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SAFER ROADSIDES AND ROADSIDE SAFETY MANAGEMENT IN SOUTH AFRICA:

BREAK-AWAY/FRANGIBLE POLES
and
KILOMETRE MARKERS

March 2024

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The Department of Transport

DECADE OF ACTION FOR
ROAD SAFETY
2021 - 2030

Road Traffic
Management Corporation

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ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
CoC	Cost of Crashes
COTO	Committee of Transport Officials
DSS	Draft Standard Specifications
EN	European standard
FARS	Fatality Analysis Reporting System
HTRU	Heavy Towing and Recovery Units
IIHS	Insurance Institute for Highway Safety
IRU	Incident Response Units
LTRU	Light Towing and Recovery Units
MASH	Manual for Assessing Safety Hardware
MRU	Medical Response Units
MUTCD	Manual on Uniform Traffic Control Devices
NHTSA	National Highway Traffic Safety Administration
NRSS	National Road Safety Strategy
NRSSC	National Road Safety Steering Committee
NRTETC	National Road Traffic Engineering Technical Committee
RAPSA	Risk Assessment Process South Africa (2022)
RoR	Run-off-the-road (accidents)
RTMC	Road Traffic Management Corporation
SADC	South African Development Community
SAMOAC	South African Manual for Outdoor Advertising Control
SANRAL	South African National Roads Agency Limited
SSA	Safe System Approach
SARSAM	South African Road Assessment Methods (2022)
SARSM	South African Road Safety Manual (1999)
SARRSM	South African Road Restraint System Manual (2022)
SARTSM	South African Road Traffic Signs Manual
SER	Self-explaining roads
TMH	Technical Methods for Highways
TRH	Technical Recommendations for Highways
UNDoA 1	United Nations Decade of Action for Road Safety (2011 – 2020)
UNDoA 2	United Nations Decade of Action for Road Safety (2021 – 2030)
WCLT	Wide Centre Line Treatment

SUMMARY

In 2018 the National Road Traffic Engineering Technical Committee (NRTETC) resolved the need to review, and update associated road safety engineering policies, procedures, and guidelines to incorporate Safe System principles in support of improved road safety. The decision to review sections of the South African Road Safety Manual 1999 the main reference document (SARSM) 1999 has resulted in the review of a series of documents to address road safety with particular focus on understanding the cost of crashes to the country, the setting speed limits in South Africa, a review of the outdoor advertising requirements as well as a review of methodologies to assess road safety on existing and new roads. A new methodology (Road Assessment Procedure South Africa) for assessing roadside risk also resulted from these reviews.

This document provides baseline information in support of motivating for a review of the SARSM 1999 Volume 6: Roadside Hazard Management which was developed to provide a best-practice guideline document regarding the management of the roadside and median area to reduce the severity of roadside crashes. A review of literature across various countries was undertaken to gain a comprehensive insight into best practices for enhancing roadside safety. By examining strategies implemented globally, it was possible identify diverse approaches and assess their effectiveness in different contexts.

This review considers best practices, in line with the Safe System Approach to improve roadside safety and elements required for the provision of more forgiving and safer roadsides (e.g., breakaway support technology) to minimise the impact and severity of crashes. Recent and historical studies focus on the performance of frangible or breakaway poles under various conditions, such as their impact resistance, durability, and effectiveness in improving roadside safety.

The term ‘road traffic crash’ is intentionally aligned with the definition as in ANS/ISO 39001 and is used throughout this report. ‘Road Traffic Crash’ imparts the same meaning as “accident” noted in the National Road Traffic Act, Act 93 of 1996. Where citations are noted, and the term ‘accident’ were used in the published work, the term ‘accident’ was not changed.

1. INTRODUCTION

1.1. Background

The National Road Traffic Engineering Technical Committee (NRTETC) resorts under the National Road Safety Steering Committee (NRSC). The NRTETC consists of road traffic engineering officials from the National Department of Transport (DoT), the South African National Road Agency (SANRAL), the South African Local Government Association (SALGA), the nine (9) provincial road authorities and the eight (8) Metropolitan Municipalities. The function of NRTETC is to coordinate road traffic and safety engineering amongst the three spheres of government and identifies the need for engineering related research and updating of road safety related standards and guidelines.

In 2018 NRTETC resolved that various road safety engineering policies, procedures, and guidelines needed review and updating to incorporate Safe System principles in support of improved road safety. This has resulted in the commissioning of a series of documents formulated with defined objectives to:

- address user behaviour (research on improved behaviour on South African roads)
- assess or audit road safety conditions,
- identify areas that require improvement and provide guidance to improve road safety on the South African road network.

1.1.1. Cost of Crashes 2016 methodology

In 2015 the Road Traffic Management Corporation commissioned a review of the 2004 Cost of Crashes (CoC) methodology which was previously developed by the Department of Transport. CoC 2016 methodology is organised to support the 'Safe System' rollout and the achievement of road safety 'results focus'. The Safe System concept embraces long term goals to eliminate death and severity. By setting of interim targets, exacting intervention strategies and the need for strengthened institutional management systems. With emphasis on institutional road safety management the SSA (ERSO, 2008):

- Builds on existing road safety interventions but reframes the way in which road safety is viewed and managed in the community.
- Addresses all elements of the road transport system in an integrated way with the aim of ensuring that crash energy levels are below what would cause fatal or serious injury.
- Requires acceptance of shared overall responsibilities and accountability between system designers and road users.
- Stimulates the development of the innovative interventions and new partnerships necessary to achieve ambitious long-term targets.

Understanding the cost of crashes to society and the impact crashes have on a middle income (developing) country such as South Africa, is important to facilitate socio-economic development and to eradicate poverty. In addition, understanding the Cost of crashes assists with prioritising efforts and with the allocation of already scarce resources. The CoC 2016 (since updated yearly) therefore assists:

- To inform national resource planning to ensure that road safety is ranked equitably in terms of investment in its improvement.
- To internalise the impact of road system failure by an expression of tangibility, achieved through appropriate monetisation of all elements of the societal burden of road traffic injuries (RTIs) and road traffic crash (RTC) damages.
- To ensure that the best use is made of any investment in road safety and to ensure the introduction of the most appropriate road safety improvements in terms of the benefits that they will generate in relation to the cost of their implementation.

1.1.2. Setting of speed limits in South Africa

Research on effective speed management indicates that the speed limits on urban roads should not exceed 50 km/h. Traffic calming measures have shown to be effective at reducing road traffic injuries and can be implemented at the sub-national level as needed (Road Traffic Management Corporation 2020).

As indicated earlier, there is a strong relationship between speed and crash risk and outcome severity in the event of a crash. Moving vehicles is a source of kinetic energy which causes injury when collisions take place. Higher speeds mean more kinetic energy and more severe injury in the event of a crash, regardless of the cause and injuries sustained from a high-speed crash and will be more severe than at lower speeds (Road Traffic Management Corporation 2020).

The National Road Safety Strategy, 2016 – 2030 (NRSS) states that speed limits in South Africa are not tailored to road environment and not aligned to international best practice. The NRSS sets the objective to intensify efforts to deal with speeding and determine appropriate speed limits (Road Traffic Management Corporation 2020). Internationally, speed limits have been reduced over the years in line with Safe System principles, and a review for setting speed limits has been carried out in South Africa (Van As 2022). The setting of speed limits in South Africa will be guided by Chapter 22 of the South African Road Traffic Signs Manual (Van As 2022).

1.1.3. Outdoor advertising and its effect on inattentive and distracted driving (Chapter 21 SARTSM)

The Road Traffic Management Corporation (RTMC) through the NRTETC and its subcommittees and working groups in 2018 identified the need for research on the effect of outdoor advertising on road safety. In addition, it was resolved that the South African Manual for Outdoor Advertising Control (SAMOAC) 2010 needed to be amended to refer to a national technical document that directs road safety matters as far as outdoor advertising is concerned.

This research aimed to address the shortcomings with respect to road safety engineering and management, apart from also considering amendments to address some of the most cumbersome inconsistencies in the SAMOAC document and to, informed by the outcome of the research provide an updated SAMOAC document, with a newly compiled road safety engineering manual with respect to outdoor advertising, provide for appropriately regulated outdoor advertising according to prescribed minimum standards.

Guidelines for Outdoor Advertising will be published in South African Road Traffic Signs Manual. Volume 2 Road Traffic Sign Applications Chapter 22 Outdoor Advertising.

1.1.4. South African Road Safety Assessment Methods (SARSAM 2022)

The RTMC, again through the NRTETC, identified the need and commissioned a review of the South African Road Safety Audit Manual (SARSAM 2012) in 2017/18. The revision of SARSAM 2012 recognises the extensive development of methodologies and guidelines aligned with the Safe System Approach and facilitates the improvement of road infrastructure safety performance. The revision resulted in the South African Road Safety Assessment Methods – SARSAM 2022 (proposed Technical Recommendations for Highways TRH 29). SARSAM 2022 considers road safety research and practices that have come to the fore since publication of SARSAM 2012 and acknowledges international trends to develop road safety engineering manuals as multi-part documents focusing on specific aspects. These aspects include screening of the road network to identify sites which hold potential to be improved by subjecting them to formal road safety assessment and inspection processes.

Experience gained in Network Screening and Road Safety Assessment processes has also been incorporated to address deficiencies and/or to repackage the document to provide a more pragmatic approach for network level assessments in South Africa. Guidance is provided for road safety audits on upgraded or proposed/newly opened roads. SARSAM 2022[1] consists of three volumes, namely:

Volume 1: Network screening	• Network screening principles
Volume 2: Road Safety Assessment	• *Network Level Assessment* • *Road Safety Inspection*
Volume 3: Road Safety Audit	• *Part A - RSA Management: Policy and Procedures* • *Part B - Conducting Road Safety Audits*

1.1.5. South African Road Restraint Systems Manual (SARRSM)

The South African Road Restraint Systems Manual (SARRSM) 2022 provides a uniform approach to the assessment, evaluation, prioritisation, and design of road restraint systems across all road networks (Road Traffic Management Corporation 2022). SARRSM 2022 consists of:

- Volume 1: South African Road Restraint Systems Manual (SARRSM)
- Volume 2: South African Road Restraint Systems Manual Standards and Requirements

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[1] Under review by the Committee of Transport Officials (COTO), published by RTMC as Guideline Document

The aim of RRS is to contain and redirect errant vehicles to avoid injury to occupants and reduce the damage to vehicles and infrastructure (SARRSM, 2022). RRS (both vehicle and pedestrian restraint systems) forms a vital part of the road planning and design process and requires detailed knowledge of civil, transportation and traffic engineering, and road safety principles.
The proposed Technical Methods for Highways (TMH) 24 [2]consists of two volumes compiled under the auspices of the Committee of Transport Officials (COTO):

- Volume I gives an overview of assessing and addressing roadside hazards and the protection of road users.
- Volume II provides guidance on standards that any RRS must comply with and the requirements that they need to fulfil.

