Agency Limited, (215/2012) [2013] ZASCA 8 [14 March 2013]

Description	The plaintiff drove on route R510 from Thabazimbi in the direction of Ellisras (Lephalale) at night. The surrounding land use is game farms. The road reserve was not mowed for at least 15 months and long grass was growing right up to the road edge. The plaintiff's vehicle hit a kudu that entered the vehicle shattering the front window. The plaintiff was seriously injured.
Attributes investigated	Maintenance of grass in road reserve
Road authority, route number and class	SANRAL, route R510, Rural Class 2
Maintenance arrangements	Routine route maintenance contractor
Location, date and time	Route R510 between Thabazimbi and Ellisras. Friday 13 January 2006, night
Pleadings, legal duty, negligence	SANRAL accepted legal duty to maintain the road. It claimed that there was no factual causation as it could not be established that the kudu would have been visible if the grass had been cut, as it could have been moving to cross the road.

Outcome, citation if available, citation if available	The claim was dismissed with cost. The most appropriate paragraph from the judgement is quoted for its importance. '*'Without knowing where the kudu came from, how it moved, the manner in which it came to be in the road, and where it and the appellant's motor vehicle were in relation to each other at any material time, it is really impossible to determine solely from the fact of a collision where the kudu would have been and at what stage it would have become visible to an approaching motorist, irrespective of the length of the grass alongside the road. In my view there are thus insufficient objective facts from which it can be inferred that if the grass alongside the road had been kept short the appellant would have seen the kudu earlier than he did, let alone that on seeing it he would have had sufficient time and space to have reacted and slowed his vehicle sufficiently to avoid a collision*. Brand JJA Crafford v South African National Roads Agency Limited, (215/2012) [2013] ZASCA 8 (14 March 2013)
Finding 1 Grass verge	The claim was dismissed on the lack of factual causation. It was not disputed that the road authority had the duty to ensure safe driving conditions and that tall grass, if it was found that the kudu could have been seen if it was short, would have constituted a hazard that the reasonable road authority would have mitigated. This is borne out by the appointment of a RRM contractor with specifications to keep the grass short.
Finding 2 Maintenance procedures and reaction times	The accident happened shortly after a RRM contractor was appointed on this route following SANRAL taking over the road from the Limpopo Province. The mowing had started but had not reached the accident location. Subsequently the grass had not been mowed to specification, as seen in the Google Streetview image in the figure below.
Conclusions	The maintenance of grass in road reserves in areas where there is a substantive risk of wild animals, especially kudu, is acknowledged by SANRAL as the national road authority. The implementation of such maintenance in view of prioritisation of maintenance in relation to the road class will depend on the facts of each case, but may not necessarily be extrapolated to all rural road authorities. In view of the labour-intensive nature of road reserve maintenance and the EPWP that subsidises such projects, there may be an imperative to ensure that grass be kept short where the need is identified or could have been identified. The difficulty of proving legal causation in this case may be addressed in the future with technology such as dashcams. Road authorities should define appropriate standards for maintenance of grass in the road reserve.

Figure 7- 10: Crafford: Condition of route R501 road reserve in 2010 Google Streetview

7.2.8 Lauwrens v MEC PWRT Limpopo Province 74388 2010 [1 February 2013]

Table 7-8 summarises the maintenance aspects of this case. The judgement was for the road authority and based on the driver not heeding the signs, despite the signs not being placed in accordance with guidelines. The depth of the subsidence at the bridge was in dispute as photographic evidence was not captured. The history of the subsidence is, however, worrying. It was clear that the failure was repaired repeatedly without fixing the root cause.

Table 7- 8: Lauwrens v MEC PWRT Limpopo Province 74388 2010 [01 February 2013]

Description	The Lauwrens family was travelling on route R518 when the driver lost control when crossing a depression in the road at the Rooisloot Bridge. The vehicle veered to the right and was involved in a head-on collision with a bakkie. The subsidence resulted from compaction of approach fill material next to the bridge. Warning signs of uneven road (634 m) and drift (296 m) were located before the bridge.
Attributes investigated	Subsidence and warning signs.
Road authority, route no, class	Limpopo Department, route R 518, rural Class 2.
Maintenance arrangements	Provincial maintenance section
Location, date	On route R518 at Rooisloot Bridge between Mokopane and Zebediela in Limpopo

and time	Province, 13 December 2008 10:00, clear conditions.
Pleadings, legal duty, negligence	Legal duty was not in dispute. See the summary by Ranchod J on the legal duty below. The defendant pleaded that the driver drove to fast, that the warning signs were adequate and no other vehicles had been involved in accidents before.
Outcome, citation if available	The case was dismissed on the ground that the driver did not heed to the warning signs. The judge gave weight to the argument that no accidents had previously been reported. Lauwrens v MEC PWRT Limpopo Province 74388 2010 [01 February 2013]
Finding 1 Road environment	The nature and extent of the depression was that it accelerated the vehicle upwards (bumped). The depth was estimated between 50 and 100 mm.
Finding 2 Maintenance procedures and reaction times	The depression had been fixed before and was a known problem on the road. The planning was to have it properly repaired by an outside contractor. The defendant claimed that the reaction time was adequate as the depression was monitored and not hazardous yet.
Finding 3 signage	The one sign, marked W331, warning of an uneven road ahead, was located 634 m from the hazard when, in terms of the South African Road Traffic Manual it should have been located 240 m from the hazard if the speed limit was 100 km/h on that road. The second sign, warning of a drift ahead, was located 296 m away from the bridge while it should have also been placed 240 m away in order to be able to communicate a proper message of a hazard ahead to a road user.
Conclusions	The depression in excess of 50 mm was hazardous to this road user. The causality test (but for) was not properly discussed. The issue of credibility of signs was not argued adequately by die plaintiff's advocate and the judge ruled rigidly that the driver had not heeded the signs. The argument of all preceding traffic not having experienced problems was flawed: there is always a first one. The defendant had constructive notice of the problem and could have foreseen that it was hazardous.

Ranchod J gave a good summary of the road authority's duties:

- [7] The following appears to be common cause:
- 7.1 The defendant admitted that he had a duty of care and maintenance responsibility regarding the R518 road between Mokopane and Zebediela;
- 7.2 the defendant admitted that his maintenance functions included the regular and proper inspection of the road including the driving surface of the road and the road pavement, in order to evaluate the condition thereof;
- 7.3 the defendant admitted that he had the duty to perform regular and appropriate maintenance of the road in order to ensure that the road driving surface and the road pavement was safe for use by the public;
- 7.4 the defendant admitted that he had to take reasonable steps to ensure that the driving surface of the road pavement did not degrade to a level where it might pose a danger for the reasonable user of the road; and
- 7.5 the defendant admitted that he had to take reasonable steps to ensure that undulations, cracks and bumps in the road pavement do not develop on the driving surface of the road and should such undulations, cracks and bumps develop, that reasonable steps were taken to maintain and rectify them.

The defendant also pleaded that its maintenance responsibility for the road was subject to its available financial and human resources.

Figure 7- 11: Lauwrens: Bridge with patches on approaches

Figure 7- 12: Lauwrens: Repairs to bridge approaches in 2010

Note the inadequate bridge balustrades and lack of tie-in or continuity of the guardrails.

7.3 Cases decided (involved)

The following cases were investigated by the researcher and went to trial.

- Botha v MEC Eastern Cape Province 2447/2008 2013 [4 August 2014];
- Schultz v MEC PWRT Gauteng Province 4905 2010 [19 August 2014];
- Matshoge v Premier NWP and others 279 (2012) [12 December 2014]; and
- Devonport v Premier Free State Province A216 2008 [26 November 2009]

7.3.1 Botha v MEC Eastern Cape Province 2447/2008 [2013] [14 August 2014]

The case summarised in Table 7-9 involved more aspects than those with respect to maintenance. The handling of emergencies resulting from natural catastrophes involving cooperation between organs of state was also an issue. The discussion focuses on maintenance issues.

Table 7- 9: Botha v MEC Eastern Cape Province 2447/2008 [2013] [14 August 2014]

Description	A tree growing on adjoining municipal property fell on the road during cyclonic conditions in the Langkloof Valley, near Joubertina, Eastern Cape Province. A tree had fallen on the road earlier in the day at Louterwater, close by. Branches of the tree had been cut, but work had been halted. Later in the night, a vehicle driving from the east towards Joubertina drove into the tree in the rain. The driver was killed.
Attributes investigated	Maintenance of highway trees, warning of short-term hazardous conditions
Road authority, route number and class	Eastern Cape Department of Public Works, Roads and Transport, route R62, rural Class 2.
Maintenance arrangements	Provincial maintenance section
Location, date and time	East of Joubertina, Eastern Cape Province. 2 August 2006 after 23:00. Night, heavy rain and high wind.
Pleadings, legal duty, negligence	The defendant denied legal duty for trees outside the road reserve. In view of the cyclonic conditions, they pleaded that the tree fell due to an ‘’Act of God”.
Outcome, citation	The plaintiff was awarded 100% of the claim. Botha v MEC Eastern Cape Province 2447/2008 [2013] 14.8.2014
Finding 1 Road environment	Trees that can fall on the road must be removed.
Finding 2 Maintenance procedures and reaction times	The maintenance teams regularly removed trees and vegetation when identified as unsafe or obstruction sight lines. They attended to a tree that fell on the road at Louterwater on that day and could have foreseen that other tress could fall. The road could have been closed, as it was done under instruction of the SAPS after the accident.
Finding 3 Signage	Warning could have been put up to warn of hazardous conditions
Conclusions	The case is ground-breaking for South Africa in terms of the recognition of highway trees as being any tree that can affect traffic on the road.

The following quotation sums up the core of the judgment:

> [28] They all had the knowledge of the dangers caused by the tree which fell on the road. It is for the same reason that both *Gamedi* and *Silumko* told the Court that on

many occasions during their employment they would go and remove trees that were next to the road. To me it does not matter whether the tree is within the road reserve or in the premises of another person. If the tree is situated within the premises of another person's property the fact of the matter is that if it has the potential to fall on the road and thus may injure or even kill the road users it has to be removed and that is the duty of the Department of Public Works and Roads. The officials of the respondent's department have a duty to approach the owner of such tree and request him to have the tree removed. There has not been any evidence to the effect that defendant's employees had made any attempt in that regard. The manner in which, on 2 August 2006, the rain was pouring necessitated immediate inspection of the road whether at night or during daylight. Their failure to close the road amounted to neglect of their duties which cannot be condoned.

Figure 7- 13: Botha: Location of accident near Joubertina

Figure 7- 14: Botha: Highway trees similar to the tree that fell on the road

7.3.2 Schultz v MEC PWRT Gauteng Province 4905 2010 [19 August 2014]

Since this case came to the attention of the researcher in 2011, the site has been visited at regular intervals. The traffic signs are still getting run over and no remedial measures are taken despite bringing the need under the attention of the road authority. Table 7-10 focuses on the maintenance issues discussed in court. The root cause of the problem, the inadequate design of the S-curve, is not being addressed.

Table 7- 10: Schultz v MEC PWRT Gauteng Province 4905 2010 [19 August 2014

Description	The plaintiff drove his car through an S-curve that was constructed where a four-lane single carriageway split into a dual carriageway road. Only one of the road traffic signs designed was in place and the road markings were faded. The driver misjudged the curve; drove into the median, over the left carriageway and hit a wall. The passenger died.
Attributes investigated	Signage, inspections
Road authority, route number and class	Gauteng Department of Public works, Roads and Transport. Route R101 (P1-2), rural / urban Class 2.
Maintenance arrangements	Departmental maintenance section.
Location, date and time	On route R101 north of N14 bridge, 11 July 2009, approximately 02:00.

Pleadings, legal duty, negligence	The defendant admitted legal duty to maintain the road, inspect and ensure that the necessary signs are installed and maintained. Negligence on the part of the driver was pleaded.
Outcome, citation	The plaintiff was awarded 40% of his claim. Schultz v MEC PWRT Gauteng Province 4905 2010 [19 August 2014]
Finding 1 Road environment	The S-curve constituted a dangerous alignment and drivers have to be warned of the alignment to follow.
Finding 2 Maintenance procedures and reaction times	The defendant failed to show in court that regular inspections were done. The evidence of Campbell for the defendant was that she travelled the road daily, which she later retracted. Her evidence was criticised by the judge: in his view she demonstrated a certain degree of bias that not only affected the reliability of her evidence, but also her credibility. No regulated reaction times were demonstrated.
Finding 3 Signage	The defendant had an obligation to inspect, maintain and replace signs and markings. It was found that at least on three occasions only one sign remained.
Conclusions	The case demonstrated the need for regular inspections, commensurate with the road class and traffic volumes. No records of inspections or replacement of signs were submitted. The regularity with which signs are hit should have led to remedial action as it indicated a systemic problem, which the maintenance teams should pick up and report on.

Fourie J summarised the legal duty as follows:

> A reasonable person would not only have foreseen this danger, but would also have guarded against it by putting up adequate signage, properly marking the verge of the road and maintaining the painted island. There is no evidence that it was not possible for the employees of the first defendant to have done so. It should therefore be inferred that these employees either did not frequently inspect the road, or, if inspections were held, they simply ignored the dangerous situation.

Figure 7- 15: Schultz: Single to dual carriageway on R101, Centurion, Tshwane

Figure 7- 16: Schultz: Signs at time of accident

The poor quality of image is due to it being scanned from the court file

Figure 7- 17: Schultz: Signage as reinstated 2011

Figure 7- 18: Schultz: Signs 2015

7.3.3 Matshoge v Premier NWP and others 279 (2012) [12 December 2014]

This case was interesting because the road condition where the accident took place is representative of a large proportion of rural roads in the North West Province. As the summary in Table 7-11 discusses maintenance issues, the institutional issues of the road department raised in the case were not included. These issues include that the roads budget for the financial year in question was spent in three months due to contractual obligations of the previous financial year.

Table 7- 11: Matshoge v Premier NWP and others 279 (2012) [12 December 2014]

Description	The plaintiff and her family drove along the road between Legonyane Village and Jericho, North West Province. The road was in a poor condition with potholes that she tried to avoid by driving on the right-hand side when there was no opposing traffic. As traffic approached, she steered back to the left-hand side and drove through a pothole that caused a tyre to burst. She lost control, veered off the road and hit a tree. She was paralysed.
Attributes investigated	Potholes and warning signs.
Road authority, route number and class	North West Province Department of Public Works, Roads and Transport. Unknown route number. Rural Class 4.
Maintenance arrangements	Provincial maintenance teams
Location, date and time	South of Legonyane village, 27 April 2009 in daylight conditions.

Pleadings, legal duty, negligence	The defendants pleaded that the road was safe despite having potholes and had no duty to warn of danger. They pleaded that the plaintiff was negligent for driving too fast.
Outcome, citation if available	The defendants were held to have been negligent and the plaintiff was awarded 100% of her claim. Matshoge v Premier NWP and others 279 (2012) [12 December 2014]
Finding 1 Road environment	The potholes on the road were all of Degree 5 severity and dangerous. The judge ruled that any of the potholes could have caused the damage to the tyres that lead to loss of control.
Finding 2 Maintenance procedures, reaction times	The defendant did not offer any evidence on the systems or procedures to inspect and monitor the road conditions, or prioritise maintenance. The extent of potholes indicated that there is no reaction time to repair failures.
Finding 3 Signage	The defendant maintained that the road was safe and thus did not need warning signs. This reasoning was clearly unrelated to the realities of the condition of the road.
Conclusions	This case established that where rural roads are allowed to deteriorate beyond routine maintenance, leading to hazardous conditions, the lack of action to preserve safety is negligent.

Kgoele J summarised the requirement of a road authority to prioritise maintenance:

> According to the experts of the plaintiff, the repair of potholes was a priority, both with regard to the safety of road users and the preservation of the structural integrity of the road. No evidence was led by the defendants to establish that by reason of the lack of funds the repair of potholes was neglected in favour of some other priority. Nor was there evidence to suggest the existence of a policy to select some potholes for repairs ahead of others and if so, the basis upon which such a selection was made. The inference of negligence on the part of the servants of the Department responsible for the inspection and repairs of potholes on this road is irresistible.

Figure 7- 19: Matshoge: Potholes at time of accident

Figure 7- 20: Matshoge: Potholes at time of site visit

7.3.4 Devonport v Premier Free State Province A216 2008 [26 November 2009]

The Devonport case was initially dismissed with cost in the Free State High Court. On appeal the Supreme Court of Appeal found 60% negligence on the part of the road authority. One of the aspects that the SCA ruled on is the absence of expert witness testimony for the defendant in the lower court. The SCA took the expert witness testimony for the plaintiff into account to find that the condition of the road was hazardous. This confirms that the court takes guidance on technical matters from experts, who are presumed to be officers of the court and not biased towards the party paying for their services. Table 7-12 highlights the maintenance issues.

Table 7- 12: Devonport v Premier Free State Province A216 2008 [26 November 2009]

Description	Devonport and friends cycled from Fouriesburg to Ficksburg in a social tour group. He rode on the left of a friend, between the road edge and the wheel track. He struck a protrusion resulting from shoving of material from the failed layers in the wheel path to the side at a relatively high speed. The protrusion was not easily visible due to its colour and rounded shape. He catapulted over the handlebars and hit the road with his face and head. He suffered brain damage and life support was later terminated.
Attributes investigated	Shoving and warning signs
Road authority, route number and class	Free State Department of Public Works, Road and Transport, route R26, rural Class 2.
Maintenance arrangements	Provincial maintenance
Location, date and time	Near Fouriesburg, Free State Province, on route R 26 toward Ficksburg, 24 September 2005, approximately 10:00.
Pleadings, legal duty, negligence	The province pleaded that the protrusion (shoving) was obvious and road users keeping a proper lookout could avoid the danger. It did not deny legal duty to repair the road if it was dangerous. The rider was primarily negligent.
Outcome, citation if available	The province was found to be 60% negligent. Devonport v Premier Free State Province A216 2008 26 November 2009
Finding 1 Road environment	The protrusion (shoving) exceeded 30 mm height and was dangerous. The danger was foreseeable and could be repaired with little cost or inconvenience.
Finding 2 Signage	Signs should have been erected to warn of the road condition.
Conclusions	The extent of shoving exceeded 30 mm and the shape was rounded. This posed a danger to the cyclists as legitimate road user and was not visible due to the colour and shape blending in with the road. On the defendant's argument that the danger was obvious, van der Merwe J remarked: ''*The logical conclusion of this argument is that the bigger the danger in a road, the more it would or should be apparent and therefore the less need to repair or warn against it. Once a hazard is recognised by a public authority such as the province in these circumstances, it cannot in my judgment be heard to say that injury was not reasonably foreseeable simply because the danger should be apparent to road users*.''

Figure 7- 21: Devonport: Shoving that caused accident

Figure 7- 22: Devonport: Surface failure at location of accident observed on site visit

7.4 Cases settled (involved)

The following cases were investigated by the researcher and expert witness reports were filed. The cases were settled before the trial started. The reasons for settlement are not known as the conditions of settlement often include a confidentiality clause. The technical aspects are, however, of importance, as these would form the basis of the merits of the case.

- Herbst v SANRAL, Roadmac and SSI roadmarkings;
- Mothlapudi v SANRAL and Rainbow Cleaners CC open grid inlet;
- Madonsela v SANRAL pothole;
- Maritz v City Tswane MM pothole;
- Zentgraff v Premier Gauteng Province guardrail;
- Boshoff v Bombela and others guardrail; and
- le Roux v Premier NW Province pothole.

7.4.1 Herbst v SANRAL and others

This case resulted from road markings not completed after resealing the road. Table 7-13 summarises the aspects related to maintenance of signage during construction.

Table 7- 13: Herbst v SANRAL Roadmac and SSI

Description	Herbst was driving in the night towards Mokopane, Limpopo Province, on a section of national road undergoing periodic maintenance. The road surface was resealed and all road markings obliterated. The road cross section is known as a 2+1 lane combination, where the two lanes alternate at distances of up to 5 km to allow passing opportunities to alternate. The accident happened at the end of a section where the additional lane was added to the left of the old two-lane roadway, resulting in a lane drop. In the absence of guidance by means of road markings or delineators in the place of the normal tapered island, he was late in steering back towards the continuous lane and hit a pothole that formed at the end of the additional lane. He swerved to the right and spun out, hitting a telephone pole. He was severely injured.
Attributes investigated	Absence of road markings and temporary guidance during maintenance. Pothole at change of cross section.
Road authority, route number and class	SANRAL, Route R101, road N11-25X, Rural Class 2.
Maintenance arrangements	Routine road maintenance (RRM) contractor that looked after the shoulders where the pothole developed. The contractor for the resealing was responsible for the roadway only.
Location, date and time	2 km before Mokopane, Limpopo Province. 23 November 2009 in the night.
Pleadings, legal duty, negligence	The defendant admitted a legal duty but maintained that the road signage consisting of guidance signs and delineators at the end of the lane drop was sufficient.
Outcome	A confidential settlement was reached.
Finding 1 Road environment	The permanent taper to guide drivers from the left-hand lane of the two northbound lane road sections takes place over 200 m. During the resealing, no substitution guidance was given, such as a row of delineators. The delineators at the end of the lane drop were insufficient guidance, as the edge of the continuing lane was not

	indicated. The pothole in the corner of the roadways was evidence of many vehicles clipping the gravel shoulder as they moved back to the through-lane too late. The RRM contractor did not fix the pothole, which was substantial and caused loss of control.
Finding 2 Maintenance procedures, reaction times	The RRM contractor should have fixed the pothole.
Finding 3 Signage	When maintenance work is being executed, the traffic control by means of signs and markings should be at a higher level as normal due to unexpected situations. The painted island taper should have been replicated by means of delineators.
Conclusions	Maintenance procedures such as resealing can result in dangerous conditions. The road authority should ensure a higher level of traffic control during the construction period as conditions change continuously.

Figure 7- 23: Herbst: Lane drop with no marking after resealing

Figure 7- 24: Lane drop with road markings at night

Figure 7- 25: Herbst: Pothole at end of lane

Figure 7- 26: Herbst: Taper island over 200 m at lane drop

7.4.2 Mothlapudi v SANRAL and others

Table 7-14 summarises the maintenance aspects of this case, which are not just the missing grid inlet, but also the proper execution of maintenance inspections.

Table 7- 14: Mothlapudi v SANRAL and others

Description	Mothlapudi was travelling on a left-hand curved loop off-ramp from the N1-1 to route R101 near Paarl, Western Cape. She encroached onto the left-hand side shoulder, which is separated from the travelled lane by a concrete V-drain that has grid covered drop inlet drains at regular intervals. The front left wheel struck an open inlet where the grid was missing. She panicked and depressed the accelerator by mistake, shot forward and then veered to the left onto the inside of the ramp. Near the end of the ramp she overturned the vehicle. Her son that sat on the back of the bakkie fell out and sustained brain damage.
Attributes investigated	Drainage: inlet structures and covers
Road authority, route number and class	SANRAL, N1-1, Class 1 freeway.
Maintenance arrangements	Routine road maintenance contractor that had to inspect the road daily in both directions. The ramps were included in the inspection schedule.
Location, date and time	Interchange 55 Paarl km 48,6 S on 6 August 2005 at approximately 10:32
Pleadings,	Unknown.
Outcome,	Confidential settlement
Finding 1 Road environment	The missing drain inlet grid resulted in unsafe conditions. The cross section design of the ramps with a V-drain on the shoulder is not to modern standards.
Finding 2	The ramps had to be inspected daily along with the freeway carriageways. In the

Maintenance procedures, reaction times	course of the expert investigation in 2010, a broken grid was observed on one of the other ramps. It was not repaired until it was reported and then it was replaced the same day
Conclusions	The specifications for inspections and reaction times were adequate and a RRM contractor was duly appointed. The execution of the inspections was, however, lacking.

Figure 7- 27: Mothlapudi: Location plan of open drain inlet

Figure 7- 28: Mothlapudi: Open drain as recorded the day after the accident

7.4.3 Madonsela v SANRAL and others

The case as summarised in Table 7-15 is illustrative of a serious local failure that resulted in a maintenance problem that was only addressed with routine procedures.

Table 7- 15: Madonsela v SANRAL and others

Description	Madonsela was travelling along the R38 from Badplaas to Barberton after sunset when her vehicle hit a pothole and veered to the left and off the road. She suffered injuries.
Attributes investigated	Pothole size, repair procedures and reaction time
Road authority, route number and class	SANRAL, route R38, rural Class 2.
Maintenance arrangements	Routine road maintenance contract.
Location, date and time	On route R 38 approximately 4.5 km out of Badplaas in the direction of Barberton. 17 February 2010 at approximately 19:40
Pleadings,	Unknown
Outcome,	Confidential settlement
Finding 1 Road environment	The recurring pothole was caused by poor subgrade conditions and base failure due to terminal fatigue on an old road. The pothole was approximately 3.5 m wide by 4 m long in the direction of travel. The depth was reported as deep > 75 mm. The severity was Degree 5. The pothole had been repaired seven days before but it

	failed in subsidence and possible breaking out of the stiffer patch material. Other smaller potholes were present in the local failure zone. The section of road is in a low point and surrounded by marshy land.
Finding 2 Maintenance procedures and reaction times	The routine road maintenance contract had been running since 2006. The contractor inspected the route at regular intervals, frequency not known. Reaction times are per RMM. The small potholes on the route had been attended on a continual basis, leading to the impression that the road was well maintained. The recurring pothole had been repaired, the last time seven days before the crash. The repairs were with cold mix patch material into a relatively shallow depth compared to the failure. Planning had been done for more extensive base repair. After the crash, the base repair was started the following day. Ponding of water was observed in the excavations. A pioneer layer of rock was placed to provide a foundation. The reaction time for the base repair was considered inadequate considering the recurrent need for repairs.
Finding 3 Signage	The contractor presented photographs of temporary signage on the approach to the pothole that would be adequate. Although not tested in evidence, it appeared that the signs were in place for the repairs the previous week or occasions and were taken down after the repairs.
Conclusions	The road authority and its independent contractors settled the claim in acknowledgement of their legal duty and negligence. The dimensions of the pothole exceeded Degree 5 by far. The superficial maintenance was done within contractual reaction time. The deep base failure to address fundamental causes was not done in a reasonable time and lead to recurring failures. Adequate signage was not provided and maintained. Signage needed to be site specific, as a general warning of potholes at the start of the road section would not have had credibility due to the small potholes already repaired.

Figure 7- 29: Madonsela: Pothole on R38

Figure 7- 30: Madonsela: Lack of signage on approach to pothole on R38

7.4.4 Maritz v City of Tshwane Metropolitan Municipality

The road failure in this case was a pothole on the side of a kerbed road, outside the normal wheel tracks of the traffic. Two-wheeled vehicles, such as motorcycle and bicycles, however, use these fringes and are entitled expect the same road condition as the rest of the lanes or carriageways. The responsibility of road authorities is towards all road users. Table 7-16 gives an overview of the maintenance issues.

Table 7- 16: Maritz v CTMM Scooter Jean Avenue

Description	Maritz pulled off from a traffic signal stop line in Jean Avenue, Centurion, on a Vespa scooter when the light turned green. As he crossed the intersection, a vehicle from Rabie Street to his right turned right on red in the same direction and pushed the motorcycle to the edge of the roadway. A pothole had developed at the edge, next to the kerb. This is at a low point on the road that developed when an access to a filling station was built. Water accumulated here and vehicles entering the filling station damaged the edge. The pothole thus grew over time. A scooter with small diameter wheels is sensitive to shocks and swerves. The pothole could also have punctured the front tyre as the depth was sufficient to pinch the tyre against the rim. Maritz was thrown off the scooter and suffered a severe blow to his head.
Attributes investigated	Pothole size and maintenance reaction time.
Road authority	City of Tshwane Metropolitan Municipality, Jean Avenue, urban Class 2.
Maintenance arrangements	Municipal maintenance
Location, date and time	Intersection of Jean Avenue and Rabie Street, Centurion. 4 September 2009 at about 19:55

Pleadings	Unknown
Outcome,	Confidential settlement
Finding 1 Road environment	The size of the pothole was of a Degree 5 severity. In particular, the length was long enough for a tyre to fall in completely and the depth more that the tyre thickness.
Finding 2 Maintenance procedures and reaction times	A road such a Jean Avenue, an urban Class 2 road, should be inspected weekly. This is more so in a dolomitic area, where a few months after the investigation, a sink hole appeared over the full width of Jean Avenue and 10 m deep. This pothole had developed over a long period. Reaction time, if this pothole had been observed, was too slow.
Conclusions	The importance of this case is that road failures on the side of the travelled path / wheel track can present a significant hazard for bicycles and motorcycles.

Figure 7- 31: Maritz: Pothole on Jean Avenue, Centurion

Figure 7- 32: Maritz: Pothole sides and dimensions

7.4.5 Zentgraff v MEC PWRT Gauteng Province

This case illustrates how a substandard design, that requires signs and guardrails, becomes a maintenance problem. Table 7-17 summarises the maintenance implications related to this case.

Table 7- 17: Zentgraff v Gauteng Province

Description	Zentgraff was travelling on a secondary road leading from Hillshaven to the junction on the R28 primary road on 10 April 2009 at approximately 19:00. The two roads are approximately parallel to each other and the secondary road then makes a sharp curve to the right to join the R28 at a right angle. He entered the curve and failed to complete the manoeuvre safely, exiting the curve and rolling the vehicle. The guardrail that starts at the beginning of the curve did not continue the full length of the curve and thus failed to contain the vehicle on the road.
Attributes investigated	Barriers.
Road authority, route number and class	Gauteng PWRT, route number unknown, rural Class 3.
Maintenance arrangements	Provincial maintenance teams.
Location, date and time	Hillshaven, near the junction on the R28 primary road. 10 April 2009 at approximately 19:00
Pleadings	Unknown

Outcome	Confidential settlement
Finding 1 Road environment	The road (in a south to north direction) leading from the access to Hillshaven follows a flat curve to the left for approximately 350 m, and then continues straight for another 350 m to turn sharply to the right. The length of the last sharp curve is about 120 m and a straight of about 50 m leads to the stop line at the R28. The sharp curve turns through an angle of approximately 105 degrees with a 65 m radius. This 65 m radius curve conforms to a design speed of 40 km/h. The guardrail on the outside of the curve is thus warranted and the damage, which is apparent on the Google Streetview images, confirms that the curve is hazardous.
Finding 2 Maintenance procedures and reaction times	From the photographs taken in 2009 and the 2010 Google Streetview images it is clear that no maintenance was done on the guardrails.
Finding 3 Signage	A W204 Sharp curve to the right warning is located 170 m before the start of curve. The other signage is GM7 STOP advance road markings 460 and 220 m before the stop line. There are no speed limits on the road section and no speed advisory for the sharp curve.
Conclusions	The 65 m radius curve in the road is severely substandard given the rural general speed limit of 100 km/h. The guardrail on the outside of the curve was approved at some point on either the design parameter or on accident history. Once a guardrail has been installed, it must be maintained. The fact that it is damaged often proves the need. Maintenance teams should report such hazardous locations and the obvious remedial measure would have been a speed limit of 40 km/h (design speed) 120 m before the start of the curve.