On existing roads, improvement of roadside-safety includes removing or treating hazards that may result in a crash or contribute to the severity of a crash. In the case of new roads, a safer roadside is achieved by ensuring that an adequate clear zone is provided immediately adjacent to the road. This clear zone is free of obstacles and designed so that drivers can regain control of their vehicles.

Volume II provides detailed design parameters for different RRSs that will fall under the proposed South African National Standards (SANS) 51317 which is based on the EN 1317:1998 and the current SANS 1350: Guardrails for roads (W-section) standards. The Committee of Transport Officials (COTO) Draft Standard Specifications for Road and Bridge Works for South African Road Authorities (DSS 2020), Chapter 11: Ancillary Road Works, Section 11.4 *Road Restraint Systems* provides some guidance as to performance-based design. The provisions in DSS 2020 may need to be enhanced to incorporate the guidance contained in this RRS manual. Designs for RRS are based on parameters such as vehicle type, as well as specific requirements (speed, containment level, working width, angle of impact and vehicle trajectory). Although South Africa adopted the European standard (EN 1317:1998), there is a need to take note of United States of America's Manual for Assessing Safety Hardware (MASH), which allows for testing of road restraint systems against heavier vehicle impacts, especially in |South Africa, where a large percentage of heavy vehicle frequent the roads.

Lastly, the SARRSM 2022 makes provision for scientifically assessing the level of risk posed by roadside hazards, through the Risk Assessment Procedure for South Africa (RAPSA) which is currently under review.

1.2. Motivation for the review of the SARSM 1999 Volume 6: Roadside Hazard Management Part B - breakaway support technology

In 1999 the government of South Africa accepted the South African Road Safety Manual (SARSM) as a best-practice guideline document for road safety engineering. Van Schalkwyk (2002) indicated that at the time general roadside safety-related knowledge of transportation

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[2] Under review by the Committee of Transport Officials (COTO), published by RTMC as Guideline Document

professionals in South Africa was improving and that some road authorities were actively trying to improve unsafe roadside practices, with some road authorities incorporating the manual in policies relating to road safety-related issues. However, the use of the manual/s was however, not contained in any regulation, and it depended entirely on the road authority to use whichever system it preferred (Van Schalkwyk 2002).

Subsequently, the South African Road Safety Manual (1999) Volume 6: Roadside Hazard Management was developed to provide a best-practice guideline document regarding the management of the roadside and median area to reduce the severity of roadside crashes.

Central to the SSA is the recognition that road users are fallible and will make mistakes, even if alert and intending to comply with the road rules. As a result, vehicles and road infrastructure need to be designed to discourage errors and protect against the consequences (damage and injury) when errors do occur. Safe System-based measures aim to improve the safety of the road environment and can be considered as 'primary' mitigation measures with the focus on reducing the severity of crashes while with 'supporting' techniques, the focus is on reducing the number of crashes. Designing within the Safe System Approach requires a consideration in terms of road *functionality*, *homogeneity, predictability, forgivingness of roads as well as awareness of road users.* Fundamental to facilitate the shift to a safe road network is designing the network in a manner that recognises the restricted tolerance of the human body towards the kinetic energy changes during an impact to eliminate fatalities and serious injuries.

South African Road Safety Manual (1999) Volume 6: Roadside Hazard Management Part B describes the roadside hazard management process, the principles thereof and provides a guideline for road safety engineering practitioners on roadside hazard management. The Volume 6: Roadside Hazard Management Part B provide guidance on the use of breakaway devices, traffic barriers and impact attenuation devices which are utilised in cases where a fixed object cannot be removed or relocated.

The following topics contribute to the chapters:

- The concept of breakaway technology
- History of breakaway technology
- Acceptance criteria for breakaway supports
- Design and location criteria for breakaway and non-breakaway supports
- Soil type
- Maintenance requirements
- Expected impact frequency.
- Sign categories.
- Traffic signals and traffic control devices support

Chapter 6 Part B provides guidance on breakaway devices using Australian research to explain the selection of locations which are considered high risk and in need of treatments. It provides an overview of reasons why there is a need for safety structures that make road environments more forgiving, a description of breakaway technology as well as the need for additional maintenance and replacement of structures that have been impacted.

The benefits and mechanisms for breakaway devices have been considered in the previous chapters. As part of this review (Chapter 6 Part B) these rationalisations are not repeated. Focus falls on additional elements highlighted in Chapter 6 Part B that have not been addressed previously.

Part B considers Australian crash data to compare the distribution of the types of objects hit in the urban environment (Perth), and the rest of the country making mention of hazardous locations as locations of highest risk.

These locations with risk are identified based on accident history that looks at:

- an elevated crash - specific locations or road sections with a high number of accidents
- an intermediate risk - locations where a combination of data from related sites that show potentially hazardous features (in other words locations with common characteristics in terms of specific accident types).

The definitions were deemed applicable to roadside obstacles such as poles and traffic control devices that may not have an accident history but that might have a large potential for high accident severity or frequency.

1.3. Problem statement

International research shows that there is a higher possibility of a fatal crash or severe injuries in instances where vehicles collide at higher speeds with roadside objects such as trees, lamp posts and other road furniture. Although there was recognition in the 1999 manual that road design features (such as curvature, widths of shoulders and lanes, road traffic signs and markings) contribute to keeping a vehicle on the roadway there is a need for a forgiving roadside with safety features such as breakaway supports, traffic barriers and crash cushions that in the event of a vehicle leaving the roadway, roadside safety features provide an extra safety margin. However, at the time it was also stated that the benefits it holds for the road user and that costs incurred by the implementation of a specific safety design compared to the benefits gained by the installation, may not be obvious.

The 1999 manual highlights that a breakaway support becomes a maintenance problem after it is hit as it should either be repaired or replaced after impact. The type of breakaway support (technology), and the components they consist of, should receive consideration when selecting a particular system as it influences maintenance cost, materials required during maintenance actions, workforce requirements and the frequency of maintenance required.

1.3. Purpose of this document

This review considers best practices to improve roadside safety and elements required for the provision of more forgiving roadsides (e.g., breakaway support technology and revision of use of kilometre markers) to minimise the impact and severity of crashes.

The industry review included a review of popular media and anecdotal evidence was from the South African national and local authorities was used. In addition, the review considers current standards and specification and guidelines, and makes recommendations pertaining to parameters in the installation and selection of equipment that can improve roadside safety.

This review supports the motivation for a review and update of the South African Road Safety Manual (1999) Volume 6: Roadside Hazard Management Part B.

1.4. Structure of this report

This report is structured as follows:

Chapter 1 provides a background to this review. This review forms part of a larger initiative that aims to review and update South African road safety guidelines and standards in support of becoming Safe System compliant.

Chapter 2 provides a description of roadside risks and the severity that fixed objects such as utility poles could have on fatalities and severe injuries.

Chapter 3 focuses on roadside safety management and reducing the severity of crashes with fixed objects. Road safety engineering considerations include reference to managing roadside safety by providing forgiving road environments, considering the function of the road (which has implications for managing speed), the provision of clear zones and safety.

2. ROADSIDE SAFETY MANAGEMENT AS A SAFE SYSTEM MEASURE

2.1. Introduction

The Safe System Approach (SSA) forms the basis of the United Nations Global Plan for the Decade of Action for Road Safety (UNDoA 1), to which South Africa became a signatory in 2010. It sets out a five tiered (pillar approach) to streamline and coordinate road safety actions to address the road safety scourge. The five pillars are:

- Pillar 1 - addressing road safety at an institutional level where actions can be prioritised and coordinated on a national and regional level.
- Pillar 2 - safer roads and infrastructure that list activities aimed at addressing road safety by improving and providing safer roads, roadsides, and infrastructure.

- Pillar 3 - safer vehicles considers the prevailing low standards of vehicles, which contribute to a considerable number of crashes and casualties. The objective of this pillar is to encourage deployment of improved vehicle safety norms and technologies for both passive and active safety.
- Pillar 4 – safer road users consider practices that encourages the education and awareness of compliant and informed road users.
- Pillar 5- post crash care that revolves around emergency response to avoid preventable death and disability, to limit the severity of the injury and the suffering caused by it, and to ensure the crash survivors' best recovery and reintegration into society.

The United Nations Global Plan for a Decade of Action for Road Safety 2021 – 2030 (UNDoA 2) brought a renewed undertaking to work towards reducing the number of road traffic fatalities. The UNDoA, in addition to the five pillars highlighted above, emphasises the management of speed, intermodal and land use planning, as well as the need for partnerships and dedicated funding in support of addressing road safety.

The SSA aims to develop a road transport system that is better able to take account of human limitations, allowing for the fact that humans are prone to error and when such mistakes occur, taking into consideration the vulnerability of the human body. It starts from the acceptance of the likelihood of human error and thus the realisation that traffic crashes may not be completely avoidable. The goal of a Safe System is to prevent crashes from happening through proactive actions and when crashes do occur, to ensure that they do not result in serious human injury. South Africa has adopted the Safe System Approach as the overarching strategy to drive down road traffic casualties.

Road safety engineering is a key component to ensure a safe road transport system, ensuring that the road and road environment is designed, constructed, and maintained for safe road traffic operations. This includes the design and provision of self-explaining and inherently safe roads. A self-explaining road guides and encourages the road user to make the correct decisions consistent with the design and function of the road and to ensure safe travel from one point to another. A self-explaining' road describes an environment where drivers know how to behave based on the road design rather than on external agents such as road signs and signals. More generally associated with geometric design, but relevant in the context of this document, as it could advocate for less signs in the roadside for instance. Inherently safe or forgiving road designs ensure that the design, from the onset, considers road and traffic characteristics (function, traffic volumes, traffic mix, roadway conditions and speed of travel) as well as human abilities and limitations (sight distance, acceptable level of risk taking and so forth).

A reduction in kinetic energy transfer, primarily through speed management, is a core to the Safe System approach (Kumfer 2019). Speeding is defined as “exceeding the posted speed limit or driving too fast for current conditions” and is a primary crash causation factor internationally (Forbes 2012). In the setting of speed limits, due diligence need to be applied in terms of setting a speed limit that is appropriate not only for the usage/type and quality of the road but also for a country’s vehicular fleet and the type and mix of the road users. The management thereof includes setting speed limits that reflect those considerations and reduce the likelihood of death or injury in the event of a crash (these are known as survivable speed limits) as well as preventing speed limit violations (speeding) (Towards Safe System Infrastructure: A Compendium of Current Knowledge n.d.).