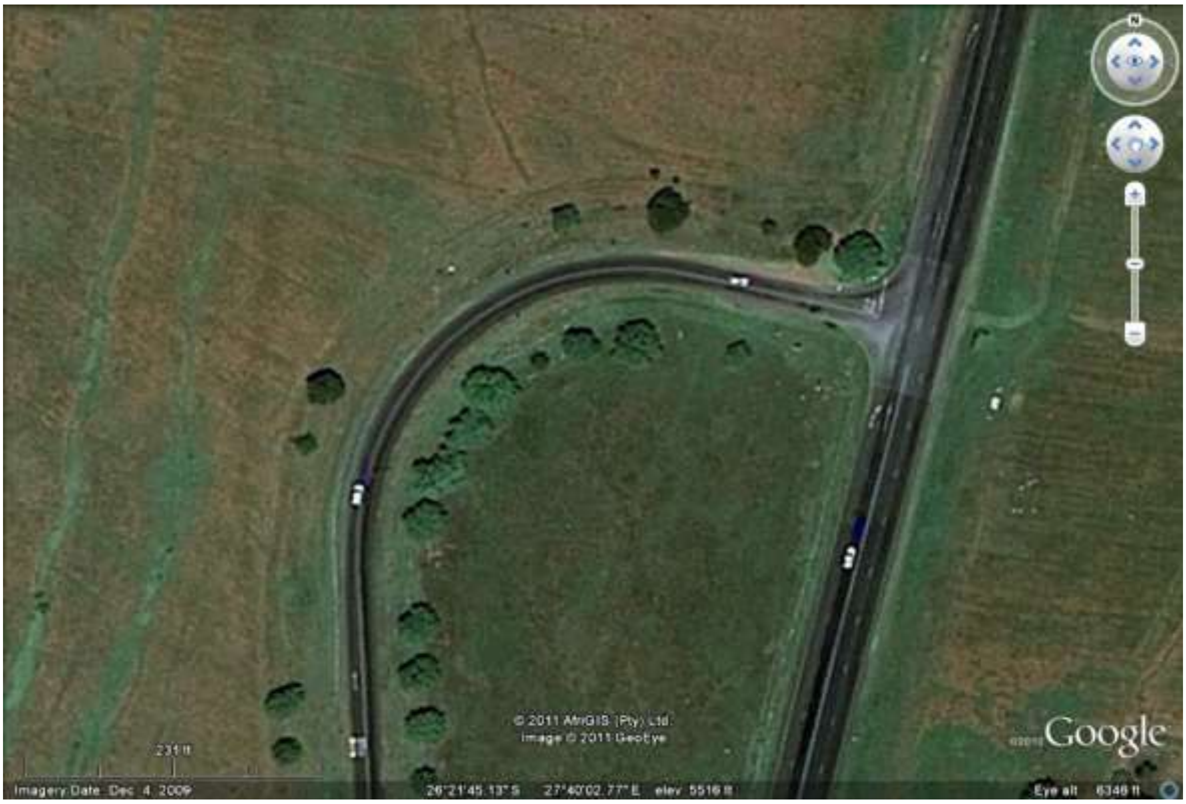


Figure 7- 33: Zentgraff: Curve where guardrail was not maintained

Figure 7- 34: Zentgraff: Guardrail too low and partially down

7.4.6 Boshoff v Bombela and others

Guardrail terminals are considered hazards. Where the terminals are missing, the severity of accidents increases due to the sharp exposed ends of guardrail end sections. The reinstatement of terminals should be done immediately. While this case summarised in Table 7-18 involved a temporary construction operation, it is included to illustrate that spearing through a vehicle is a reality. The municipality, as part of its maintenance operations and procedures on arterial roads, should have picked up this hazardous condition and instructed the contractor to fix the problem.

Table 7- 18: Boshoff v Bombela and others

Description	Boshoff drove along Duncan Street, Hatfield, Tshwane, in a southern direction. After crossing Schoeman Street, the road curves to the left. On the right-hand side, a new slip road was being built for access to the Gautrain station parking. The guardrail on the outside of the curve to the left was removed in the area where the slip road was built and the last section was left hanging in the air. Boshoff drove in the right-hand lane and for reasons unknown drove wide and encroached into the new deceleration lane for the slip lane. As he steered back to the through lane, he drove over the kerb where the guardrail was hanging. The guardrail pierced through the vehicle from the front, pushing through the fire wall next to the steering column and impaling the driver.
Attributes investigated	Guardrail maintenance, inspections
Road authority, route number and class	City of Tshwane Metropolitan Municipality. Gordon / Duncan Street, urban Class 2. The work was done by an independent contractor that obtained a way leave (permission to work in the road reserve) that indemnified the CTMM. The claim was this directed at the contractor and its client, Bombela.
Maintenance	The responsibility to inspect and monitor the activities of contractors lies with the CTMM as road authority. In this case, it had to ensure that the way that the work

arrangements	was done in the road reserve would not cause hazards, such as the loose guardrail end.
Location, date and time	Gordon / Duncan Streets, Saturday 24 April 2011, between 06:30 and 07:30
Pleadings,	Unknown
Outcome	Confidential settlement
Finding 1 Road environment	Guardrail terminals are of great concern in road safety, as it is known that end wings and bull-nosed terminals can penetrate into vehicles. An unprotected loose end is totally unacceptable.
Finding 2 Maintenance procedures and reaction times	The CTMM cannot delegate its responsibility to inspect the work of other contractors that work in the road reserve and should have picked up the hazard that was created when the guardrail was dismantled.
Finding 3 Signage	On the photographs of the accident scene, it was not possible to see whether delineators had been positioned at the loose end of the guardrail. Adequate signs could have attracted attention and the crash could have been avoided.
Conclusions	The danger posed by exposed guardrail terminals is well known and such situations should not occur in public road reserves. The CTMM road inspectors still have a duty to inspect and monitor the activities of independent contractors.

Figure 7- 35: Boshoff: Suspended guardrail end

Figure 7- 36: Boshoff: Guardrail end after remedial work

7.4.7 le Roux v MEC PWRT NWPG

This case is similar to Madonsela discussed in Section 7.4.3, where the root cause of the recurring potholes was not addressed. The isolated nature of this poor road section in relation to the rest of the route violates driver expectation and surprise the driver. The maintenance aspects are summarised in Table 7-19.

Table 7- 19: le Roux v MEC PWRT NWPG

Description	Mr AC le Roux (Plaintiff) was driving a Toyota Hilux light delivery vehicle (LDV) towing a trailer on route R509 from Koster in the direction of Swartruggens. At a point in the road, the vehicle and trailer drove through potholes so severe that the trailer coupling broke off from the tow hitch. The trailer jammed under the LDV, lifting it off the ground and causing the driver to lose control and veer off to the right across the road. The LDV rolled and was damaged. Mr le Roux was injured.
Attributes investigated	Potholes, maintenance procedures for recurring failures
Road authority, route number and class	North West Province Department of Public Works, Roads and Transport. R509, rural Class 3 road.
Maintenance arrangements	Provincial maintenance teams.
Location, date and time	R509 between Koster and Swartruggens, North West Province. 5 May 2010, at about 08:05,
Pleadings	Unknown
Outcome	Confidential settlement
Finding 1 Road	Numerous potholes were shown on the photographs, mostly round or ellipse in

environment	shape and are more than 500 mm in diameter or width. Their sides are sharp and the depths are estimated to be between 50 and 75 mm. On the Google Earth images, the ploughed field shows green vegetation, but a darker area can be observed. This indicates swampy conditions that extend up to the road. The damp / moist conditions in this low point on the road explain the localised road pavement structural failures. These conditions should have been recognised and mitigating measures implemented. Such measures could have been deeper side drains, subsoil drains or the lifting of the road alignment.
Finding 2 Maintenance procedures and reaction times	The weak area should have been monitored closer than the rest of the road in order to remedy and make safe the potholes that would develop more frequently in the summer rain season.
Finding 3 Signage	Warning signs should have been erected at this weak section of road.
Conclusions	The road authority failed to act in a reasonable manner to warn of and maintain the specific problematic section of road.

Figure 7- 37: le Roux: Potholes on day of accident

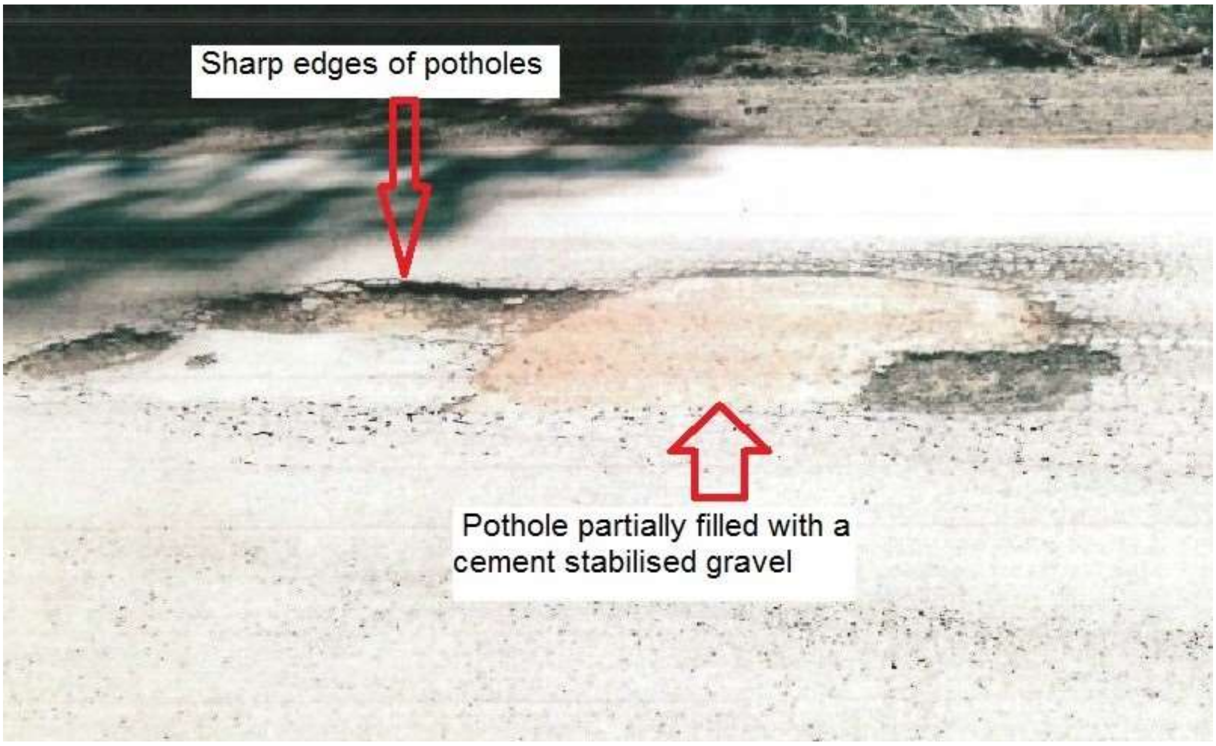


Figure 7- 38: le Roux: Potholes 2

Figure 7- 39: le Roux: Drainage problem next to the road

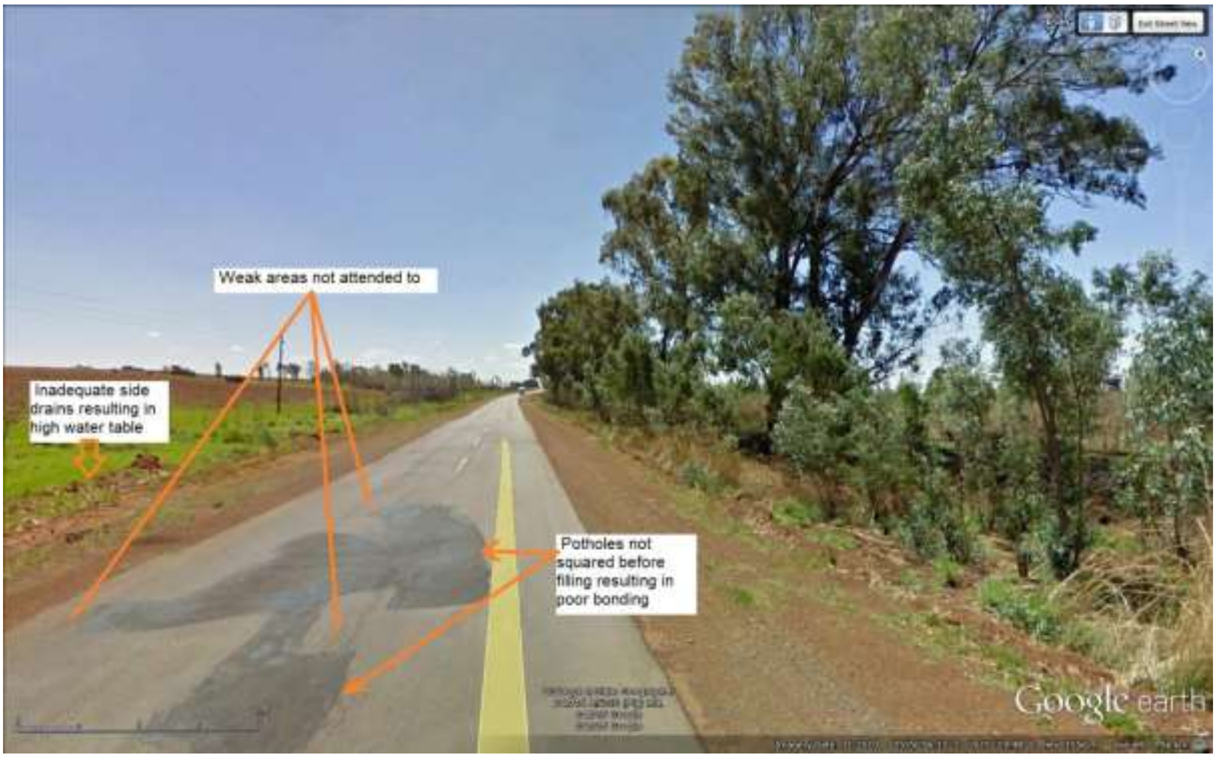


Figure 7- 40: le Roux: Repairs to the road

7.5 Cases investigated (not concluded)

A number of cases that have not been concluded have been investigated as part of the research.

- December v SANRAL N1 hydroplaning;
- Pienaar v Rustenburg Municipality pothole and kerb;
- Mathebathe v Premier Gauteng Province K103 debris on shoulder;
- Deysel v CTMM K69 edge drop / break vegetation;
- van der Merwe v Premier Mpumalanga Province;
- de Beer Dullstroom hydroplaning;
- Buijs v Premier WC Province N7 drop-off and road marking; and
- Andrew v SANRAL and other N1 road marking.

7.5.1 December v SANRAL

While is can be argued that the root cause of hydroplaning on this superelevation runoff is a design issue, the case as summarised in Table 7-20 is used to highlight the need for maintaining adequate texture in these situations. Similar problems are known to occur on other road sections, such as at the Greystone onramp to the north on the M1 route near Sandton.

Table 7- 20: December v SANRAL N1 hydroplaning

Description	December was driving north on the N1-20 Pretoria Eastern Bypass freeway. The road was widened to four basic lanes per direction under the Gauteng Freeway Improvement Scheme in 2010. At the John Vorster Interchange, the on-ramps to the north were improved by providing an additional loop ramp to the existing diamond on-ramp. At the nose of the on-ramps, the total number of lanes is six. At this point the road was in superelevation development and at the point where the cross fall was zero. The road is on a slight downwards longitudinal grade. The roadway drainage in the superelevation runoff area thus results in a flow path that starts on the median side and flows diagonally to the outside, but at the widest point the flow path curves back to the inside. The length of the flow path is in the order of 120 m. This flow path results in a sheet flow in excess of the depth that leads to full or partial hydroplaning at freeway speeds for passenger cars. December entered this sheet flow while in the inner lane. A partial hydroplaning was compensated for by over-steering to the right. As the sheet flow was crossed, the relatively drier road surface resulted in increased grip and the over-steered front tyres veered sharply to the right, causing the vehicle to crash into the concrete median barrier. The tyre skid marks were captured on photographs.
Attributes investigated	Road surface drainage, side drain covers.
Road authority, route number and class	SANRAL, N1-20, rural / urban Class 1.
Maintenance arrangements	Routine road maintenance contracts.
Location, date and time	N1-20 Pretoria Eastern Bypass freeway. 24 November 2012. Time unknown. Rain occurred on the day. 42 mm was measured at the nearby Irene weather station. The duration and thus intensity were not recorded.
Pleadings,	Unknown
Outcome,	None
Finding 1 Road environment	The road suffers from a design weakness as the flat spot that occurs in the superelevation development is a known design reality. It is rarely a problem as the flow lengths are limited due to short superelevation runoff and narrow road width. In this case, the old design approach of a fixed 100 m superelevation runoff and the addition of 2 ramp lanes to the four freeway lanes contributed to the long flow path length.
Finding 2 Maintenance procedures and reaction times	The RRM contractor would have noticed the regular collisions with the median barrier and the breaking of the median drain grid covers. This should have been reported and the problem could have been investigated and mitigation measures such as increased texture depth used to counter the flow depth and hydroplaning problem.
Finding 3 Signage	Signage of warning for slippery when wet could be provided.
Conclusions	Although the problem of long flow paths stems from an inherent design weakness, maintenance of texture in the superelevation development zone must be ensured.

Figure 7- 41: December: Location of accident on N1, Centurion, Gauteng

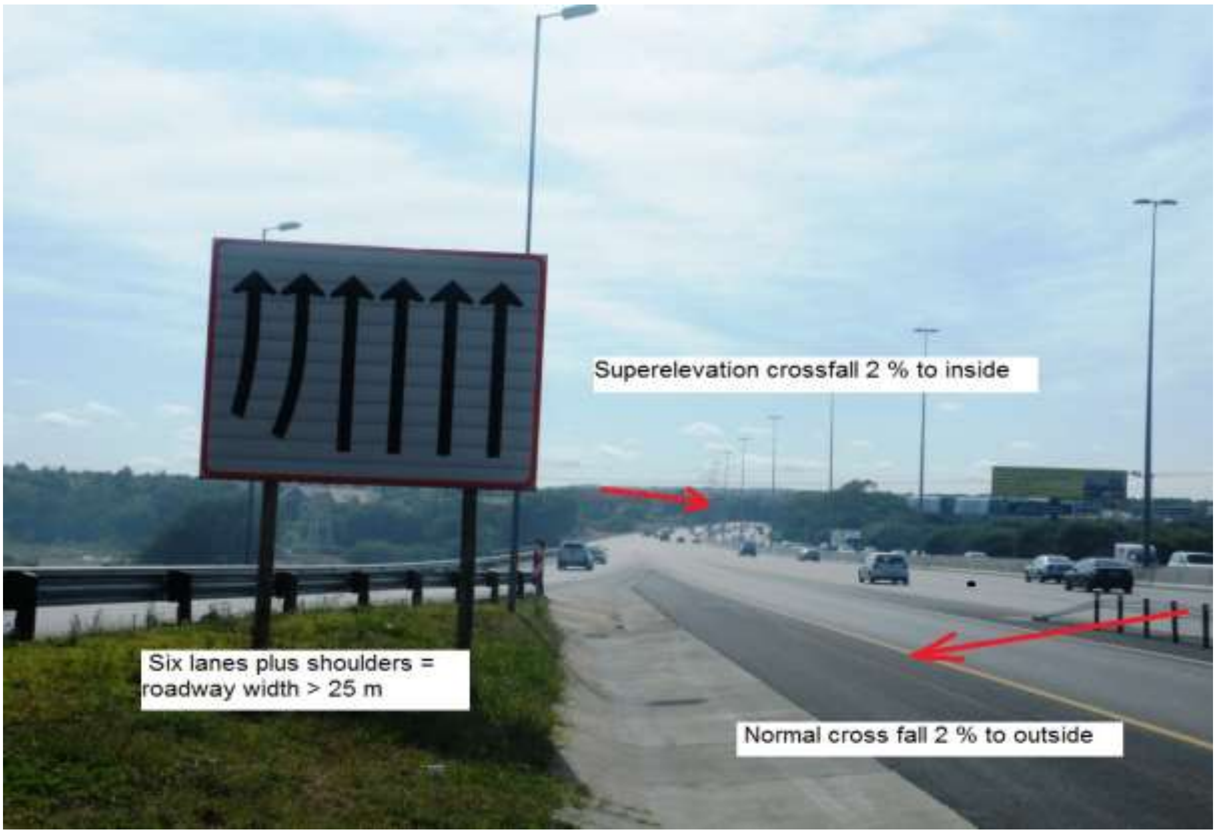


Figure 7- 42: December: Cross fall of road before and in curve

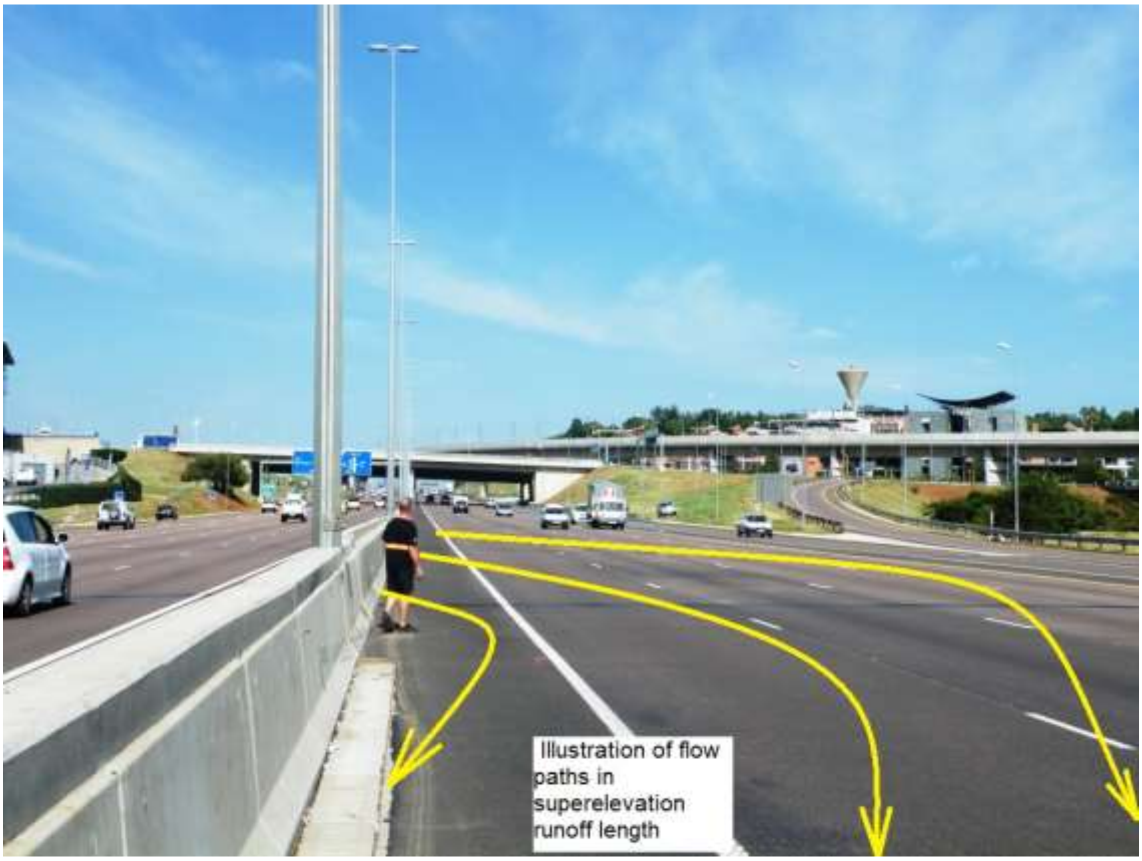


Figure 7- 43: December: Drainage paths in superelevation development

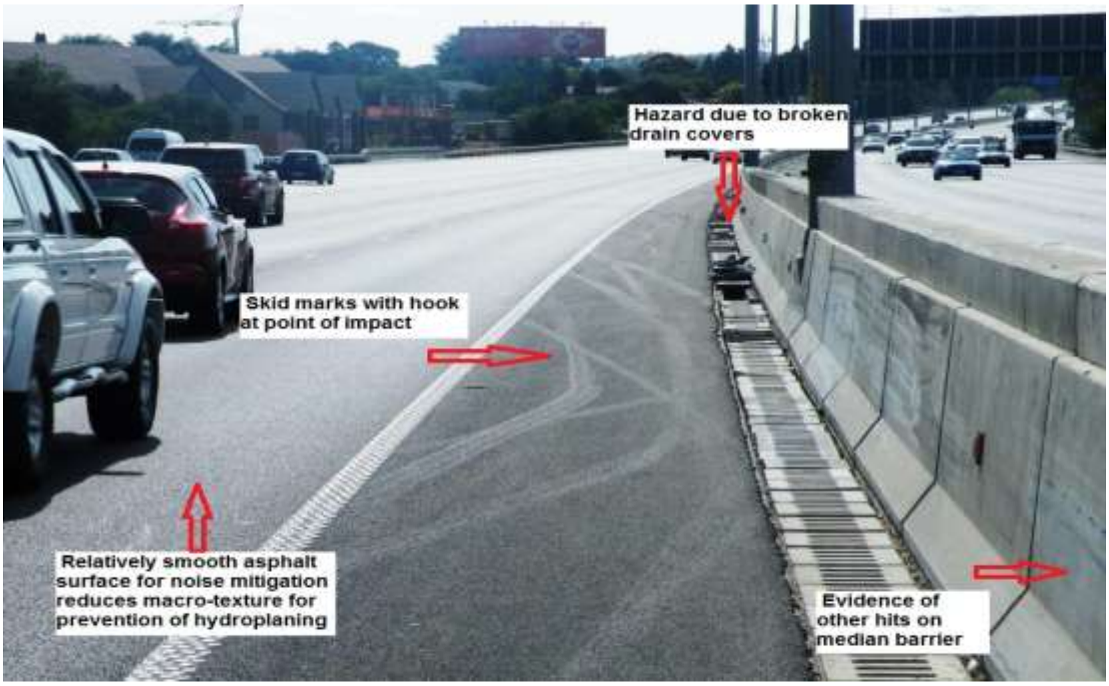


Figure 7- 44: December: Collision with median barrier

7.5.2 Pienaar v Rustenburg Municipality

The case summarised in Table 7-21 involves a trench excavated over an urban Class 3 road. The reinstatement of the kerbing was not done. This failure should have been picked up in maintenance inspections.

Table 7- 21: Pienaar v Rustenburg Municipality

Description	Pienaar was travelling in Beyers Naude Drive, Rustenburg at night. It is a 4-lane urban arterial. Repairs to a municipal water pipe resulted in a trench over the road and a break in the concrete side drain and kerb. The backfilling was done but the asphalt surface repair was postponed to allow for settlement. This was seemlingy forgotten and the gravel backfill eroded until a pothole formed and started to expand along the length of the road. From the initial trench width of 600 mm it reached a length of 2 m. The pothole developed mainly in the left-hand wheel track closest to the broken concrete side drain and kerb, where water would accumulate, and soak and weaken the backfill that could be splashed out. The depth was not measured. The vehicle had low-profile tyres and when it drove through the pothole, the tyres were damaged. The tyres did not burst on impact but seemed to have burst some distance beyond. The driver lost control of the vehicle and collided with a fixed object next to the road. A passenger was severely injured.
Attributes investigated	Pothole and lack of warning, reaction time
Road authority, route number and class	Rustenburg Municipality, Beyers Naude Drive, urban Class 3.
Maintenance arrangements	Municipal maintenance team
Location, date and time	Beyers Naude Drive in June 2014
Pleadings	Unknown
Outcome,	None
Finding 1 Road environment	The road was severely compromised when the trench was not properly reinstated after the municipality had worked on the water pipe. A pothole was allowed to develop to dimensions of 1.5 m wide, 2 m long and of unknown depth. However, with that surface dimensions, the depth could have been considerable.
Finding 2 Maintenance procedures and reaction times	Although the municipality excavated the trench itself and thus had notification of the defect, it did not respond. The internal communication procedures obviously failed. No road inspections picked up the failure.
Finding 3 Signage	No warning signs were erected for what was an obvious hazard.
Conclusions	The municipality failed in the application of basic standard procedures and created a hazard on the road. Lack of inspection caused the hazards to deteriorate substantially.

Figure 7- 45: Pienaar: Pothole in wheel track after trench not reinstated

7.5.3 Mathebathe v Premier Gauteng Province

The responsibility of maintenance teams, in-house or contracted, to properly clean up after completion of work, is considered a procedural standard- The hazard created on the shoulder in the clear zone was a consequence of failure to work to standard procedures. The case is summarised in Table 7-22.

Table 7- 22: Mathebathe v Premier Gauteng Province

Description	Mathebathe pulled onto the shoulder of provincial road K103 to avoid a vehicle approaching from the opposite side and making a U-turn in front of him. His vehicle then drove over a heap of rubble dumped on the side of the road and hidden in tall grass. It was severely damaged, while Mathebathe was seriously injured.
Attributes investigated	Road side: shoulder design width
Road authority, route number and class	Gauteng Province Department of Roads and Transport. K103 rural Class 2.
Maintenance arrangements	Provincial maintenance teams
Location, date and time	Hans Strijdom Drive also known as provincial road K103 and municipal route M10, approximately 05:45 on 1 February 2012.
Pleadings	Unknown
Outcome,	None
Finding 1 Road	The road is in a wide road reserve next to the Waterkloof Air Force Base. It is in

environment	shallow fill and the shoulder is a flat side slope that appears for be trafficable up to 4 m wide. About 1 m is open gravel surface and the rest has grass cover, mainly tall veld grasses. This seemingly forgiving roadside was, however, compromised when the road maintenance team doing a wheel track base repair over at least 20 m dumped the excavated road material on the shoulder and did not clean up the work site as per specification. Grass was allowed to grow and hide the dumped material.
Finding 2 Maintenance procedures and reaction times	The initial failure of the road patching maintenance team to not clean up the work site was compounded by the failure of the road inspectors to not report the problem or have it cleared up by the road cleaning teams. The work on the road can be seen on Google Earth images dated September 2011. The debris was clearly left for at least 4 months.
Conclusions	The Gauteng Province road maintenance teams failed to comply with standard operating procedures and this resulted in compromising the safety standards for clear zones.