2.2. National Road Safety Strategy 2030 in support of safer roads, roadsides, and infrastructure

In 2016 the Department of Transport (DoT) published the National Road Safety Strategy (NRSS) 2016-2030 which represents a new national action plan/programme to address the road safety scourge. In line with the international road safety agenda and activities (UNDoA and Safe System Approach) the South African NRSS makes provision for safer roads and infrastructure and places emphasis on the following priority areas:

- improved road traffic management.
- infrastructure improvements.
- vehicle standards.

The strategy refers to the various elements of the road or the traffic system which are the road user, the vehicle and the road environment and the various collections of actions/strategies under the five pillars of the UNDoA and interventions that are designed to impact the three elements to better the safety performance of the system. Under Pillar 2: Safer Roads and Mobility, the objective is to raise the inherent safety and protective quality of road networks for the benefit of all road users and that this will be achieved through the implementation of road infrastructure assessment and improved safety conscience planning, design, construction, and operation of roads (notably the clear zone concept is an imported aspect of limiting harm and damage).

2.3. Roadside safety as a shared responsibility

The SSA has significantly changed the way road safety is managed by road authorities. The SSA encourages designers to provide a safe environment and to consider the combined system as the major factor in crashes rather than the traditional approach that blamed the road user for casualties on the road. Proactively identifying safety deficiencies in the road network is critical to implementing a Safe System. Road authorities have a responsibility to minimize risks to road users. Whilst road authorities traditionally used to be challenged with the trade-off between mobility objectives and road safety, the strict application of Safe System principles is about establishing the concept of safe mobility which is defined as ‘mobility maximised within the limits of safe operation’ (Austroads 2017). The implication is that the priority of the road authority will be to establish safe operation. Thereafter mobility can be maximised within the boundaries that do not compromise safe operation - the other way around to the traditional approach which is to first satisfy mobility (or other utility) requirements and then consider the level of safety that can be achieved. A consequence of this approach is that when the desired level of mobility cannot be realised after safety is appropriately addressed, the context and function of the road will need to be re-evaluated.

Road authorities are therefore tasked with the management of roads and traffic and should be devoted to the provision and management of these environments to ensure that the transport system can perform efficiently and effectively in accordance with acceptable operational, and specifically road safety standards. The safe management of roadsides is becoming an increasingly important task as more efforts are being directed toward reducing the cost of road crashes across the world (Asian Development Bank 2018).

Within this context, governments and road authorities are increasingly being urged to implement treatments and interventions that can reduce the severity of accidents (ESCAP UN 2019). The Safe System advocates for a safer road transport system by simplifying traffic situations (removing potential conflict points), by considering the role that separation of different traffic streams/modes can have on limiting conflicts (separating vulnerable road users and motorised traffic) and by slowing traffic down (managing speed to levels that humans can survive). Speed management is a key intervention to address the number of fatal and serious crashes.

2.4. Road design elements

2.4.1. Road function

Roads have two functions namely a) roads must flow (mobility), and b) roads connects towns and districts as well as provide access to residential and other areas. The flow function prioritises traffic space as a public area while the residential area prioritises private space (Sucha, 2015). Through roads enhance mobility and the flow of traffic, distributor roads connect through roads with access roads. Access roads provide access to destinations such as residences (Sucha, 2015). This road classification hierarchy comprises of roads with a through function, a distributor and collector function as well as roads with an access to property function (Sucha, 2015). Each of these categories must comply with specific requirements so that road users are able to recognise the purpose and function of the road easily. Secondly, the aim is to develop vehicles that simplify the driving task and, lastly, to have informed and well-educated road users (Schermers et al., 2010).

The Sustainable Road Safety Principles (Netherlands) and Vision Zero (Sweden) revolves around the design of roads and environments that limit the chance of human error by facilitating safer road usage through better designs. Accordingly, different classes of roads need to be designed in such a manner that the differences in classes are significant enough for the driver to adapt behaviour accordingly (Enzfelder, 2013). The Sustainable Safety vision of the Netherlands has five guiding principles (Table 2) which aims to facilitate the recognition and behavioural adaptation (Wegman and Aarts, 2006).

The Sustainable Safety approach of the Netherlands promotes the notion that by minimising speed, the severity of injuries sustained in a collision is reduced. In addition, where road users/vehicles with large mass differences use the same traffic space, the speeds should be sufficiently low that, when in the event of a traffic crashes, the most vulnerable road users and modes should be able to walk away without any severe injuries.

The function of the road (mobility vs. access) influence the setting of speed for a specific road. High mobility roads have higher speeds where roads with an access function typically have lower speeds to minimise conflicts between vehicles travelling straight and vehicles slowing down to turn. Any additions or changes to the road and traffic environment need to be carefully considered in terms of the consequences when any type of vehicle collide with a roadside structure. As such there is a need to take cognisance of the following (table 1):

- Mass of vehicles and the potential damage to the vehicle, structure, and human in the event of a collision
- How vulnerable the road users are (difference in mass and ability to absorb the impact without causing an injury).
- Velocity and impact if there is a collision as the higher the speed and mass of the vehicle, the more severe the injury.
- Differences in direction as the severity of a conflict therefore also depends in part on the fact that the modes of transport and the vehicles, have a different level of resilience in different directions.

Table 1: Principles of sustainable traffic safety (Wegman and Aarts, 2006)

	Principle	**Description**
1	Functionality of the road	• Ensure monofunctional properties of the road (mobility vs. access) • Ensure hierarchical structure of road network
2	Homogeneity (load, direction, speed)	• Ensure equality in speed, direction, and mass at high and medium speeds
3	Forgiving roadsides	• Limit injuries through a forgiving road environment (and anticipation of road user behaviour)
4	Predictability of the road and road user behaviour through self-explaining and predictable roads	• Road environment that anticipates and support road user expectations (and behaviour) through consistency and continuity of design
5	Situational awareness (state of awareness of the road user)	• Ability to assess driving task capability and to successfully manage the driving task

2.4.2. Provision of self-explaining and forgiving road environments

The Safe System advocates for a safer road transport system by simplifying traffic situations (removing potential conflict points), by considering the role that separation of different traffic streams/modes can have on limiting conflicts (separating vulnerable road users and motorised traffic) and by slowing traffic down (managing speed to levels that humans can survive).

Predictable road environments are consistent in design and layout. Road designs through predictability, homogeneity, and recognisability, need to create the right expectations (Sucha, 2015).

Roads need to be designed in line with these expectations. Recognition is a mental process that is preceded by mental categorisation (Sucha, 2015). The characteristics of the road environment should facilitate the categorisation and recognition according to the road category which then in turn facilitate safe and correct behaviour (Wegman and Van Aarts, 2006). The driver is encouraged to adopt a behaviour according to the design and function of the road as the road provide information to road users that explain the situation on the road ahead and induces correct and safe driving behaviour through the road layout itself. To achieve this there is a need for road designs to be classified and standardised for road users to recognise and adapt safe behaviour accordingly (Pretstor et al., 2014). Categorisation and user perception of the road environment are key elements of self-explaining roads as individuals store abstract representations of the road rather than specific aspects of a road environment (Theeuws, 1995). These abstract representations contain a basic set of properties associated with different road environments that developed through experience. This is referred to as prototypical representations and roads should be planned and designed in such a manner that unity is created in how different road users perceive and react to the road environment. Theeuws (1995) states that the expectation is that by shaping these typical representations, all users would have the same view of the road environment. For a driver to extract the correct information from the SER the driver needs to be highly aware of the driving context (situation) and this situational awareness is dependent on the type of road on which the driver is driving (Walker et al., 2013). Hazard perception and the degree to which the driver perceives and react to hazards are key considerations in the design of interventions and countermeasures to prevent crashes. This includes an inability to perceive hazards in the road and traffic environment as well as, for example, coming to the wrong conclusion about the traffic situation due to misinterpretation of information (Rowea, 2015)

Forgiving roads limit the seriousness of the consequences. Thus, the safety aspects are planned for, designed, and executed in such a way that road users' mistakes do not kill them or reduce the severity of outcomes (injuries) of traffic accidents (Pretstor et al., 2014). The concept of infrastructure that is inherently safe for all road users is however not new. Theeuws (1995) stated that traffic systems have self-explaining properties and designs which should be in line with road user expectations. Ogden (1996) emphasised that knowledge of the road user (performance, capabilities, and behavioural characteristics) is essential for input into road designs that influence road user behaviour. The safe operation of the traffic system therefore depends on the road user making a sequence of decisions, and if these are incorrect, the road environment needs to be designed in support of this decision making (Ogden, 1996).

2.4.3. Speed management.

Road infrastructure should be forgiving and consider the vulnerability of the human body to avoid death or serious injury in the event of a crash. The SSA advocates the need to adopt the viewpoint that roads or roadsides should be "*forgiving*."

The primary purpose of the speed limit is to advise drivers of the maximum reasonable and safe operating speed under favourable conditions. It provides a basis for enforcement and ought to be fair in the context of traffic law. It is important to understand how speed impacts safety because setting speed limits is primarily a road safety measure.

Roads are designed to suit the speed of the vehicles using the road. The operating speed of roads is set at the 85th percentile speed. The speed limit of a road is traditionally set by determining the speed of 85 % of cars that travel on the roadway. In other words, the speed limit is set by the speed of drivers, and this is the basic rule that determines traffic speeds worldwide. The 85th percentile method assumes that most drivers are reasonable and prudent, do not want to have a crash and desire to reach their destination in the shortest possible time and that they will travel at a speed at or below which 85 % of people drive at any given location under clear weather and visibility conditions may be considered as the maximum safe speed for that location (http://www.copenhagenize.com/2012/11/the-85th-percentile-folly.html). Design speed is a key parameter in determining values for several highway geometric features in highway design including horizontal radius and stopping sight distance and so forth. There is also a relationship between design speed and other measures of speed (Bartlett, 2016). These include:

- Operating speed.
- Posted speed.
- Design speed.
- 85th percentile speed.
- Target speed.
- Political speed.

Section 1.5 in the South African Road Safety Assessment Methods Manual 2022 postulate that management of speed is at the core of a forgiving road transport system. Since there is a direct correlation between vehicular speeds and the likelihood of people suffering physical harm, with the probability of crashes, injury and death rising as the speed of vehicles increases (figure 1), there is a need for policies and design standards to be re-engineered to build more forgiveness into the system, both limiting speeds naturally and changing the way that collisions occur to reduce kinetic energy exchange (Kumfer 2019).