Figure 7- 46: Mathebathe: Debris on shoulder in clear zone

7.5.4 Deysel v City of Tshwane Metropolitan Municipality

This care was included to illustrate how the cumulative effects of failures of different road characteristics can result in hazardous conditions. Table 7-23 summarises the maintenance related aspects of this case.

Table 7- 23: Deysel v CTMM

Description	Deysel drove along Solomon Mahlangu Drive at night through the S- curve section where the dual carriageways merge into a single carriageway to cross the bridge over the N1 near Waterkloof High School, Tshwane. The road was not lit and the edge of the road presented with edge break and edge drop-off due to poor maintenance of the gravel shoulders and the use of this area as a bus stop. He encroached onto the shoulder which should be a recovery area, but the edge condition destabilised the vehicle. He steered to the right to regain traction on the roadway, but the vehicle veered sharply to the right and hit the guardrail on the opposite side. Instead of the guardrail redirecting the vehicle as it is designed to do, by stretching and deflecting, the guardrail struck a tree that was allowed to grow behind it. The solid impact exacerbated the collision and the car was severely damaged, caught alight and burned out.
Attributes investigated	Edge drop-off, edge break and guardrail working space
Road authority, route number and class	City of Tshwane Metropolitan Municipality, Solomon Mahlangu Drive, urban Class 2.
Maintenance arrangements	Municipal maintenance team.
Location, date and time	Solomon Mahlangu Drive. 22 October 2011 at about 22:15.
Pleadings	Unknown
Outcome,	None
Finding 1 Road environment	Edge drop-off and break are known hazards. The dimensions of the failures were in excess of 50 mm and 100 mm respectively. The road alignment contributes to the hazardous nature of the area, as the alignment is an S-curve to steer from the right-hand side of the dual carriageway to the single carriageway that aligns with the opposite lanes. Drivers either cut the corners or run wide, with the risk of encroaching into the oncoming traffic or onto the shoulder.
Finding 2 Maintenance procedures and reaction times	The road edge was repaired shortly after Deysel's accident. The gravel shoulder should be filled up and compacted when the trigger value of 50 mm is reached. This will help to contain the edge break. As these failures develop over time, maintenance can be planned and reacted to in a long cycle, instead of waiting for a crisis and reactive maintenance. The tree behind the guardrail that increased the severity of the accident should not have been allowed to grow in that position. It can be concluded that roads inspectors are not informed or skilled with respect to safety features.
Conclusions	The edge drop-off and break could have been managed and fixed as the extent of the failures were beyond the Degree 5 severity. Regular inspections by competent inspectors would have identified these failures as hazardous.

Figure 7- 47: Deysel: Edge break and drop-off

7.5.5 van der Merwe v MEC PWRT Mpumalanga Province

Polluted road surfaces lead to unpredictable conditions for drivers / riders. Table 7-24 summarises the maintenance aspects of this case. By ignoring the loose gravel washed onto the road from high-lying ground in this hilly to mountainous road environment, despite the opportunities to have observed the gravel on the road (not only at this location) hazardous conditions are created; two-wheeled vehicles are specifically at risk.

Table 7- 24: van der Merwe v MEC PWRT Mpumalanga Province

Description	van der Merwe and friends were motorcycling on a Sunday between Sabie and Hazyview, a popular weekend pastime on this twisty road. Rounding a curve at km 12 opposite the Bergvliet Forestry Station, he felt sand on the road and rode wide to increase the turning radius and reduce the demand for sideways friction. There was no opposing traffic for a distance in excess of the stopping sight distance. When he reached the point to steer back to the correct lane, he saw loose gravel and sand that were washed from the Bergvliet access road onto the roadway. In his experience he would slip if he turned on the loose material and he chose to go straight, hitting a hidden kerb that catapulted the motorcycle in the air. He landed in a side drain and sustained injuries to his spine, making him a paraplegic.
Attributes investigated	Loose material on the roadway.
Road authority,	Mpumalanga Province Department of Public Works, Roads and Transport.

route number and class	Route R356 (P33-4), rural Class 2.
Maintenance arrangements	Provincial maintenance team based in Sabie.
Location, date and time	Km 12 on route R356. Sunday 30 January 2011 at about 11:00.
Pleadings	Unknown
Outcome,	None
Finding 1 Road environment	Loose material on the road reduces the skid resistance / coefficient of friction / drag coefficient substantially. It also introduces great variations in the grip of the tyre on the road surface, as some loose material can act as rollers. This is especially true for motorcycles that have small contact patches on only two tyres.
Finding 2 Maintenance procedures and reaction times	The road should be inspected weekly. There are only three regional roads leading from Sabie. Road department officials drive on these roads towards other projects. The problem of loose material washing in from side roads and accesses is a longstanding one in forestry areas and the department has the authority to instruct the offender to clean up or do the work and charge for it. Or, it can choose to do it anyway. Loose material can thus be cleaned within a week.
Conclusions	The reasonable driver has an expectation of the road surface being clean of loose material that can endanger the control of the vehicle. The road authority cannot allow deterioration of the road surface due to preventable actions. Where contamination with loose material occurs, it is obliged to remove it, as it can be reasonably foreseen to cause dangerous conditions.

Figure 7- 48: van der Merwe: Curve to the left

Figure 7- 49: van der Merwe: Gravel at Bergvliet access

7.5.6 de Beer v MEC PWRT Mpumalanga Province

The failure to execute simple labour intensive cleaning of storm water features resulted in hazardous conditions as summarised in Table 7-25.

Table 7- 25: de Beer v MEC PWRT Mpumalanga Province

Description	de Beer was driving on route R540 between Dullstroom and Lydenburg. At about km 41, after a steady downhill that ends in a curve to the right, the vehicle drove through a sheet of water running over the road at the start of the curve. The vehicle slid forward due to hydroplaning. The driver probably overcorrected, steered to the right and after exiting the sheet flow, the vehicle regained traction and veered to the right in an unexpected manner. His vehicle hit another vehicle travelling in the opposite direction. Both drivers were killed.
Attributes investigated	Drainage from the roadway.
Road authority, route number and class	Mpumalanga Department of Public Works, Roads and Transport. Route 540. Rural Class 2.
Maintenance arrangements	Provincial maintenance teams.
Location, date and time	Road R540, at about km 41.35. Monday 15 August 2011 at approximately 14:05. Wet conditions, but intermittent rain. It was just before a snow fall.
Pleadings	Unknown

Outcome	None
Finding 1 Road environment	The drainage from the roadway on the approach to the curve to the right is to the left side of the road, channelled by means of an asphalt berm to down chutes at regular intervals. These down chutes were blocked by vegetation and the water accumulated over a distance of 900 m. At the development of superelevation the water was redirected in a sheet flow over the road to the right. The thickness of the water film induced hydroplaning and the accident happened as described above.
Finding 2 Maintenance procedures and reaction times	The control of vegetation in drainage features should be routine or planned seasonal as well as reactive maintenance. The extent to which the vegetation blocked the down chutes indicated neglect. Vegetation control is primarily hand labour and is not a burden to do. Funding can even be obtained from the Extended Public Works Programme. The reaction time can be within a week, as the inspector can bring labourers to site with the following inspection.
Conclusions	Drainage features must be able to function as designed. Maintenance must be aimed at ensuring the design conditions. The control of vegetation at down chutes is a trivial effort with high risk if not done.

Figure 7- 50: de Beer: Blocked down chutes

Figure 7- 51: de Beer: Drainage over road at superelevation development

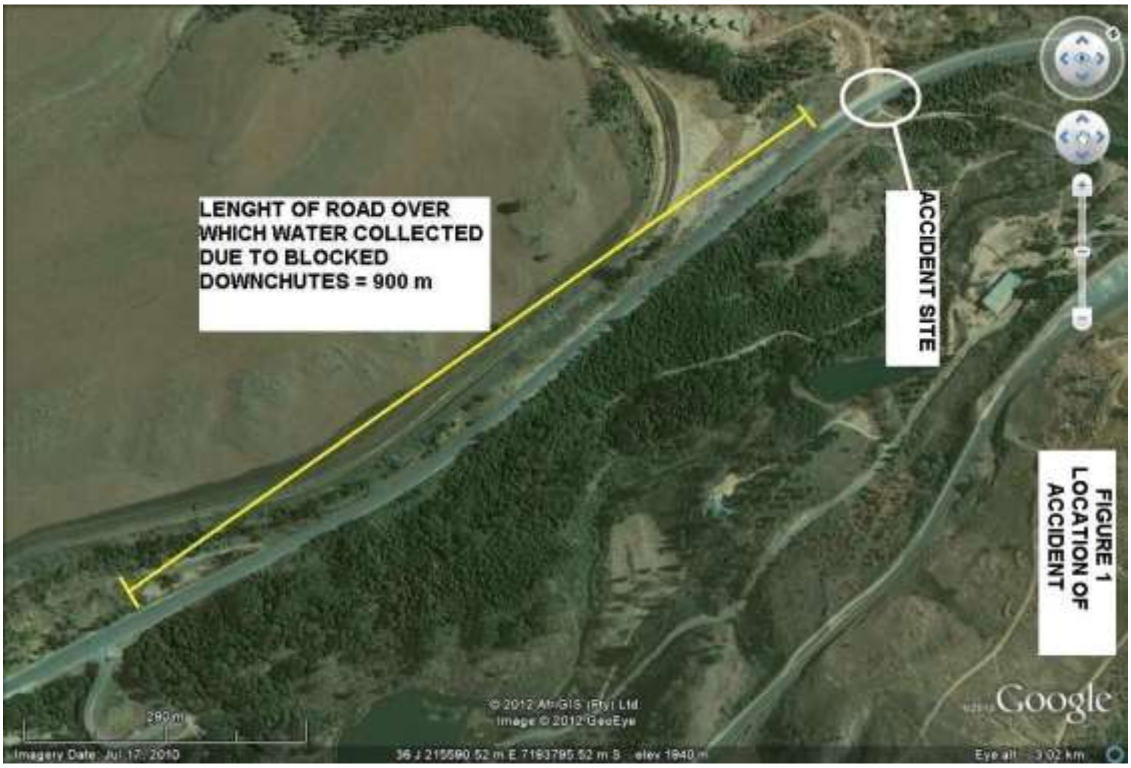


Figure 7- 52: de Beer: Length of drainage path

Figure 7- 53: de Beer: Accident location

7.5.7 Buijs v MEC PWRT WCPG

This case illustrates the cumulative effects of resurfacing resulting in hazardous conditions. Table 7-26 summarises the case where the grid inlet was not lifted to eliminate the level difference between the grid and the road surface.

Table 7- 26: Buijs v MEC PWRT WCPG

Description	Buijs was travelling north on the N7 freeway between the Bosmansdam and the Plattekloof interchanges, with the purpose of taking the off-ramp at the latter. At the start of the off-ramp, she followed a curve, clipping the separation point of the ramp and freeway edge lines (yellow-line break point). The left front wheel of the small car fell into a drain inlet next to the yellow line. The vehicle pulled sharply to the left. She overcorrected to the right and drove into the median, damaging the car and sustaining injuries.
Attributes investigated	Edge drop due to build-up of asphalt in successive overlays.
Road authority, route number and class	The Provincial Government of the Western Cape, DPWRT. N7, Class 1 freeway.
Maintenance arrangements	Provincial maintenance teams.
Location, date and time	At the start of the off-ramp to the Plattekloof Interchange direction north. Date and time unknown
Pleadings	Unknown
Outcome	None

Finding 1 Road environment	The original design of the off ramp from N7 to Plattekloof Interchange had a design flaw as the V-drain on the shoulder line created a hazard due to possible loss of steering control. The design flaw was exacerbated by intermittent resealing of the road surface by means of asphalt overlays, building up to an elevation that constituted an edge drop-off. The design of the 1:15 taper off ramp acknowledges that vehicles will cut over the yellow-line break point. A drop inlet drain exists next to the yellow-line break point. With the build-up of the asphalt overlays the difference in elevations was more than 150 mm. This drop-off was specifically dangerous to the Opel Corsa with only 140 mm clearance between the road and the suspension. An experienced and knowledgeable road engineer and or road supervisor would have identified these elements of the road as hazardous, especially as part of supervision during the resurfacing. The scrape marks on the road next to the drop inlet drain testify to previous incidents or accidents that should have alerted the road authorities to the hazardous location, as this is construed as constructive notification
Finding 2 Maintenance procedures and reaction times	The maintenance teams should have picked up the scrape marks on the edge of the road next to the drain inlet and reported the drop-off. The drain grid could have been raised to eliminate the hazardous drop-off.
Finding 3 Signage	The road markings were adapted as a mitigation measure to steer vehicles further from the hazard.
Conclusions	The cumulative effects of maintenance action such as asphalt overlays must be taken into account when evaluating critical safety points on the road. Such potential hazards must be corrected in an appropriate time: The paint markings were done within a week of notification. The rebuilding of the drain inlet to a higher level can be done in a month.

Figure 7- 54: Buijs: Location of inlet grid on off-ramp from N7, Plattekloof Interchange

Figure 7- 55: Buijs: Drop-off due to asphalt build up at inlet grid

Figure 7- 56: Buijs: Hazardous drop-off on driving line

Figure 7- 57: Buijs: shift from hazardous drop-off with painted island

7.5.8 Andrew v SANRAL and others

This case is about failure to reinstate road markings after resealing. It also illustrates the dilemmas that may result because of lack of maintenance of road markings. The case is summarised in Table 7-27.

Table 7- 27: Andrew v SANRAL and others

Description	Periodic maintenance on Route N1-2 between Rawsonville and Worcester involved a slurry seal to even out surface irregularities, followed by a single seal for texture. The work was done in sections and lane marking followed. At the start of a long weekend and school holiday construction was stopped and the full route opened to traffic. There was, however, a section of about 500 m where the road markings had not been completed. This happened on a changeover of the 2+1 alternating lane assignment. Vehicles approaching from both sides were under the impression that they could overtake and the two overtaking vehicles hit each other in an offset head on collision. The two drivers were killed.
Attributes investigated	Missing lane markings
Road authority, route number and class	SANRAL, N1-2, Class 1
Maintenance arrangements	Routine road maintenance contract in place, but this work was done as periodic maintenance by an independent contractor.
Location, date	At km 12N on the N1-2, on 26 April 2012 at approximately 17:00. Daylight overcast

and time	conditions, with wet road from intermittent rain.
Pleadings	Unknown
Outcome	None
Finding 1 Road environment	The gap in the road markings due to unfinished maintenance created confusion. The road should not have been opened in this format. If the rain prevented the painting to be finished, the centre lane should have been blocked out with delineators, of which the contractor had sufficient stock.
Finding 2 Maintenance procedures and reaction times	The approval of the opening of a section of road after maintenance should be made by an appropriately skilled road safety practitioner. The reaction time to fix the paint marking was one day; the lines were painted the next day, which was a public holiday (Freedom Day).
Finding 3 Signage	The reliance on the existing road signs indicating the deduction or increase in number of lanes were not adequate as drivers rely on road markings for guidance in terms of lane configuration. Static road signs can be obscured by trucks ahead of a driver.
Conclusions	The planning and execution of maintenance, with specific reference to road markings, must be done to achieve the requirement of the SA Road Traffic Signs Manual of continuity of lanes.

Figure 7- 58: Andrew: Gap in lane markings view to the west

Figure 7- 59: Andrew: Gap in lane markings view to the east

Chapter 8: Synthesis

8.1 Introduction

In this chapter the synergy of the three themes of maintenance standards, procedures and the legal duty to road safety are discussed in the context of the characteristics of the road that have the most significant impact on safety.

The road authorities are responsible to execute the engineering functions required to fulfil their legislative mandates. These functions can be discretionary or obligatory. The discretionary provision of infrastructure is driven by public policy and is thus within the political arena. The maintenance of such infrastructure, once provided, becomes obligatory. The manner of execution of engineering functions is determined by state of the art of road building, operation and maintenance. The standard of conduct of engineering officials and their contractors will be determined by that of the reasonable, knowledgeable, skilled and experienced member of the profession. This conduct is based on academic knowledge, guidelines, codes and standards that are in general use as best practice. Where standards have been formulated, non-performance or deviations can be construed as negligence. Where the risk of harm or damage can be foreseen, the reasonable authority must take steps to prevent it from happening.

Standards for maintenance of safety-related road infrastructure have not been formalised. This thesis proposes such standards in terms of characteristic of the road and procedures to ensure that the road elements are maintained to provide a reasonable level of safety to road users. The need for standards for such characteristics are viewed from legal principles and illustrated with cases that have been decided, settled or investigated.

In the discussion, a decided case will be referred to “case’’, but a settled or investigated matter will be referred to as a “case study’’.

The characteristics of the roadway for which standards for maintenance are proposed are not comprehensive, but selected for the importance they have in ensuring safety. The standards are not proposed at idealistically high values, but at practical values based on good practice as identified in appropriate research in countries with comparable conditions. The proposed attributes, inspection procedures and reaction times take into account the constraints of the South African economy and industry capacity. By starting with a few significant characteristics, safety could be promoted and steered towards the development of more standards and refined values.

8.2 Standards for maintenance for road surface texture

Surface texture is a characteristic that falls in the category of the roadway features of lanes and shoulders where vehicles are driven. Macro-texture determines the ability to dissipate water between the tyre and road surface to prevent hydroplaning and loss of steering and braking control. Hydroplaning is a critical problem at speeds over 80 km/h, although it can occur at lower speeds. It is therefore primarily a rural road problem. Texture can be assessed with relatively simple visual techniques, sand patch tests or laser scanners. Texture does not deteriorate quickly, unless there is a bleeding problem due to excess binder in asphalt or in the seal. Adequate macro-texture typically ensures adequate skid resistance.

The proposed trigger value for macro-texture is 1 mm, from which point onwards the roadway surface must be monitored more frequently, specifically in curves and in areas where vehicles must stop. The minimum standard for safety is proposed as 0.5 mm at which point the road must be resurfaced to restore macro-texture.

The visual inspection cycle for macro-texture is proposed to be every two years until the trigger value is reached, from whence the inspections must be done annually and augmented with sand patch tests or laser scans.

As the reinstatement of texture is typically done as periodic maintenance and can be planned in advance, the reaction time from the point where the 0.5 mm minimum standards is reach is proposed as six months. Small local patches of bleeding can be reinstated as special maintenance within the proposed reaction time.

Macro-texture has not been a basis for a claim for damages in local court cases. The unreported criminal case of the State v Ndebele (the Springbok Atlas bus accident on a rural road between Pongola and Piet Retief) in which the researcher was an expert witness was argued on the lack of skid resistance measured with a grip tester. Macro-texture could have been used as well, as the bleeding of the road surface in the wheel tracks completely obliterated the macro-texture. If a standard for macro-texture had been in place, the hazardous nature of the road would have been identified long before the number of accidents on this road escalated to 26 in the year preceding the bus accident. In the year after resealing the road, only one accident occurred.

8.3 Standards for maintenance for skid resistance

Skid resistance falls under the roadway category features of lanes and shoulders. This characteristic is the primary determinant of the ability to accelerate, brake and steer, as friction is required between the tyre and the roadway. The proposed standard for skid resistance applies to urban roads with operating speeds less than 80 km/h where the risk of hydroplaning is low and macro-texture is not a requirement.

Skid resistance values reported in literature vary with traffic volume, location and speeds. While these different values are rational, it also results in complicated systems of monitoring, not suited for the South African road engineering context. The proposed single value of CoF of 0.45 is simple to administer and is strongly linked to the legal definition of braking performance.

The inspection frequency proposed is every two years in critical areas such as intersection and roundabout approaches until patterns of deterioration are established and the occurrence of a trigger value of 0.5 can be predicted. When the trigger value of 0.5 is reached, inspections must be done annually.

The lack of skid resistance as basis for a claim for damages has not been reported in local decided court cases. As mentioned under macro-texture, the case of State v Ndebele (unreported) involved the measurement of skid resistance. The bus driver was discharged on the charges of culpable homicide, as the skid resistance was measured as low as 0.1 due to bleeding of polymer-modified bitumen binder used for the seal.

Reaction time to reinstate skid resistance in urban areas is proposed as six months as it could be planned maintenance.

8.4 Standards for maintenance for rutting, shoving and ponding

Rutting refers to depressions in the roadway due to permanent deformations of the road pavement layers. Rutting is longitudinal deformations in the wheel tracks of heavy vehicles that can be rounded or sharply defined, leading to a “rail” effect. Water can pond in ruts in sag curves. Ponding can also be associated with local failures (see potholes). Shoving is the upwards movement of material and often associated with rutting.

Literature does not strongly link rutting, shoving and ponding to accidents. This lack of linkage may be explained by inadequate accident reporting and investigation. Severe rutting is often associated with other failures such as potholes and these characteristics are more commonly known. Rutting and shoving lead to destabilisation of light vehicles with small diameter tyres as well as motorcycles.

The proposed standard for safety for rutting is 20 mm. This value corresponds with terminal values for structural rehabilitation.

As rutting is a long-term failure, it is proposed that roads should be inspected every two years and annually when a trigger value of 10 mm is reached.

Reaction time of six months is proposed in line with other planned maintenance.

Rutting was the basis of a case that was investigated and settled out of court. The ruts were deeper than 25 mm (based on interpretation of photographs as the road had been fixed before the investigation was done) and the vehicle was a light vehicle with narrow 13 inch diameter tyres. The conclusion to be made from the settlement is that the road authority admitted that the risk of injury or damage could have been foreseen.

8.5 Standard for maintenance for potholes

Potholes are localised failures that form a specific hazard when the wheel of a vehicle drives through or over it. The narrow wheels of bicycles, motorcycles and light vehicles dictate the size and depth of these failures from a safety point of view. When the pothole can “swallow” the wheel, the risk of bending the rim, punching through or cutting the tyre is high and this can destabilise the vehicle, especially two-wheelers.

A pothole of Degree of Severity 3 in terms of the TMH9 (200 mm diameter and 25 mm deep) is proposed to be the trigger for fixing potholes and the absolute minimum standard proposed as 200 mm x 300 mm x 50 mm.

The inspection frequency for potholes is proposed as every two years for roads in good condition until weak sections are identified. Inspection frequencies must then be increased to monthly in the wet season and potholes must not be allowed to extend beyond Degree 3. A severely distressed road that continues to break up and is patched must be monitored weekly until stable and where potholes cannot be fixed within the reaction time, temporary filling must be monitored daily until permanent patches are provided.

The reaction time to fix a Degree 3 pothole is proposed to be one week.

Potholes have been the subject of numerous claims. The sizes of potholes are often the full width of the lane and as long. It is, however, the isolated potholes that surprise the driver. In McIntosh v MEC Roads and Transport, KZN Province, the adequacy of the inspections and planning of repairs were criticised and the lack of credible warning contributed to a 60% award for damages to the cyclist that swerved to avoid the pothole and fell on a guardrail. In Matshoge v MEC Roads and Transport North West Province, the road was described as despicable due to the numerous potholes and the judge remarked that any of the potholes could have caused the accident. In the case of Davenport, shoving caused the cyclist to be hurtled over the bicycle handle bar. The poor visibility of the rounded shape of the shoving was seen to be the more reason to fix such a failure before it became dangerous.

8.6 Standard for maintenance for loose material

Loose material and debris on the road are usually random occurrences. Loose gravel washing onto the road at gravel access roads on the side are, however, predictable and should be monitored. Large-size loose material such as rocks can form obstructions and fine material will affect skid resistance.

The proposed standard for loose material on the road is that it should not occur, unless it is between the proposed inspection cycles.

The proposed inspection frequency for Class 1 and Class 2 roads is weekly, which ties in with other operational safety inspections such as guardrails (in section 8.18).

Reaction time to clear the road of loose material or an obstacle is proposed as two days from either receiving a complaint or from observing it as part of inspection.

The case study of van der Merwe v MEC Roads and Transport Mpumalanga illustrates that it could have been foreseen that the gravel and sand that washed onto the road at the Bergvliet Forestry Station could be hazardous to passing vehicles, as it was in a curve.

8.7 Standard for maintenance for edge drop-off

Edge drop-off occurs at the interface of the surfaced roadway and gravel shoulder due to erosion. This is a road failure that is often the cause of accidents and claims.

The proposed standard of 50 mm is based on local and recent experience where light vehicles with small diameter wheels and low-profile tyres are found to be at risk. These vehicles were not considered in research in the US that led to the typical values of 75 mm. South African road building practice often precludes the construction of a tapered (bevelled) edge as we do not use thick asphalt surfacing on high-speed rural roads.

As edge drop-off does not develop overnight, the inspection frequency proposed is twice a year, typically in the beginning and end of the wet season when erosion occurs. Areas that are more susceptible to edge drop-off, such as where vehicles encroach on the shoulder when passing turning vehicles or on curves should be inspected more frequently.

The reaction time proposed is six months, as edge drop-off repairs are best repaired by a dedicated team with the necessary equipment for which planning needs to be done on a network basis.

Local problem areas must be done on a reactive basis until the root cause of the problem can be addressed.

The case of Esterhuizen v MEC Roads and Transport Free State Province involved a severe edge drop-off that caused the driver to swerve across the road when trying to re-enter the road after running off the road with the vehicle’s left-hand wheels. The depth of the drop-off was not mentioned, but was considered to be the cause of the accident: but for the edge drop-off the driver could have returned to the road.

8.8 Standard for maintenance for edge break

Edge break (horizontal) often follows edge drop-off as the roadway surface and base layers lose edge support and slip or break off. A jagged edge of road is more likely to cut the tyres on the wheels running onto the shoulder.

The proposed standard for edge break is 100 mm. Some pavement management systems only trigger a repair instruction if the edge break exceeds a percentage of the edge length (for example, 25%), but it is proposed that edge break be patched in an annual cycle.

The inspection frequency is proposed as twice a year, tying in with the edge drop-off inspections.

If the edge drop-off is well managed, the edge break will be limited and the reaction time can be six months to plan the remedial work at a network level.

The investigated case of Deysel v City of Tshwane Metropolitan Municipality, the road had both edge drop-off and edge break. Based on the driver’s version of events, the light vehicle not only snagged on the drop-off, but in the process of steering back, the wheel went through the edge break that destabilised the vehicle. This caused a sharp pull to the left, which he tried to correct and steered to the right where the vehicle hit the guardrail. The edge break was more than 200 mm into the road surface.

8.9 Standard for maintenance for road marking visibility

Road markings for regulation (transverse Stop and Yield lines, longitudinal barriers lines), and guidance (lane and dividing lines) are primarily white lines. The yellow lines are used as shoulder / edge markings.

The minimum retroreflectivity of white lines is typically 100 mcd/lux/m^2. This is in line with the threshold values for performance-based maintenance contracts of SANRAL. However, the availability of measuring equipment is lacking.

The proposed standard for the visibility of road markings is based on visual assessment of the paint cover of the road using the SANS 6248:2007 approach (South African Bureau of Standards, 2007). The road marking is assessed by estimating the area of the marking and the remaining percentage of paint. The standard is that 75% of the area of the marking must have at least 70% of paint left.

Painted road markings have a variable and a relatively short life-span. Immediately after construction, the volatile hydrocarbons in the bitumen will discolour the white markings and the second round of painting may be less than a year. Thereafter, the paint may last longer than a year. The inspection frequency is proposed as once a year, with the proviso that for new construction the markings are repainted in the retention period, within one year.

Road marking contracts are often planned on a network basis and the reaction time can be set for one year because the deterioration rates are known.

The legal recognition of the importance of road markings for guidance can be found in a number of cases where lines were not completed after resealing and in the case study of Herbst v SANRAL and others, the driver drove off the roadway at a lane drop at night. A pothole had developed at the point where the roadway for the additional lane stopped. The vehicle hit the pothole and the driver overreacted by steering sharply to the right, skidding off the road and hitting a telephone pole. In the case of Andrew v SANRAL and others, the lane markings on a three lane road were left uncompleted over a distance of 500 m. Drivers from opposite directions both assumed that the central lane was open to overtake and both moved into the central lane, colliding head on.

8.10 Standard for maintenance for road signs visibility and readability

Road signs have a longer useful life than road markings. It is now common practice to have a road sign inventory and management system. The sign orientation will have an influence on the life of the material, as the retroreflectivity and colour fade faster in direct sunlight. North-facing signs thus have shorter lives than south-facing signs in the southern hemisphere. Reserves of small signs are typically kept in stock, especially signs that are often hit, such as STOP signs and signs on traffic islands. These signs can then be replaced as they become unsuitable. Large signs like direction and facility signs are typically replaced in a specific road signs periodic maintenance contract.

The proposed standard for retroreflectivity, colour and durability is based on the SANS 1519-1: 2014 (South African Bureau of Standards, 2014). This is already an industry-accepted standard. The durability test requires that 80% of the prescribed reflectivity values for new material must be retained after three years of weathering outside. The proposed standard for maintenance is 75% of the new material values, measured with an approved instrument. The measurements need only be done on signs that were identified through visual assessment as nearing the end of their useful lives.

The inspection frequency for road sign visibility, which should be done at night by experienced observers, is proposed as once a year.

The reaction time is then set as one year to allow a contract for replacement to be compiled. Due to the relatively long life of signs, the quality of road signs do not deteriorate significantly in one year.

No cases were encountered involving signs with inadequate retroreflectivity. This may be due to the complex technical issues involved in proving substandard signs and lack of experts in private practice to give expert opinions.

8.11 Standard for maintenance for missing road signs

Missing signs are hazardous. In order of importance, the regulatory, warning, guidance and direction signs control and manage traffic flows on the roads.

The standard proposed for the presence of regulatory, warning and guidance road signs is 100%.

The inspection frequencies proposed depends on the road class. Class 1 and Class 2 roads should be inspected once a week. Urban and rural roads of classes lower than Class 3 should be inspected at least once a year. A customer care system must be in place to record all complaints and react in the proposed reaction time.

Signs that are overrun or stolen must be re-instated within the reaction time, which is proposed as one day for regulatory, warning and guidance signs.

Directions signs can be dealt with in terms of planned maintenance contracts or *ad hoc*. It is important that direction signs be placed in relatively safe positions, as they are large and have strong poles or gantries that are actually obstacles and hazards as such.

The case of Minister of Transport v du Toit [2006] SCA 40 (RSA) illustrates a number of problems with signs that are missing, not visible due to being obscured by other signs and are not noted due to distractions while driving.

8.12 Standard for maintenance for side drain blockages

Side drains must be kept clean of debris and vegetation. Blocked side drains can cause water to dam up on the road where ponding can cause hydroplaning or differential drag that will destabilise vehicles. They need to be checked at the start of the rainy season. Side drains in cuttings with unstable slopes are particularly vulnerable and should be inspected more regularly.

The proposed standard for side drains is that there should be no blockages in the flow of water.

The inspection frequency of six months is to align with the start and end of the rainy season. It is a formal inspection with condition assessment that is recorded and filed. The road inspectors doing weekly inspections for grid inlet covers and guardrails must, however, report on *ad hoc* blockages too.