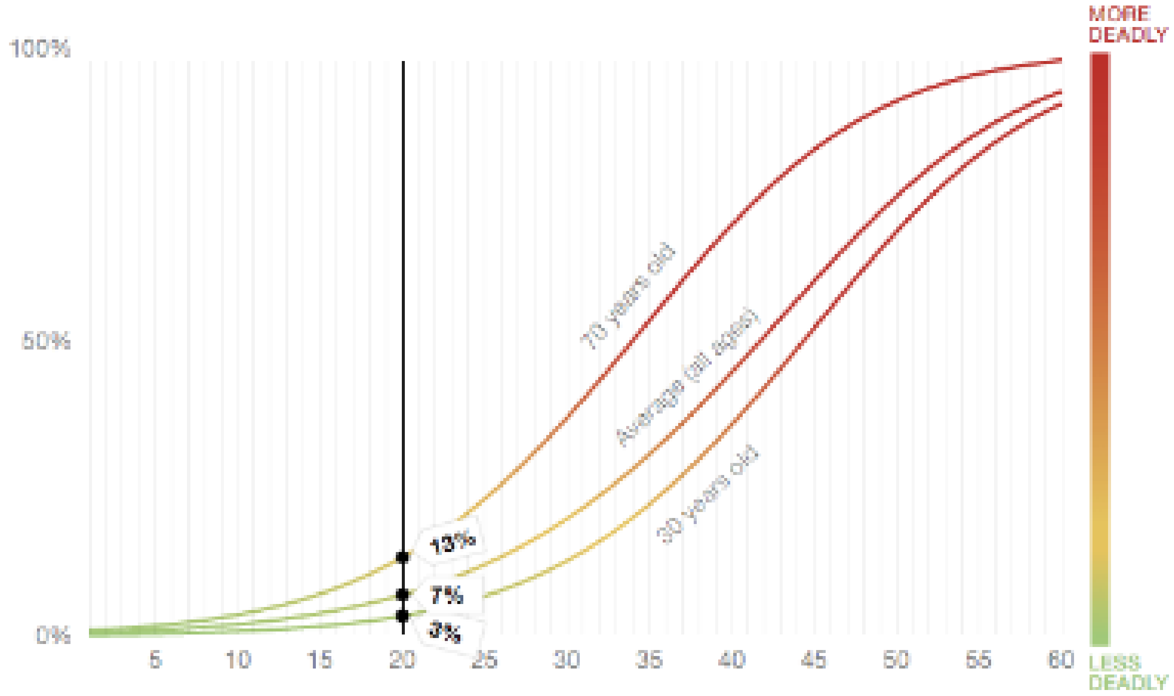

Figure 1: Risk of injury and death increase with age and speed (https://usa.streetsblog.org/2016/05/31/3-graphs-that-explain-why-20-mph-should-be-the-limit-on-city-streets)

Changes to design(s) or incorrect designs can result in (for example) drivers adopting higher operating speeds, because it seems safe, and the road design allows for it. Dumbaugh et al (2019) state that the safety implications are contingent upon the context in which these modifications occur. The use of higher-speed design solutions may enhance safety on limited access routes with high operating speeds characterised by little vulnerable road user or access-related activity. But the same design solution is likely to be problematic on urban arterials where higher operating speeds create conflicts with pedestrians or vehicles attempting to access adjacent access and egresses. This shows the important relationship between road design, the adjacent land use (especially in South Africa where communities live next to high mobility roads) and human behaviour/selection of behaviour deemed appropriate for that scenario. Highlighting the need for understanding the transport system (operating) dynamics - including an understanding of the physical environment (design characteristics of the roadway, environment, and social environment)as these characteristics influences by user decisions and behaviour..

Furthermore, vulnerable road users, including pedestrians, cyclists, and motorcyclists, are all at substantial risk of severe or fatal injury in crashes, even at low speeds, because they are poorly protected. Table 2 provide an overview of sustainable speeds to minimise risk to vulnerable road users.

Table 2: Sustainable safety and speed in the Netherlands (Dumbaugh 2019)

Scenario	**Target (max) speed**	**Application area**
Where pedestrians cross the road	20 mph / 30 km/h	Local and residential streets Crossing areas
Where bicycles are mixed in traffic	20 mph / 30 km/h	Local and residential streets Crossing areas
Where vehicles meet at a 90-degree angle (intersections)	30 mph / 50km/h	Intersections (signalised and unsignalized
Where vehicles pass in opposite directions	40 / 50 mph or 60 /80 km/h	Undivided highways.

The harmful effects of speed also increase on wet, snowy, or icy roads. However, any action taken to reduce vehicular speeds helps to reduce the number of crashes, injuries, and fatalities, regardless of weather conditions and among all categories of road user (Economic and Social Commission for Asia and the Pacific (ESCAP) 2019). In addition to safety benefits, lower vehicular speeds are more economical than high speeds, and can enhance people's environment, health, and quality of life because of a reduction in costs associated with crashes, road maintenance, noise, fuel use, and emissions.

Infrastructure solutions, such as addressing roadside safety must be combined with speed management and vehicle technology to achieve safer outcomes. In addition, vehicle technologies have the potential to significantly reduce death and injury on the road network especially in relation to road departure and intersection crashes. Accelerating the deployment of these technologies in the fleet can lead to faster reductions in trauma (Towards Safe System Infrastructure: A Compendium of Current Knowledge 2018). Although international research indicates that it could potentially be safe to introduce high operating speeds on freeways and express lanes, the situation in South Africa beckons that designers and authorities responsible for roads, rethink this scheme.

2.5. Roadside safety, hazard, and risk management

The road transport system is a social and dynamic system where the basic properties adapt and change when in interaction with each other in a dynamic and non-random manner (Dumbaugh 2019). There is thus a need for understanding the transport system operating dynamics including an understanding of the physical environment (design characteristics of the roadway, environment and social environment influenced by user decisions and behaviour).

The design context is formed from the combination of factors, such as (Troutbeck 2022):

- what is physically possible to construct at that location?
- what is reasonable to expect?
- what operational and safety performance can be achieved?
- what costs are involved?

- what social, community and environmental effects might result?

Figure 2 provides an overview of road design elements, with a focus on roadside and road environment safety which include new and innovative research pertaining to material, technology and so forth.

Roadsides provide space for parking, for landscaping, for services, for lighting, and for drainage as well natural flora and native fauna. The roadside however is occupied by fixed objects such as roadside structures (culverts, bridges), stockpiles of materials, rigid poles, rocks, undrivable side slopes, and deep drains (Asian Development Bank 2018).

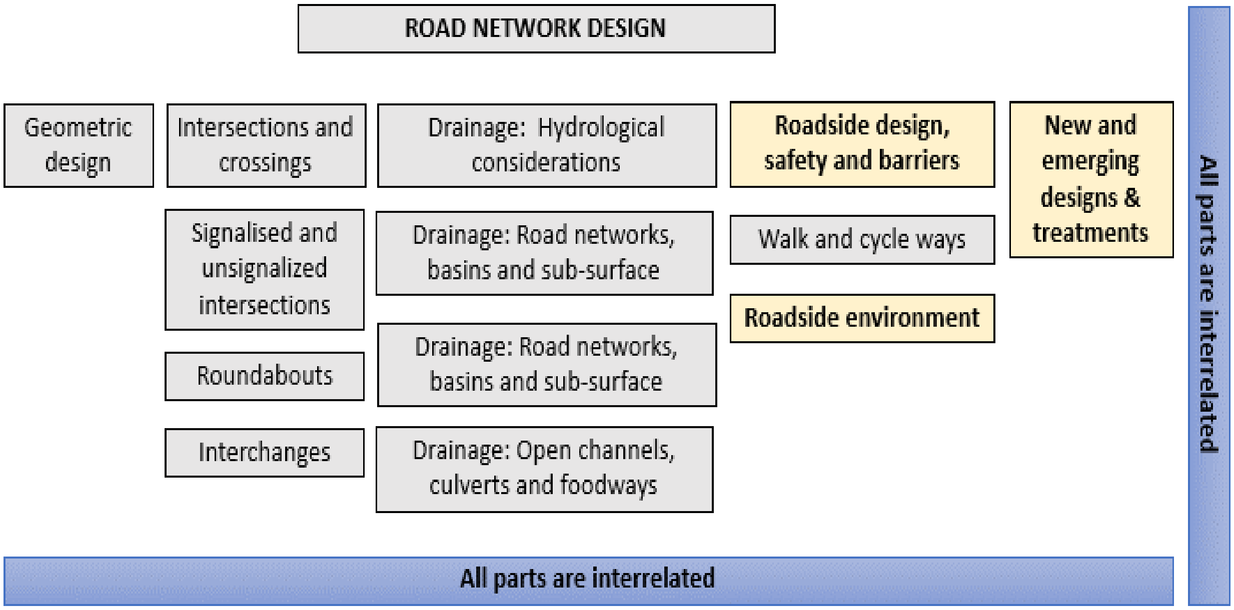

Figure 2: Network design elements: focus on roadside safety (adapted from Jurewicz et al., 2014)

2.5.1. Roadside safety

Roadside safety is concerned with the selection of parameters such as the road width, type and width of hard shoulder, roadside trees and road signs, road structures (bridges, culverts road signs), roadside obstacles (trees, poles) and road equipment (road barriers and fencing) that can influence run-off-road accident risks (Jamroz 2019). The roadside includes the hard shoulder, ditch, an area directly adjacent to the road.

2.5.2. Provision of clear zones

Elements required for the provision of more forgiving roadsides include understanding the role of different clear zone widths in controlling the likelihood and severity of run-off-the-road (RoR) casualty crashes, making roadside structures more forgiving (e.g., frangible poles), and the more effective selection and placement of safety barriers (C. S. Jurewicz 2014). In time there should be consideration of safety barriers/attenuators to improve motorcycle and heavy vehicle safety (C. S. Jurewicz 2014).

Special consideration should be given to the importance of the clear zone in the provision of “forgiving roads.” The clear zone is the driveable roadside area that should be kept clear of hazardous objects to minimise the danger of a collision should a vehicle leave the road (Jordan 2019). It is the recovery area adjacent to traffic lane and should be able to allow for around 85 % of vehicles to recover. The clear zone is determined based on vehicle speeds, vehicle volumes, road curvature, and embankment slope.

Figure 3 below provide an overview of the steps to decide whether a hazard needs to be removed from the clear zone.

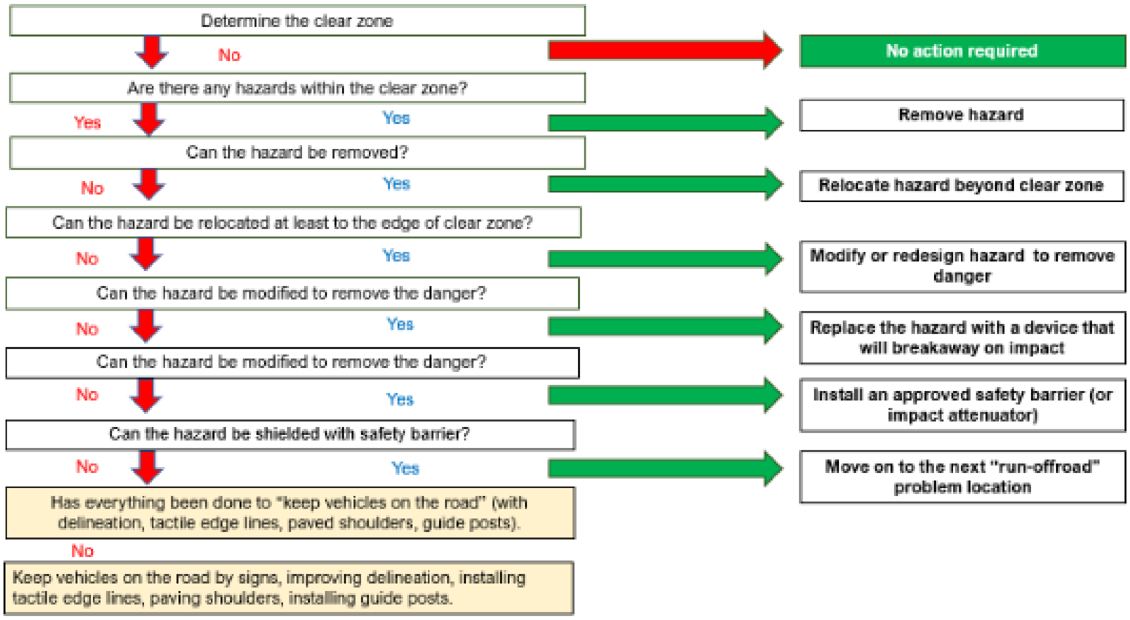

Figure 3: Decision framework regarding the removal of hazards from the clear zone (Jordan 2019)

The safety factors on rural roads to consider are (Woolley et al., 2018).

- Severe injury accidents on rural roads continue to be dominated by single vehicle lane departures and head-on collisions.
- Most benefit from clear zones is obtained within the first few meters of width and for vehicles that have “drift off” low angle departures, this is thought to represent in the order of 80 % of departures.
- No matter how wide a clear zone or central median, the risk of incursion cannot be eliminated.
- A desired clear zone width (+- 12 meter) will be achieved with on only parts of the road network.

- A high level of safety performance appears to be possible from the use of continuous lengths of accident barrier both in the centre of the road and on roadsides.

The safety on rural roads can be improved by (Woolley et al., 2019):

- The clear zone approach has contributed to safer roads in the past and will continue to do so, especially on lower order roads. However, if harm minimization is to be achieved, we need to rethink the way in which we use the combination of clear zones and barriers on the rural road network.

- Clear zones should be regarded as holding the potential to be a hazard in the same way that barriers considered dangerous.

- Clear zones should include the concept of “run out” areas where attention is focused on ensuring safe vehicle departures from the roadway, free of non-survivable impacts and rollover.

In Australia, some of the states have adopted a Wide Centre Line Treatment (WCLT) which is introduced on many of their rural roads. The WCLT is a wide median with wire rope barrier and rib lines. Wide centrelines are showing promise, yet they cannot deliver Safe System outcomes in isolation and should be regarded as (step towards) supporting treatment; they do have a potential benefit in that a barrier system might be retrofitted to achieve a primary Safe System treatment in future.

Once clear zones are established, it is necessary to identify all roadside hazards within the clear zone and consider high-risk hazards located beyond the clear zone. A roadside hazard is an object or feature located between the edge of the traffic lane and road reserve boundary or within a median that could cause significant personal or fatal injuries to vehicle occupants when impacted by an errant vehicle (SARRSM 2022).

2.5.3. Roadside hazards

Roadside hazards include any feature or object beside the road that may adversely affect the safety of the roadside area should a vehicle leave the road at that point. There are two groups of roadside hazards namely (i) point hazards, and (ii) continuous hazards (Asian Development Bank 2018).

Point hazards are individual hazards or roadside hazards of limited length. They include:

- trees (over 100 mm diameter)
- bridge end posts
- large planter tubs
- monuments
- landscape features
- non- breakaway signposts (over 100 mm diameter)
- interchange supporting piers.

- driveway headwalls
- culvert headwalls.
- utility poles (more than 100 mm diameter)
- solid walls, and
- pedestrian overpass piers and/or stairs.

An isolated pole, for instance, presents a risk to an errant vehicle. But increasing numbers of poles along that road will increase the risk. An errant vehicle may be lucky enough to miss a single pole, but with more poles comes increased risk that one will be struck. Because of their individual nature and limited length, the preferred treatment for point hazards is to remove them from the clear zone, rather than to shield them with a barrier.

Continuous hazards differ from point hazards in that they extend for a considerable length along a road. It is therefore generally less practical to remove or relocate them. When located within the clear zone, these continuous hazards are roadside hazards. The length of the hazard increases the likelihood an errant vehicle will strike it, and some hazards (such as cliffs) have a high crash severity regardless of the speed of the errant vehicle. Examples of continuous hazards include:

- rows and forests of large trees
- uncovered longitudinal drains.
- retaining walls
- steep embankments
- rock cuttings
- cliffs
- areas of water (such as lakes, streams, channels over 0.6 m deep)
- unshielded hazards (such as cliffs) beyond the clear zone, but within reach of an errant vehicle
- curbs with a vertical face more than 100 mm high on roads with operating speeds above 80 kilometres per hour (km/h)
- fences with horizontal rails that can spear vehicles or vulnerable road users (pedestrians, informal traders etc) adjacent to the road.

2.5.4. Roadside risk management.

There is a need to consciously make the choice to apply traditional measures such as hazard removal, safety barriers and replacement of roadside furniture in such a manner that it minimises the risk of severe injury or death (Jurewicz, Lim, McLean, and Phillips, 2012). This means that any crash should result in property damage only or at most, minor injuries (Jurewicz et al., 2012).

Roadside hazard management aims to "identify, prioritise, and treat roadside hazards to maximise safety by reducing the incidence and/or severity of such crashes (Jordan 2019). The aim is to "keep vehicles on the road" by providing inherently safe roads and to manage speed. However, if vehicles do run of the road, there is a need to understand and identify potential roadside hazards present due to wrong design, construction, installation, and maintenance of road restraint systems

(Budzynski 2019). Under the SSA, addressing severe run-off-road crashes through safer roads and roadsides involves providing roads that (C. S. Jurewicz 2014):

- minimise the risk of vehicles leaving the carriageway (e.g., via delineation or deflection)
- provide adequate recovery space when vehicles do run off the road.
- ensure that any collision that does occur in the roadside will be with objects that limit the impact forces on vehicle occupants to minor levels (no fatal or serious injury outcomes).

The appropriate geometric design and the prudent use of road features can help to keep vehicles on the road. The geometric design standard should be based on a realistic assessment of the operating speed of a road section considering the road function, the terrain through which the road exists, and the road environment (Asian Development Bank 2018). Considerations to prevent vehicles from leaving the roadway are summarised in Table 3.

Table 3: Considerations to keep vehicles on the roadway (Jurewicz et al., 2014)

Measure	**Description/ Function**
Width of traffic lanes	• Width of a traffic lane influences the ease with which vehicles can operate in that lane. • Higher traffic volumes and higher speeds warrant wider lanes to allow a greater level of safety relative to oncoming vehicles, as well as clearances relative to roadside features. • Lanes that are too wide create problems if vehicles form two lanes or if drivers or riders try to overtake by squeezing another vehicle (motorcyclists) to the side.
Road shoulders	Shoulders provide: • Recovery area for errant vehicles • Safe area for stopped vehicles. • Route for pedestrians, bicyclists, or other slow-moving vehicles (separate from faster motor traffic) • Trafficable area for emergency vehicle use • Clearance from roadside hazards. • Shoulders should be well maintained. • Sealed shoulders reduce casualties by 40% in the event of vehicles leaving the roadway.
Horizontal alignment and localized curve widening	• Providing a curve radius that is appropriate to the speed environment of the road is providing a safe road. • Need for consistent alignment along a section of road with well-designed transitions from generous to tighter alignments. • Widening of the road pavement may be required at curves in the road, subject to the curve radius, lane width, and the design vehicle for the road. • Localized curve widening is often required for the following.

	reasons:
	  ◦ Vehicles traveling around a curve, particularly trucks and buses, will occupy more of the lane width than the same vehicle traveling on a straight section of the road.
	  ◦ This increased width occupied by these vehicles reduces the clearance between vehicles traveling in opposing directions.
	  ◦ Extra lane width at curves maintains an acceptable clearance.
	  ◦ Vehicles typically do not maintain the same lateral position in a curve as they would on a straight section of the road. This is due to a driver needing to steer into and around the curve.

Vertical alignment	• A poor vertical road alignment may result in increased vehicle speeds through sags in the road, or poor sight distance on the approach to a crest - Can result in a driver losing control and, in turn, running off the road. • Grades should be as flat as possible, subject to the nature of the terrain. • Steep grades contribute to excessive speeds or differential speeds for different vehicles, which can create a higher risk of rear-end crashes. • Differences in vehicle speeds also contribute to bunching on single lane roads, which may lead to frustration and inappropriate overtaking manoeuvres. • Flat grades allow all vehicles sharing a road to travel at the same speed.
Sight distance	• Provide adequate sight distance to allow all road users to see each other, and to make safe decisions about using or crossing the road. • Sight distance is related to design speed for the road and can be affected by the road geometry (horizontal and vertical alignments), the terrain (particularly on the inside of horizontal curves), and roadside objects such as trees and signs. • Roadsides need to be well maintained to ensure that sight distance requirements are not impacted. • Roadside features such as embankments, safety barriers, bus shelters, and vegetation that restrict sight distance may need to be removed or modified to ensure sufficient stopping sight distance on curves
Road surface	• Maintain a good road surface to a safe standard to minimize the risk of vehicles losing control. • A good road surface is even and is free of potholes.