Reaction times proposed are on two occasions: after the inspection at the start of the rainy season, blockages must be cleared in two weeks. Following the inspection after the rainy season, the reaction time is proposed as three months for planned maintenance to repair broken drains, erosion and eradicate vegetation. For *ad hoc* blockages such as rock falls, the reaction time should be one week.

No cases relating to side drains were discovered or investigated. Blocked or eroded side drains would not initiate accidents, but could contribute to the severity of the damage or injury, or prevent driver action that could mitigate the consequences of the accident.

8.13 Standard for maintenance for grid inlet covers

Grid inlet covers to manholes or drainage chambers are essential for safety in the road reserve. In instances where underground storm water pipes are required to drain water off the road or from side drains, the risk of a vehicle driving into an open manhole can be foreseen. The theft of cast iron manhole and grid inlet covers has led to many open holes. Modern composite covers are now available to counter the scourge of theft

The standard proposed is that 100% of grid inlet covers are present.

The inspection frequency for covers on Class 1 and Class 2 roads are proposed as weekly, while lower classes of road should be inspected once a year. A complaint system must be in place with contact detail for the municipality website, displayed at gateways to municipal areas and published in local print media.

Reaction time to reinstate a cover is proposed as one day after discovery following a formal inspection as well as in response to complaints, in view of the hazardous nature of an open manhole.

The case study of Mothlapudi v SANRAL and others, which was settled out of court, involved an open manhole on the loop off-ramp from the N1 to the R101 near Paarl. A routine road maintenance contract was operational and the route manager inspected the route on a daily basis. The on-ramps and off-ramps were, however, not inspected at the same frequency. The driver encroached on the sealed shoulder of the off-ramp where the side drain is situated and drove through the manhole. She then overturned the vehicle. The defendants admitted negligence.

8.14 Standards for maintenance for culvert openings and flow channels

Culvert openings and the entry and exit flow channels determine the hydraulic capacity of the culvert. The design assumptions for the flow through the pipe or box culvert must be provided at all times. Culverts can be designed to have sunken inlet conditions where the water is allowed to build up and provide more energy to push the water through. If the pipe cross section is reduced by blockage or siltation, the water will dam up higher and may over-topple the road. In the worst case, the road can be washed away.

The proposed standards for cross drainage under roads are that the culvert openings shall be open with no blockage or siltation that will reduce the design flow capacity. The stream flow channels on either side must be clear of vegetation, specifically shrubs, trees and long grass that can impede flow.

The proposed inspections will be aligned to the inspection regime of the side drains. The proposed frequency of six months is to align with the start and end of the rainy season. It is a formal inspection with condition assessment that is recorded and filed. The road inspectors doing weekly inspections for grid inlet covers and guardrails must, however, report on *ad hoc* blockages too.

Similar to the side drains, reaction times proposed are on two occasions: after the inspection at the start of the rainy season, blockages must be cleared within two weeks. Following the inspection after the rainy season, the reaction time is proposed as three months for planned maintenance to clean culverts and flow channels.

The case that this researcher investigated in 2014 that illustrates the problem of poor culvert and stream flow channel inspections occurred in Mpumalanga where a corrugated metal culvert rusted through due to acid rain in the area where coal-fired power stations are situated. The culvert buckled when a severe rainstorm built up a dam on the upstream side of the road and eroded the fill material first from the bottom of the rusted culvert and then from the sides. The fill over the culvert then collapsed the roof of the culvert and the culvert was washed 100 m down towards a dam. The water left a square trench 10 m wide perpendicular to the road, into which three vehicles rode and 11 people in the first vehicle, a taxi, drowned.

8.15 Standard for maintenance for roadway flow path drainage

Roadway drainage is designed in such a way that on a straight section of road the cross fall sheds the water to the outside of the roadway. In a curve, the cross fall rotates into superelevation to assist the vehicle in resisting the centrifugal forces generated in the curve. This results in a point where the road has no cross fall. In combination with the longitudinal gradient, this results in a diagonal flow path. This flow path can become so long that the water flow becomes deep enough to cause hydroplaning, especially on wide divided roadways.

The only way to mitigate this inherent hazardous flow condition is to provide sufficient macro-texture to enable water to dissipate under the tyres. The standard for maintenance of the road surface in the crown and superelevation runoff then becomes the same as for macro-texture, which is 0.5 mm of estimated texture depth, inspected every two years and considered for planned maintenance to reinstate macro-texture before the 0.5 mm value is reached.

The problem of long flow paths on freeways manifested in two cases on the M1 at Greystone Interchange in Sandton, Johannesburg and at N1 near the John Vorster Road Interchange in Centurion. In both cases the on-ramps joined the three and four through lanes respectively at or near the inflection point and the water flowed outwards and returned inwards at the widest cross section. In both cases the longitudinal gradient is flat and downwards. As the vehicles entered the curve to the right in the inside lane, they encountered the building up of sheet flow. As the film of water became thicker, a partial hydroplaning and slip to the left developed and the drivers over-steered to the right to keep to the lane. As the vehicles then exited the sheet flow to an area of normal drainage, which was relatively drier, the tyres, at an over-steered angle, gripped suddenly and the vehicles swerved violently to the right and hit the concrete barrier on the median side.

8.16 Standard for maintenance for road edge drainage

The gravel shoulder of rural roads often gets a ground cover of various weeds and grasses. This can build up to a height above the road surface and acts as a kerb to guide water along the edge of the roadway. Shoulder maintenance becomes a fine balance between allowing the vegetation to stabilise the gravel and prevent erosion and keeping the vegetation lower than the road surface. Water can accumulate on the shoulder and encroach towards the travelled lane. Driving with the tyres on one side in water and the other on a relatively drier surface results in differential drag and can destabilise a light vehicle with wide-low profile tyres and an inexperienced driver.

Drainage from the roadway onto the shoulder must be possible at regular intervals to prevent the build-up of water on the road edge. This can be done by means of constructed down chutes or openings in the vegetation that are lower than the road surface.

The proposed standard is no blockage of down chutes or required openings.

It is proposed that the shoulder vegetation be inspected at least once a month in the rainy season and the reaction time be within a week.

In cases study of de Beer v Premier Mpumalanga Province blockage of the edge drainage on the road between Dullstroom and Lydenburg in Mpumalanga led to the accumulation of a significant flow of water. It bypassed four down chutes that were blocked with vegetation. The last down chute to the left was at the beginning of superelevation for a curve to the right. The problem of the sheet flow rotating back as described above then resulted in a deep layer of water on the road. A vehicle driving downhill hit the sheet flow and the hydroplaning caused the vehicle to move tangentially in the direction of the momentum vector. The driver oversteered to the right and when the vehicle moved through the sheet flow. It swerved violently to the right and hit an oncoming vehicle head on.

8.17 Standard for maintenance for the clear zone

The clear zone or recovery area is founded on the forgiving roadside philosophy. Encroachment onto the shoulder and verge of the road is acknowledged as part of the human limitations for which the engineer designs. This zone must therefore be kept clear of any unnecessary roadside furniture, trees and obstacles. The roadside furniture, such as signs that are necessary, must be placed on frangible poles and other non-removable obstructions made safer with barriers.

The maintenance standard proposed is that no unauthorised objects, signs or trees be allowed to be located in the clear zone.

The proposed formal inspection frequency is one year but the maintenance teams looking at guardrails and other weekly items can prompt an intermediate reaction that should be attended to within a month.

The investigated case of Boshoff v Bombela involved a guardrail that was partially taken down for the construction of a slip lane in Hatfield, Pretoria. The terminal was not secured and the W-shaped steel barriers hung suspended above the ground. The driver drove wide through the curve to the left and encroached onto the right-hand side median where the guardrail then penetrated the vehicle, killing him.

8.18 Standard for maintenance for roadside barriers

Roadside barriers include guardrails of all types, their terminals and bridge balustrades. These safety appurtenances are erected where a risk of danger has been identified. Guardrails that are hit often prove the point. The maintenance of roadside barriers for safety should be high priority.

The proposed standard for functionality and availability is therefore set at 100% repaired within the reaction time.

The inspection frequency proposed should vary from more than once a day on a Class 1 road, such as the N1 between Cape Town CBD and the Koeberg interchange carrying more than 140 000 vehicles per day, and the N1 between Johannesburg and Pretoria, south of Allandale interchange, carrying more than 220 000 vehicles per day, to once a week on a rural Class 2 road carrying 2 000 vehicles per day. As a guideline for roads other than national roads under the authority of SANRAL, an inspection frequency of once a week is proposed for all Class 2 and Class 3 roads.

The importance of barriers forces a reaction time of one day, as the location of the accident could be due to a systemic safety problem on the road.

8.19 Standard for maintenance for highway trees

Maintenance strategies for highway trees may be directed at an urban / low-speed environment and a rural / high-speed environment. A low-speed environment is taken as having speed limits below 80 km/h. The urban / low-speed environment can tolerate roadside trees for edge definition in conjunction with kerbs and the esthetical value of tree-lined roads. The rural / high-speed category defines the speed regimes and driver expectation that is not commensurate with trees in the clear zone or recovery area. Landscaping and greening of rural roads should be done using local shrubs, such as fynbos in die Western Province.

The proposed standard for maintenance of highway trees is to eliminate trees in the clear zone. Trees outside the clear zone but within or bordering the road reserve should be trimmed and topped to a height that is less than the distance from the road. The health of any tree in the road reserve not topped and trimmed back has to be assessed and certified by a qualified arborist once a year. A tree management plan can then be used to manage the trees within the proposed response time of 12 months.

The case of Botha v MEC Roads and Transport Eastern Cape Province involved a tree outside the road reserve that was blown over in cyclonic conditions and landed on the road. A vehicle drove into a branch that penetrated the cab of the vehicle and killed the driver. The finding of the court was *inter alia* that the road authority must look out for the safety of the road users even from threats of trees from outside the road reserve.

8.20 Standard for maintenance for vegetation affecting lines of sight

Vegetation that can interfere with line of sight, albeit stopping or intersection sight distance, must be trimmed or removed to satisfy the design assumptions of the road.

The standard proposed is that all vegetation in these critical areas be reduced and maintained at less than 1 m height.

The inspections should be done on a monthly basis and reaction time of one week is proposed to eliminate the risk.

The case of Gerber v MEC Roads and Transport of Western Cape Province involved a pedestrian that walked on the median of a freeway hidden from sight by the median shrubbery that was at least 1.5 m high. A motorcyclist travelling in the fast lane had no time to react when the pedestrian stepped in front of him. Although the judgement was not in favour of the claimant, the reasonable measure would be to trim the vegetation to below 1 m as the function of the shrubbery is to shield drivers from glare of the opposing traffic. The height of a typical passenger car headlight is 600 mm.

8.21 Summary of synthesis

The following table summarises the proposed standards for the selected characteristics and processes for maintenance for safety of road infrastructure for South African conditions.

Table 8- 1: Standards for maintenance for safety of road infrastructure

Category	Feature	Characteristics	Standard	Inspection frequency	Maintenance type	Response time: fix within
Roadway	Lane and surfaced shoulder	Texture on roads with operating speed > 80 km/h	0.5 mm estimated texture depth	Two years	Planned	6 months
		Skid resistance on road with operating speed < 80 km/h	0.45	Two years	Planned	6 months
		Rutting and ponding	20 mm depth	Two years	Planned	6 months
		Potholes and shoving	200 mm x 300 mm x 50 mm depth	12 months	Reactive	One week
				One month if distressed		One week
				Daily if not fixed		One day for temporary fix
		Loose material	No loose material	One week	Reactive	2 days
	Gravel shoulder	Edge drop-off	50 mm	12 months	Routine	6 months
		Edge break	100 mm	12 months	Routine	6 months
Traffic control	Road markings	Visibility	70% residual paint on 75% of area	12 months	Planned	12 months
	Road signs	Visibility and readability	75% of new values per class of reflective material	12 months	Planned	12 months
		Missing signs (regulatory, warning and guidance)	No missing signs	One week for Classes 1 and 2	Reactive	One day
					Planned	One week
				12 months for other classes complaints	Reactive	One day
Drainage	Side drains	Blockages	No blockages	Six months Aligned with rainy season	Planned	Six months
				Complaints	Reactive	One week
		Grid inlet cover	100% in place	One week	Reactive	One day
	Cross drainage	Culvert openings	100% open: no siltation	6 months Aligned with rainy season	Planned	Six months
		Flow channel	No shrubs or trees	12 months	Planned	Six months
	Roadway drainage	Flow path texture	0.5 mm	12 months	Planned	12 months
		Edge drainage	No blockage of down chutes	One month in rainy season	Routine	One week

Category	Feature	Characteristics	Standard	Inspection frequency	Maintenance type	Response time: fix within
Roadside	Clear zone/ Recovery area	Designed width	No unauthorised objects, signs or trees in designed width	12 months	Routine	One month
	Barrier	Guardrail and terminals	No damage	One week	Reactive	One day
		Bridge balustrade	No damage	12 months	Routine	Six months
	Vegetation	Highway trees	Height less than distance from road Tree health certified	12 months	Planned	12 months
		Lines of sight	Stopping sight distance Shrubs and grass height < 1 m	One month	Routine	One week

8.22 Prioritising maintenance per class of road

The application of the proposed standards for maintenance will require funding and resources that may not be available in the short term for all road authorities. SANRAL already has routine road maintenance contracts on all of its roads and many of the standards proposed are incorporated. SANRAL can adopt new standards for safety based on the proposed standards or further developed in the transport industry within the existing contracts or when the contracts are renewed. Provincial and metropolitan municipality road authorities typically have pavement management systems in place that can be expanded to include management systems for road safety. They control the road network with high-traffic volumes. These road authorities should set up timetables for implementing such safety management systems, giving priority to routes and roads with a high accident history.

The limitations of Class C and Class D municipalities have been discussed and their lack of technical staff and resources has to be taken into account. The implementation of safety management systems can be developed in line with the Asset Management Systems required under the Treasury regulations such as GRAP 17 (Department of National Treasury: Republic of South Africa, 2014).

8.23 Reasons why existing standards are not maintained

The reasons why accepted engineering standards (especially safety-related maintenance requirements) are not diligently applied in the maintenance of roads are varied and not the same for different road authorities. However, the result is that roads are not always kept in a reasonable state of repair.

The use of the term standard is not standard. Confusion is caused by some standards being compulsory, others only enforceable in contract and others only used as guidelines. The meaning of the term ''standard'' is very wide, as can be seen from the ISO definition that restricts it to a document, while the attribute of a characteristic can also be described as a standard value:

> A standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose (ISO, n.d.)

In the road maintenance field, the definition is formulated as:

> *Standards*: A standard is a criterion for determining whether a characteristic or feature requires maintenance attention. A standard can be thought of as a tolerance level that helps identify whether a feature is functioning as intended. Standards may also help identify the particular aspect of the feature that should be measured. (Smith & Adams, 2006).

Road authorities, through the eyes of their employees, often do not apply the industry standards as found in codes of practice, guidelines, manuals or specifications as compulsory, especially if it is not specifically called a standard. Officials then fail to see the seriousness of road features not complying with good practice or to reasonable safety, as evident from the testimony of the Gauteng Roads Maintenance Supervisor in the Schulz case. A number of competent road inspectors in the UK failed to see hazardous conditions due to inattention or poor procedures or inappropriate time intervals – as is evident from the cases discussed above.

A strong and recurring theme in the reasons for not doing adequate maintenance is inadequate funding. South Africa is not unique in this regard, as road is public good and the political process will rather allocate funds to social needs and new projects than to maintain roads that may still look functional to the untrained eye.