	• It must offer adequate skid resistance to vehicle tires to maintain control during braking or cornering manoeuvres.
Signs and guideposts	The visual guidance of drivers along the road through delineation and signage is an essential safety aspect of preventing vehicles from running off the road. Signing and delineation are used to provide road users with guidance, information, and knowledge about the road ahead, including: • changes in road alignment, including curves and the severity of those curves. • visibility or where it is unsafe to overtake. • need to slow down or stop at intersections. • changes to the lane configuration or width of the road • temporary changes to the road conditions including road works.
Warning and road markings	• Width markers alert drivers to sudden narrowing of the road ahead. • Hazard markers are used to delineate roads, and to alert drivers to curves ahead. • Centrelines are marked to separate opposing directions of traffic flow on sealed pavements: • Separation lines on two-lane, two-way roads, these are broken lines (like lane lines). • Barrier lines are either continuous double lines or a single continuous with a parallel broken line which shows that overtaking is not permitted. • Edge lines provide guidance of the vehicle path within the traffic lane and discourage travel on the road shoulder. • Tactile line markings provide an audio-tactile warning (sound plus vibration) whenever a vehicle drifts across the line marking. • Pavement markings provide essential guidance for drivers and riders in relation to road alignment and the position where they should drive or ride within the road space.

2.5.5. Mitigation of risk

Once a hazard has been identified the mitigation strategies include:

- remove the hazard.
- relocate the hazard.
- alter to reduce severity.
- shield the hazard using barriers.

Hazard removal

Fixed roadside hazards injure and kill the occupants of errant vehicles. During impact, they impose enormous forces on the occupants; sometimes, these are so strong that the occupants suffer unforgiving internal injuries. Hazard removal refers to the removal of all existing roadside objects that are fixed and are 100 mm in diameter or larger within the clear zone. Removing the hazards will not prevent a crash, but it will reduce the consequences of a crash (Asian Development Bank 2018).

If there are several fixed roadside hazards in one location, there should be an attempt to remove them all. If it is not possible to remove the roadside hazards, consideration should be given to shielding the hazard with barriers. To prevent the problem of hazardous objects being created within the clear zone, road authorities need to develop policies that will avoid the placement of new potentially hazardous objects on the roadside. When designing a new road, avoid locating any new hazardous objects within the clear zone.

Relocation of hazards

Relocation of hazards to a less vulnerable location will reduce the risk of an errant vehicle hitting them. This may mean relocation to further from the edge of the road or it could mean relocation from the outside of a curve to a location on a straight section of the road. If not possible to totally remove a roadside hazard from the clear zone, the next option is to relocate it beyond the clear zone to minimize the potential for it to be hit by an errant vehicle.

Poles, structures, lighting columns, even drains can be relocated. A relocation of even a few meters will reduce risk, even if it is not possible to place the hazard outside the clear zone.

Trees are a hazard that cannot be easily relocated. They are also one of the most common hazards along and as a result tree is within the clear zone, there are three choices:

- remove it (albeit with environmental issues), shield it (with suitable barrier)
- or do all possible to keep the vehicles on the road at that point.

Alter the hazard.

After doing all that can be practically done to keep the vehicles on the road, examining the possible removal of the hazards, and considering options to relocate the hazards, the next step in the strategy is to alter (or redesign) the roadside hazard to reduce its potential for severe injury or death during a crash.

This option includes covering drains with drivable covers, replacing rigid posts with frangible (breakaway) posts, flattening side slopes, or installing drivable end walls at driveway crossings.

Altering or modifying a hazard is an option to consider when attempting to improve roadside safety in locations where removal or relocation of a roadside hazard within the clear zone area is not feasible or practicable. Modifying a roadside hazard can reduce the severity of a crash and the potential for serious injury.

Modifications include:

- modifying open longitudinal drains by piping them or covering them with a drivable cover
- modifying end walls of driveway culverts to make them drivable.
- redesigning rigid signposts to provide frangible (breakaway) posts.
- designing frangible posts that break away, if struck
- redesigning rigid street lighting columns to provide frangible columns; and
- flattening a steep fill slope to make it drivable.

Shield the hazard.

The clear zone should be kept free of fixed roadside hazards. But if this is not achievable the aim should be to protect the occupants of errant vehicles from striking the hazards by the installation of safety barriers. Road restraint systems (RRS) / safety barriers are designed to redirect an impacting vehicle and dissipate crash forces in a controlled manner. The use of safety barriers requires a good understanding working width and containment levels. However, Jurewitz states that barriers cannot be safely fitted to shield all roadside hazards and where they are fitted there is a need to meet appropriate standards to ensure they perform satisfactorily. They must be capable of redirecting errant vehicles and absorbing energy to reduce the severity of a crash to levels that will minimize injury to vehicle occupants (Jurewitz et al, 2014).

3. ROADSIDE RISK AND ROADWAY DEPARTURE CRASHES

3.1. Severity of roadway departure crashes

3.1.1. International evidence

Research shows that the severity of the outcome (seriously injured/death) exponentially increases with higher speeds especially when an object (tree, pole, supports, front wall of a culvert, barrier) is hit (Jurewicz et al., 2014). Roadside hazards therefore need to be managed in such a manner that it reduces the severity in the event of an accident (Liu, 2009; Budzynski, 2019).

In the United States of America, roadway departures account for most of all fatal crashes. Jones (2016) states that 56 % of fatal crashes fit the roadway departure definition: a crash which occurs after a vehicle crosses an edge line or a centre line, or otherwise leaves the travelled way. Of this data set, 40 % of vehicles were involved in a collision with a fixed object. Trees and utility poles (next to the roadway) comprises 63 % of the fixed objects struck, making them the most harmful event in 14 % of all fatal crashes (Jones 2016). AASHTO roadside design guideline highlights that Utility poles are more prevalent adjacent to urban roadways than rural highways, and demands for operational improvements coupled with limited street right-of-way often leads to the placement of these poles proximate to the roadway edge. AASHTO (2011) also highlights that utility poles are second only to trees as the object associated with the greatest number of fixed-object fatalities. Though utility poles are often impacted directly, considerations should also be given to the placement of the way in which the poles are stabilized wire rope for example can pose a hazard when impacted directly as well.

In 2018 the United States Insurance Institute for Highway Safety (IIHS) analysed data from the National Highway Traffic Safety Administration (NHTSA) Fatality Analysis Reporting System (FARS), and concluded that in 2017, the USA recorded 37,133 total highway fatalities of which 7 833 were related to fixed-object crashes. A total of 914 crashes involved utility poles. IIHS (2018) based these figures on fatal crashes when the most harmful event coded was a crash with a fixed object, regardless of whether the first harmful event also was designated as a crash with a fixed object or represented another type of crash, such as a collision between two motor vehicles that in led to a crash into a fixed object (National Academies of Sciences, Engineering, and Medicine 2020).

A 2009 National Highway Traffic Safety Administration (NHTSA) survey highlighted that the most influential factor in the occurrence of fatal single-vehicle run-off-the-road crashes is driver performance-related factors. These include driving fatigue/sleepy; inattentive driving (talking, eating, etc.); over-correcting of the vehicle; avoidance manoeuvres (swerving, or sliding due to severe crosswind, tire blow-out or flat, live animals in road, vehicle in road, etc.); distractions inside vehicles (cellular telephone, computer, fax machine, etc.); and other driver-performance-related factors, such as mentally challenged, following improperly, failure to signal and so forth. Additional contributory factors included roadway alignment with curve, vehicle speeding, rural roadway and lighting poles have contributed significantly to the upward trend in fixed object collisions (Rowan 1967).

3.1.2. South African fixed object crash statistics

In 1999, South Africa research indicated that 50 % of all run off-the-road crashes, the vehicle leaves the roadway in a skidding manner which has a significant impact on vehicle behaviour when confronted with roadside features and hazards.

Currently, road and environmental factors contributes to approximately 10 % to the total number of fatal crashes (State of Road Safety Report 2022). RTMC crash statistics (supplied from the RTMC for the period 2018 - 2022) showed that in terms of the top ten type of fatal crashes recorded for the period January 2018 to December 2022 (5 years), the percentage of crashes with fixed/another object was in the region of 4,1 % (2 118) in 2022 (Figure 4).

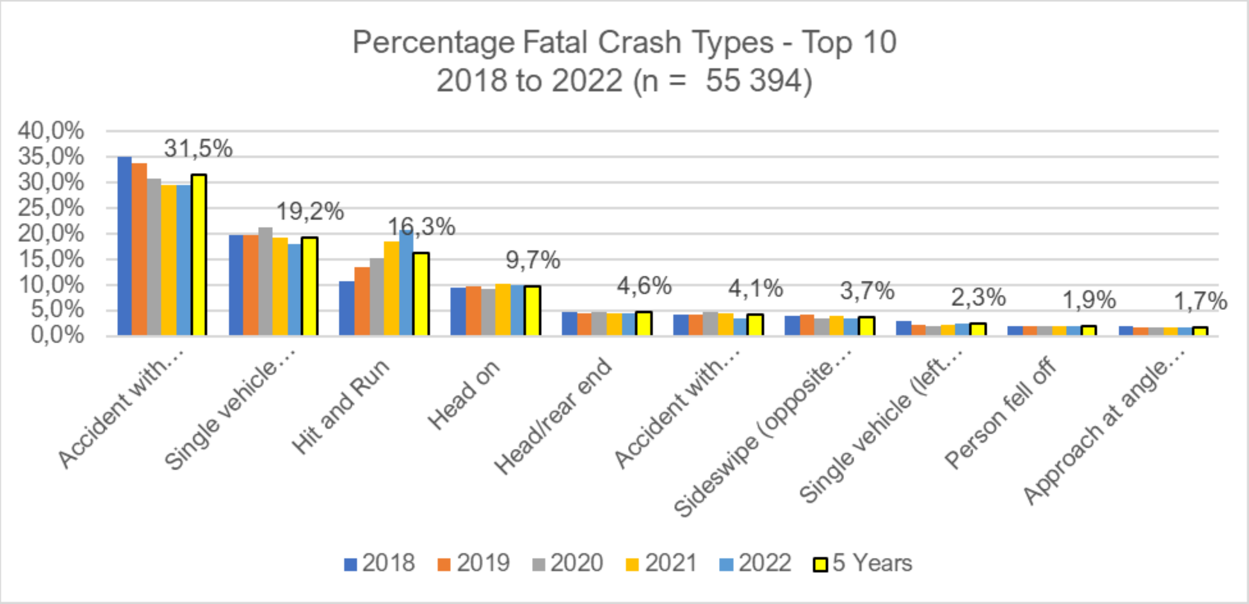

Figure 4: Percentage contribution of fixed object crashes for 2022/2021 (Source: RTMC, 2023)

RTMC data for 2015 - 2017 showed that young driver fatalities (age 18 to 24 years) constituted approximately 10 % of all driver fatalities during the three-year period. The research also found that for young South African drivers, fixed object crashes constituted 11 % and single vehicle crashes 4 % of fatal crashes (Venter 2017).

Gelderblom (2021) investigated the relationship between the severity of the road traffic crashes, which occurred on the N4 Toll Route in South Africa, and the interaction of the human factors involved in these crashes (Gelderblom 2021). The study confirmed that the human factor plays a critical role in road traffic crashes. Of the almost 9 000 crashes analysed, 16.1% of the crashes were caused by vehicle-, 8.7 % by road and environmental-, 4.4 % by unknown-, and 72.8 % by human- factors. The study established that there exists a relationship between the various human factors and crash severity (Gelderblom 2021). Single vehicle type of crashes (including RoR and overturned) constituted more than half of the crashes (54 %), followed by head-tail crashes (19 %), head-side (10 %), sideswipe (7 %), multiple pileups (6 %) and head-on crashes (3 %).

Fixed object crashes per province for the previous five years (2018 - 2022) are the latest available crash statistics in terms of fatal crashes per annum, which means fatal road crashes are a pressing issue that must be addressed. RTMC data (2018 to 2022) shows that 2 118 fatal crashes were recorded for collisions with fixed objects (Figure 5). A total of 2 585 fatalities were recorded in the 2 118 crashes. Gauteng accounts for the most fixed object crashes (37 %) followed by KwaZulu Natal (14 %) and Limpopo (11 %).

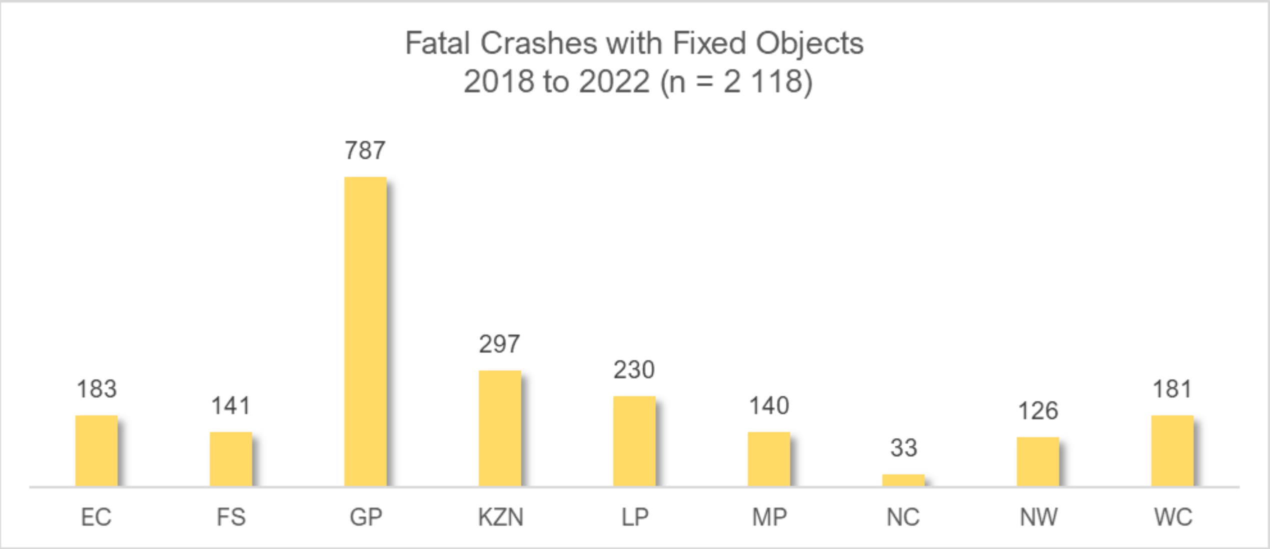

Figure 5: Fatal crashes per province (2018 – 2022) involving fixed objects (Source RTMC 2023).

Figure 6 illustrates that age groups overrepresented in these crashes are 30 to 39-year-olds (21 %), 20 to 29-year-olds (18,6 %) and 40 to 49-year-olds (11,4 %).

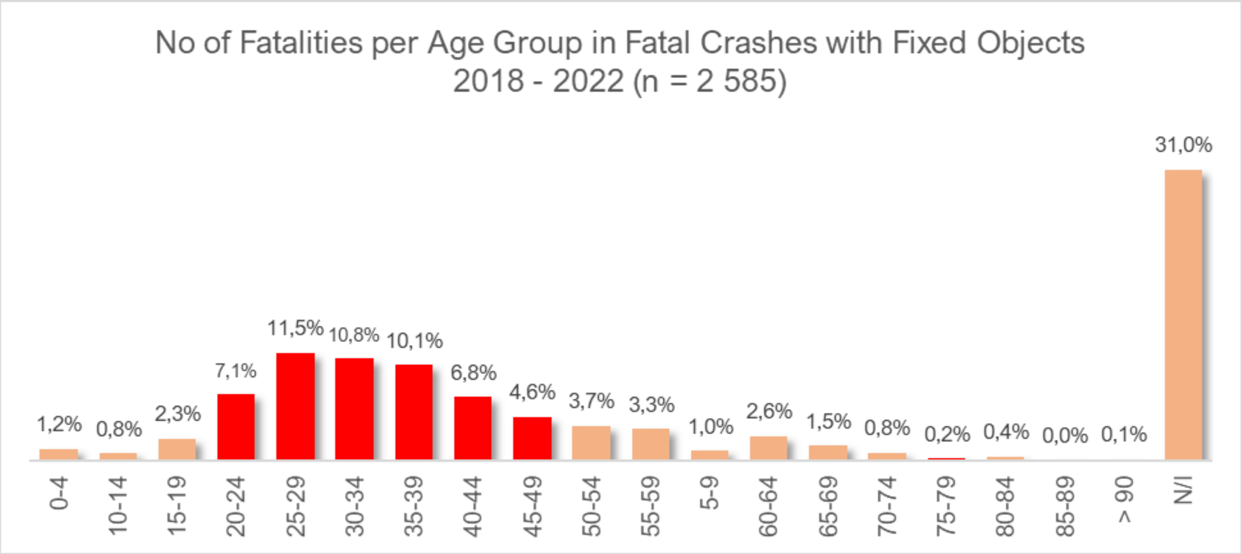

Figure 6: Fatal crashes with fixed objects according to age groups 2018 - 2022 (Source RTMC 2023).

The age groups between 20 and 49 seems to be the most overrepresented and figure 7 provide an overview of a breakdown per province for these age groups. Age groups between 20 to 29 years constituted the largest proportion of fatal crashes in North-West (21,5 %) and Mpumalanga (24, 2 %), Northern Cape (14,3 %).

Age groups 30 to 39 years constituted the largest proportion of fatal crashes with fixed objects in the Western Cape (25,6 %), KwaZulu Natal (16,3 %), Free State (27,7 %) and Eastern Cape (22 %).

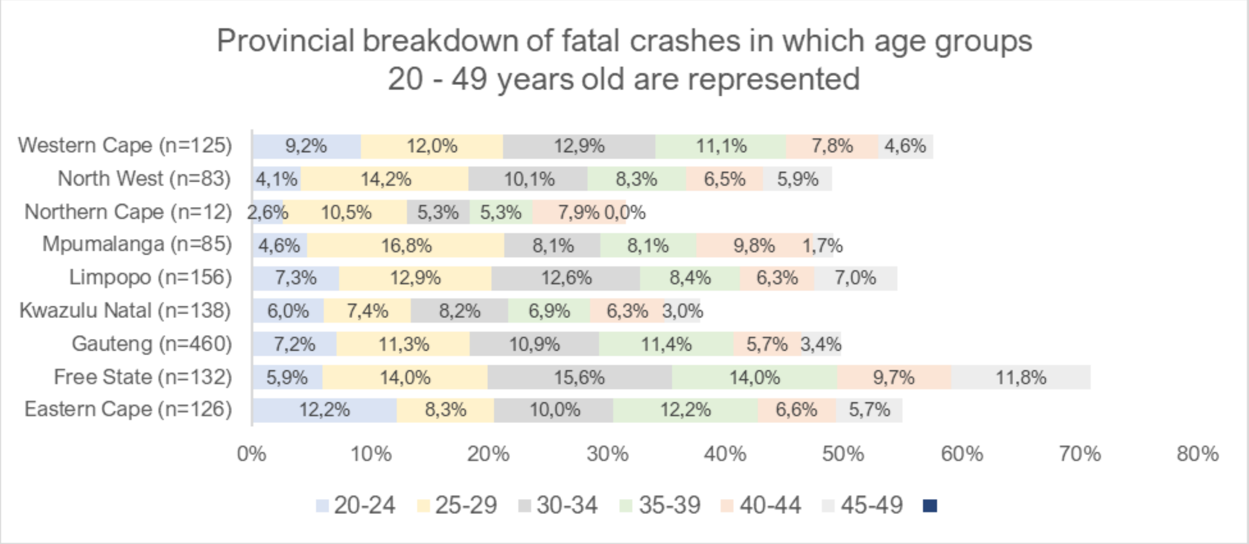

Figure 7: Provincial breakdown of crashes in which age groups 29 to 49-year-olds represented (Source RTMC 2023).

A qualitative analysis (RTMC crash data for 2017 to 2022) was conducted making use of the descriptions in the comments regarding the type of crashes and the secondary causes highlighted (where applicable).

Collisions with trees constituted the largest proportion of fixed object crashes for the years 2017 to 2022 (Figure 8). Collisions with trees (47.8 %) were followed by collisions with walls (15,2 %) and utility poles (14 %).

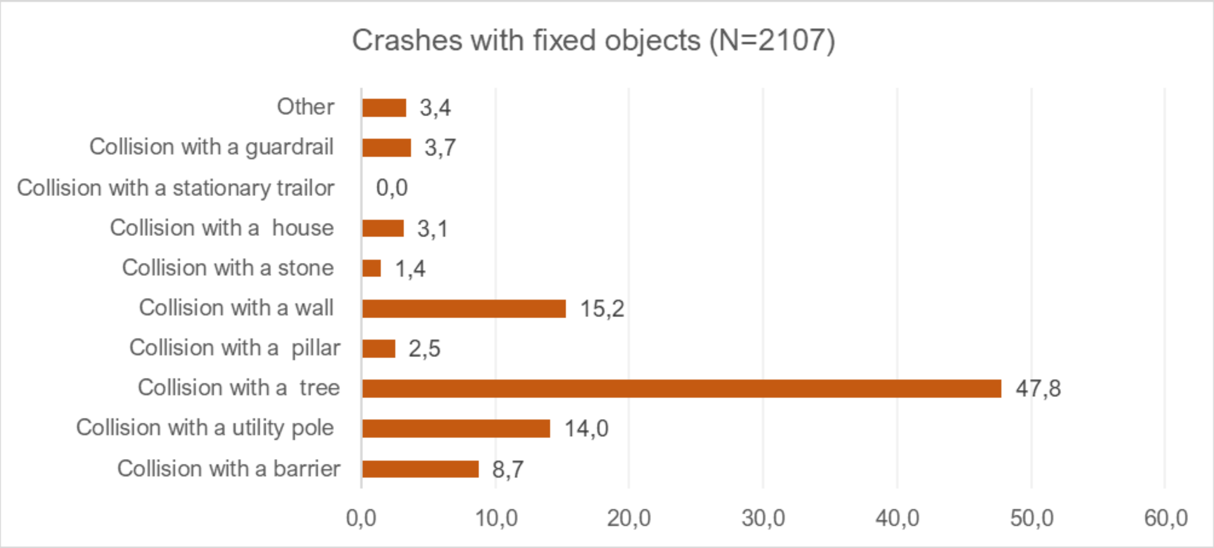

Figure 8: Percentage of fatal crashes with fixed objects according to type of object (RTMC 2022).