The research by the Municipal Demarcation Board and SAICE also highlighted the lack of skills that are especially endemic at provincial and local municipality level.

A lack of knowledge of administrative and common law has been identified as a limitation in the education of engineering professionals.

The poor road safety situation in South Africa also contributes to the perception that the roads are in a poor condition.

Employees of road authorities are not held responsible for road safety failures are they are protected by vicarious liability.

Chapter 9: Conclusions and recommendations

9.1 Summary of findings

South Africa has a road safety problem that results in nearly 14 000 fatalities per year. Societal expectations as expressed in public policy include the demand to reduce road fatalities, injuries and damage. The target set in the South African Road Safety Strategy 2011–2020 (Department of Transport, 2011) to halve the 2010 fatalities of 15 000 by 2015 was not achieved.

The road is one of the factors that contribute to accidents, along with human and vehicle factors. Inadequate road maintenance plays a dominant role in accidents caused by road factors. Safer roads can lead to a reduction in accidents.

Road authorities are mandated to provide, operate and maintain transport infrastructure. As public bodies, they are obliged to manage these assets to accounting standards that ensure functionality and limit risks of failure, loss of value and claims. The provision of new infrastructure is discretionary but maintenance of existing assets is obligatory.

A legal duty to keep roads in reasonable safe condition has been confirmed in statute, policy and case law. The duty to protect public health and well-being is also based on rules of ethical conduct for registered persons in the engineering profession. The sources of information on road safety include design guidelines and maintenance manuals.

Standards for maintenance of road infrastructure for safety have not been developed. This is due to *inter alia* the concern of road authorities of not being able to uphold such standards, of more claims for damages and lack of knowledge of legal duty.

Effective control of engineering products and processes are against specifications and standards. Standards are required for measurable characteristics of the road elements and procedures for inspection and response. Road maintenance standards, specifications and guidelines do exist, but are not comprehensive with respect to safety. The performance of the maintenance for safety is not formalised and needs to be elevated to the level of standards.

Examples of guidelines, codes of practice and management systems from developed countries provide norms for a wide range of aspects and values that could be incorporated into standards.

Professional road design is the ability to foresee and optimise the conflicting objectives that are to be achieved, of which safety is the prime consideration. The road safety crisis in South Africa is partially due to the severe shortage of competent road engineers and the risk of unskilled persons occupying technical posts in road authorities.

The lack of technical capacity and resources requires that the characteristics selected for the development of standards in South Africa be simple, effective and implementable. The expansion of standards to more characteristics can be done as road authorities become more familiar with the implementation of standards and funding becomes available to maintain roads to a higher standard of service.

Claims for damages against road authorities as evident in cases decided by the courts and from investigations conducted as case studies provide good indications of the characteristics and procedures that need to be standardised first.

A synthesis of values and processes for the selected road maintenance characteristics produced a list of proposed standards that could be used as a basis to formalise and institutionalise road infrastructure asset maintenance management.

9.2 Conclusions

The condition of roads plays a significant role in the road safety problem in South Africa. A dire lack of maintenance has developed over decades where spending on new roads and other infrastructure have taken precedence. The contribution of the road to the nearly 14 000 fatalities on our road is less than the contribution of human factors. Notwithstanding the fact that most accidents are caused by human factors such as negligence, it is acknowledged that reductions in the road factors could prevent the sum of all the contributory factors from exceeding a critical value, thus preventing or mitigating the consequences of accidents.

Infrastructure asset management in the public domain is mandated by treasury guidelines and general requirements for accounting practices, in particular GRAP 17: Property, Plant and Equipment (Department of National Treasury, 2014). The demand for compliance with these requirements will escalate as the government needs to spend its resources more effectively and reduce risk of failure and claims for negligence.

The legal duty to provide and maintain safe road infrastructure stems from statutory requirements, policy and precedents. This legal duty towards road users should apply to the road authority unless there is a valid basis for its exclusion. Various cases established that the condition of the road must conform to reasonable acceptable norms for the reasonable road user and such norms must be determined from the industry best practice.

The development of standards from norms as used in practice is a process of formalisation and institutionalisation of best practice in the interest of society.

Maintenance standards can cover a wide range of road features. In this research, critical features were identified from:

- Literature that indicates the causes of accidents and claims;
- features that are recorded in condition assessments; and

- case studies.

Standards are proposed in terms of values of characteristics and procedures to ensure safety.

The critical characteristics that influence maintenance for safety are found in the four categories of roadway, namely, roadway elements, traffic control, drainage and the roadside:

- Roadway elements of the travelled lanes, and surfaced and gravel shoulders have characteristics that lend themselves to quantification. Minimum or maximum values could therefore be proposed;
- traffic control elements of road markings and signs have existing SANS standards for colour and reflectivity, which should be enforced and procedural standards for inspection and replacement are added;
- drainage features such as side drains, cross and roadway drainage must be maintained to standards that ensure that the design conditions are met; and
- roadside maintenance standards are procedural and aimed at ensuring full functionality of the designed clear zone and preventing new obstacles to be established. The concept of a highway tree is introduced as any tree, even outside the road reserve, that can affect traffic, and it must be controlled by the road authority.

The proposed standards are suggested to form the basis of a position paper for the Roads Coordinating Body (RCB) of the Committee of Transport Officials (COTO) to be developed into an industry-accepted code of practice.

9.4 Reasons for road authorities' failure to execute maintenance duties

The reasons for road authorities failing to execute their maintenance duties based on current knowledge of standards, guidelines, specifications and good practice, are varied and complex. Table 9-1 gives a summary of the reasons that were identified in the literature, cases and synthesis.

Table 9- 1: Reasons for road authorities' failure to execute maintenance duties

	Cause	Example statements
	Maintenance code of practice The lack of a maintenance code of practice for road authorities with explicit and adequate engineering standards and minimum specifications and threshold levels for intervention to prevent deterioration of safety conditions for maintenance of roads, available in a structured framework for proper reference.	Comprehensive standards for maintenance of road infrastructure for **safety** have not been developed. This is due to *inter alia* the concern of road authorities for not being able to uphold such standards, of more claims for damages and lack of knowledge of legal duty. Failures of road safety occur because road authorities' intuitive norms and rules of thumb are not always codified and adhered to in a consistent and measurable way. Norms and standards are presently scattered in guidelines, manual and directives. Published norms and standards must be collated and interpreted, and confirmed to expand the body of knowledge into a comprehensive suite of practice guidelines.

	Skills constraints; Lack of skills and competence; Lacking qualifications and experience Technical managers lack engineering qualifications and experience to properly supervise maintenance of roads. **Loss of key technical staff**: Key staff are often not replaced or they are replaced by less qualified staff. The South African Institute of Civil Engineering revealed that 79 of the 231 local municipalities had no civil engineers, technologists or technicians on their permanent staff (SAICE, 2011).	South Africa has, by proportion of population, up to twenty times fewer engineers than Australia, America, Western Europe, and even India or China. Furthermore, the racial and gender balance is overwhelmingly white and male and close to retirement. This crisis compounds slow delivery of basic services through its effect on the engineering profession that provides this infrastructure. A comprehensive municipal skills survey was undertaken by SAICE in 2007. Of all 283 municipalities surveyed, 83 had no civil engineers, technologists or technicians on staff. A further 48 employed only one civil technician, and municipalities with civil engineering staff reported 35% vacancies (over 1000 professionals), often owing to budget constraints. It is clear that much of local government is indeed in distress, and that this state of affairs has become deeply rooted within our system of governance. A recurring theme is the inadequate capacity of service providers to fulfil their responsibilities. Delivering and operating new infrastructure are complex activities but competent skilled persons are in short supply, especially in rural areas. The lack of competent and experienced practitioners, especially within management levels, results in standards not being applied. The standard operating procedures are based on the collective wisdom and technical knowledge of the industry. The road safety crisis in South Africa is partially due to the severe shortage of competent road engineers and the risk of unskilled persons occupying technical posts in road authorities. A 2006 survey observed that many municipalities lacked the capacity simply to answer the survey questionnaire, implying that they would be similarly incapable regarding roads maintenance and management (SAICE, 2006)
	Negligence Negligence in road maintenance: Routine safety inspections are neglected, problems identified are not rectified, poor workmanship, lack of quality assurance on road maintenance Keeping to reaction times as dictated by urgency (the extent of hazard to safety) and importance of the road. (Response times to react to hazardous conditions) Excessive reactive maintenance increases risk	Failures of road safety occur because road authorities often neglect supervision of maintenance due to incompetence or complacency. There are rarely consequences for failure of road maintenance, even though “maintenance of existing assets is obligatory”. Potholed roads have become the rule, especially in the northern provinces. “The Team is required to inspect the site frequently so that problems are identified, the causes investigated and assessed and the actions required identified and carried out timeously. Obvious problems should be noted as soon as they become evident and serious situations should be reacted to and reported immediately (SANRAL 2009:2-2).” Neglect is also costly in financial terms - for example,

		roads maintenance that is delayed for one year could cost three to six times more when there is eventually no choice but to do it (SAICE, 2011).
	Lack of funding for road maintenance. Poor planning, execution and control of the budget for road maintenance. Inappropriate prioritisation in allocating budgets: Prioritisation of new infrastructure happens at the expense of maintaining existing assets. Maintenance budgets: These are often treated as discretionary budget line items and are the first to be cut to realise savings.	Failures of road safety are exacerbated by inadequate funding through the politicised process of budgeting within government. **Prioritise**: Current funding available for roads and storm water infrastructure is insufficient for meeting existing maintenance and rehabilitation requirements in the sector. There is therefore a need for reprioritisation on municipal budgets to effectively deal with its core services and manage competing needs. To utilise the limited budget in a reasonable and logical manner, it is accepted practice that high-volume, strategic and economically important roads are prioritised over lesser roads. The allocation of maintenance funding is, with very few exceptions, simply not sufficient, especially in circumstances where it is expected to also cater for a maintenance regime that has led to neglect.
	Lack of integrated asset management Lack of planning, implementation and control of Treasury guidelines on roads-related asset management, including regular audits. The lack of understanding that all aspects of road maintenance must be implemented in an integrated way to meet acceptable standards to provide a safe road infrastructure. There is a lack of implementation of **road maintenance systems** and **asset management systems**.	Infrastructure asset management in the public domain is mandated by treasury guidelines and general requirements for accounting practices, in particular GRAP 17: Property, Plant and Equipment A full inventory and condition register of all public capital works such as buildings and roads must underpin maintenance programmes. The requirements of public asset and risk management have become part of government obligations and are subject to auditing. Lack of asset lifecycle planning capability: Maintenance of roads and storm water infrastructure is mainly done on an ad hoc basis as there is no proper base for planning and budgeting for planned maintenance of infrastructure. The importance of life-cycle costing has already been mentioned, but cannot be overemphasised. A 2007 DoT survey observed that of the municipalities that did reply, only 36% indicated some form of a road management system (SAICE, 2011)
	Road authority legal duty not prescribed The South African legal system has defined the legal duty of the road authority but road authorities do not motivate for resources on this basis or take the judgments as prescriptive. The political will to reduce road fatalities and accidents is not matched by resources. Policy and legislation promoting road safety with regard to road maintenance aspects.	South African courts treat each case on its merit, preferring to neither prescribe the legal duty nor the standards of care in provision or maintenance.

	Lack of legal duty understanding within the engineering community The lack of understanding of the legal duty of the road authority within the engineering community (the road authority is responsible to provide a safe road).	South African engineering education does not incorporate a course in legal aspects that affect the engineer. Engineers working for road authorities are often ignorant of the legal duties that society imposes on them and how their work is viewed by the legal profession. Engineers often do not communicate effectively as a result of being unfamiliar with the terms and processes.
	Deterioration of the provincial and municipal road network The condition of the road network is deteriorating due to a backlog of road maintenance. Due to the country's size, the extended South African road network is a substantial asset to be maintained comprehensively and successfully.	SANRAL estimates (2010) the South African road network comprises some 606 978 km plus 140 000 km of unproclaimed roads in the rural areas for a total road network of 746 978 Km. This data indicates that the proportion of paved provincial and national roads in a poor or worse condition now constitutes nearly 20 per cent of the paved road network. The efficiency of the Provincial Road Maintenance Grant has not been researched.
	A dearth of data pertaining to infrastructure – and the problem seems to worsen. Reliable, consistent data is a prerequisite for the urgently required shift to routine maintenance. Data permits planning, prioritisation of targets and adequate budgeting for maintenance and extension.	There is extreme variation in the availability of information and condition of roads both between spheres of government and between geographical areas (SAICE, 2011): Road condition data is available for **82% of provincial roads**, but extrapolation suggests that well over half of these roads have exceeded their design life, rendering them highly susceptible to rapid, costly deterioration in many sections. For **metropolitan** roads, condition data is available for **64%** of the network. **Municipal roads** are not well managed, with road **condition data available for only 4% of these**, and much confusion regarding municipal coordination and responsibility.

9.3 Recommendations

It is recommended that:

- The Roads Coordinating Body (RCB) of the Committee of Transport Officials (COTO) of South Africa set up a committee to investigate development of standards for maintenance;
- research on economic cost of claims against road authorities be done;
- empirical research on delictual liability of road authorities be done;
- research into awareness among road authority officials of the duties towards safety be done;
- research on risk assessment of road infrastructure safety with a focus on maintenance features and characteristics be done;
- academic education and in-service training be provided on the duties of the road authorities by developing undergraduate module content, postgraduate module content and continued professional development courses.

- practice guidelines or codes of practice, with clear distinction between compulsory standards, standards based on best practice and reasonableness and guidelines be compiled; and
- in service training and capacity building, to bring knowledge and skills to the engineering professionals already in the work place.

9.4 Summary of contributions

The research leading to this dissertation resulted in two conference presentations at the International Road Federation / South African Road Federation conference in Somerset West in 2010, titled "Preserving functionality of and safety on Africa's road network" and "Road transport safety in the maintenance environment".

Presentations at the Southern African Transport Conference in Pretoria were titled "Maintenance and claims for damages" (Roodt, 2014) "Skid resistance of roads contaminated with gravel" (Roodt, 2013) and "Managing trees in road reserves for road safety" (Roodt, 2012). A presentation titled "The municipal engineer as good parent" was given at the Institute of Municipal Engineers of South Africa (IMIESA) in 2015.

A peer-reviewed paper titled "Engineering for road safety" was published in the Higher Education Department accredited journal IMIESA (Roodt, 2014).

9.5 Future research

The area between the law and engineering offers a wealth of research opportunities. The quantification of the claims against road authorities, split into claims received, rejected, and paid at a discount, decided in court and legal costs is an obvious starting point. Empirical research should also be done into the community's views of the legal duty of road authorities, the legal process of claiming for damages and the quantum of damages.

The field of road infrastructure asset management is still in a development phase in South Africa and the implementation, adaptation and evaluation of systems calls for research. Maintenance is an important aspect of asset management. Standards for maintenance of roads are not formalised. Risk management as a component of asset management, with an impact on safety, has not been explored.

The expansion of standards for maintenance into a wider range of characteristics of roads that affect safety is needed. These standards can form the basis of a comprehensive suite of practice guidelines.

The impact of road geometric and pavement design on maintenance aspects that could lead to hazardous conditions need to be explored under local conditions and design approaches.

The change of the Road Accident Fund into the proposed Road Accident Benefit Fund that will introduce a no-fault system with reduce benefits for accident victims may lead to more accident victims electing to claim from the road authorities.

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