Secondary descriptions of crashes were available for 782 of the fixed object collisions. According to these descriptions the cause of the crashes is listed in table 1 below. Almost half of the crashes were attributed to speed that were too high for the circumstances (49,87 %). Approximately 10 % of the collisions were attributed to intoxicated drivers and tyre defects (9,08 %), swerving for pedestrians jaywalking contributed to 8,31 % of collisions (Table 4).

Table 4: Causes of collisions with fixed objects (N=782)

Cause/secondary descriptor of crashes	**% Contribution**
Speed too high for circumstances	49,87
Hit-and-run	3,71
Pedestrian (jay-walk)	8,31
Fatigue	4,35
Poor visibility	1,66
Disregard for a traffic sign	5,12
Tyre defect	9,08
Intoxicated driver	9,72
Trapped/fallen out	8,18

3.2. Utility poles as a roadside risk

The FHWA (1993) defines a utility as “a privately, publicly, or cooperatively owned line, facility, or system for producing, transmitting, or distributing communications, cable television, power, electricity, light, heat, gas, oil, crude products, water, steam, waste, stormwater not connected with highway drainage, or any other similar commodity, including any fire or police signal system or street lighting system, which directly or indirectly serves the public” (Thome 1993).

SWOV Institute for Road Safety Research in the Netherlands states that lighting posts along the road can have a negative effect on road safety since lighting columns could be collision objects. On average, annually, Dutch police register 16 fatal accidents on account of a collision with a lamp post. In 71 % of these accidents, a car collides with the lamp post. The share of fatal accidents involving lamp posts in the total number of fatal accidents, in the Netherlands is largest for motorcycles (SWOV, 2022).

The American Association of State Highway and Transportation Officials (AASHTO) Roadside Design Guide (3rd edition) released in 2006, indicated that in the United States, crashes with utility poles result in ten percent of all fatal fixed-object crashes (Gagne 2008). The crashes and the severity of the outcomes (fatalities and serious injuries) are the result of the quantity (number) of poles in use, the proximity of the objects to the edge of the road and their rigid nature (Gagne 2008).

Complicating the remediation efforts to make roadsides safer is the fact that utility poles in the United States are privately owned and are allowed on public rights of way, making it difficult for road authorities to implement corrective measures (J. Jones 2016). Hence, there is a dual responsibility (public and private interests) to considering how best to accommodate the poles on public rights-of-way (Scott 2019). In determining what effect utility poles may have on a highway or street project and how they should be handled, full consideration should be given to measures to ensure the safety of the traveling public and features to preserve and protect the operation, integrity, and visual quality of the highway or street. These measures and features should reflect sound engineering principles and economic analysis.

High frequency crash locations should be investigated and recommendations pertaining to mitigating measures can be implemented to reduce both the severity and the frequency of crashes. High risk locations for utility pole collisions include roadway environments where there is an above-average risk of being struck by an errant motorist and where serious injury or death is a likely outcome of such a collision. It has been estimated that no more than 1/10 of 1% (0.001) of utility poles within highway rights-of-way are atypically exposed (National Academies 2020). Road environments that should receive attention include areas where utility poles are in:

- In the critical quadrants of an intersection
- On the outside of curves especially on curves where the advisory speed is lower than the design speed of adjacent tangent sections (which can be especially critical at the apex of vertical curves where the S-curve is hidden until the crest is reached)
  On the roadside immediately after, and in line with, a lane termination
  In an area exposed to oncoming traffic in the zone where the pavement narrows significantly
- In the median of divided roadways
- On traffic islands exposed to oncoming traffic
- In an area adjacent to reversed curves when the pole line moves from one side of the roadway to the other side.

Zeeger et al (National Academies, 2020) highlighted the following factors as contributory causes to severe crashes with utility poles:

- Crashes with utility poles on horizontal curves are considered slightly more severe than those on tangent sections because of the increased number of side impacts on curves.
- Vehicle impact speed is considered an important factor in crash severity:
  - Utility pole crashes were more severe at non intersections than at intersections, probably because of lower vehicle speeds at intersections.
  - Impact speeds and pole circumference were related to the severity of utility pole crashes, but the spacing and offset of utility poles did not affect utility pole crash severity.
- Other factors influencing the severity of crashes included:

- utility pole type (e.g., wood, metal),
- presence of yielding poles,
- vehicle characteristics (e.g., weight, size)
- impact configuration

3.3. Addressing roadside risk

Since the 1960s, several alternatives have been suggested as solutions mitigate the severity of crashes with roadside objects. These included moving the lighting poles to a point away from the travelled way or controlling the impact behaviour of the lighting poles to reduce the severity of collisions (Rowan, 1967; SWOV, 2022). Measures taken to reduce or eliminate tree and utility pole-related crashes vary based on many factors, including location (e.g., urban versus rural), proximity to traffic, appropriateness of certain countermeasures, and environmental and historical factors (Jones 2016).

The TRB State of the Art Report 9 (Ivey and Scott 2004, 18–21) highlight a three-thronged approach to reducing utility pole fatalities namely best defence, offense and bet (table 5).

Table 5: Approach to reduce utility pole collisions (Ivey and Scott 2004, cited in Zeeger et al 2020)

Path	**Description**	**Requirements**
Best offense	Identifies where an overrepresented number of collisions are occurring, assesses available countermeasures, prioritizes these high-risk poles for treatment, and implements the improvements.	Documentation of collisions to better pinpoint specific locations or segments of highways where an atypical number of collisions have occurred and are occurring
Best Bet	Prioritizing potentially hazardous poles and roadway sections (using statistical prediction algorithms) before a crash history develops and implementing appropriate improvements.	Identify where collisions are most likely to occur in the future: • (Requires knowledge of the roadway system, including utility positions; right-of-way to detail where vehicle exposure to poles is most significant. • Predictive algorithms calculate and include traffic density and speed, pole frequency, and pole lateral placement.

Best Defence	complements the first two and entails striving to meet the recommendations of the Roadside Design Guide (AASHTO 2011b) and Ivey and Scott (2004).	Knowledge of the highway and utility systems. Examples include large rigid wooden poles. These present a danger to passing motorists if close to the roadway

Zeeger et al (National Academies, 2020) highlight that corrective measures should be prioritized to ensure that maximum safety benefits are considered in the most cost-effective manner. The scheduling of utility safety improvements should take into consideration planned utility replacement or upgrading schedules, accident potential, and the availability of resources.

AASHTO Guidelines on Geometric Design stipulates that utility lines should be placed as close as possible to the right-of-way line. Installations should also make provision for space for potential future road improvements and utility operations. The design should support utility line servicing that causes minimal traffic interference. Utility lines should also fit within the clear roadside policies that are appropriate for roadway, type, or functional class (Zeeger et al., 2020).

3.3.1. Clear zones and minimum offset for utility poles

Minimum offset and clear zone distances are normally set by road authority policy and dictate where new utility poles should be located, and whether existing utility poles should be removed, relocated, or mitigated. Recommended criteria for establishing offset distances are for example set forth in AASHTO's A Policy on Geometric Design of Streets and Highways (American Association of State Highway and Transportation Officials 1994):

- Where there are curb and gutter sections along the highway or street, utility poles should be located at least 0.5 meters behind the face of the curb, and where feasible, behind the sidewalk.
- This 0.5-meter offset is not a "clear zone" in the usual sense of the term, but a setback for practical and operational purposes.

Recommended criteria for establishing clear zone distances are set forth in AASHTO's Roadside Design Guide (American Association of State Highway and Transportation Officials 1996):

- If there are trench sections along the roadway, utility poles should be located beyond the clear zone established by the road authority, taking into consideration the type of road, volume of traffic, speed of vehicles, steepness of roadside slopes, horizontal curvature, and other features known to influence off-road accidents.
- The minimum clear zone distance should be least 3.0 meters from the edge of the travelled way on low-speed, low-volume roads, and will increase as speeds and volumes increase.
- The final placement of both new and relocated utility poles should be as far as practical from the roadway, consistent with other fixed objects along the road.

- If poles must be placed or must remain within the minimum offset or clear zone area, the reasons why this was considered acceptable should be fully documented. The lack of sufficient right of-way width to accommodate existing utility poles, is not a valid reason to preclude utilities from occupying the highway right-of-way.
- Where sufficient right-of-way is not available to accommodate the utilities, highway agencies should consider acquiring additional right-of-way.
- In all cases, utility facilities should be treated the same as other roadside hazards.
- Little will be gained by moving utilities unless their presence presents a significantly greater hazard to motorists than any other existing hazards.

3.3.2. Manual on Uniform Traffic Control Devices (MUTCD) – minimum requirements

Since the 1980s, road authorities have installed collapsible lighting columns to increase roadside safety. The advantage of these columns is the lower likelihood of impact damage and injury; the disadvantage is the fact that the falling pole can be a hazard to surrounding traffic, pedestrians, or property. Non-breakaway poles are still used in cases where pedestrian traffic is high, overhead electric lines are close, or if the pole is mounted on top of a concrete traffic barrier.

The 2000 edition of the Manual on Uniform Traffic Control Devices (MUTCD) made breakaway supports mandatory for signs within the clear zone of all roads open to public travel in the United States. This requires that all new sign installations be on breakaway supports. While shielding with a guardrail is an option, use of breakaway supports is preferred.

The 2003 edition of the MUTCD set out a 10-year implementation period to retrofit sign supports on highways signed at 80km/h or greater. In the United States, per the MUTCD there was a requirement that all sign supports within the clear zone of highways signed at speeds of 50 mph/ 80 km/h or greater must be mounted on breakaway support structures or be shielded with a barrier by January 1, 2013 (FHWA, 2020).

The most recent 11th addition of the Manual on Uniform Traffic Control Devices (MUTCD) published in December 2023 makes specific reference (Section 8A.06) to Uniform Provisions and states that all signs used in grade crossing traffic control systems shall be retroreflective or illuminated to show the same shape and similar colour to an approaching road user during both day and night. In addition, that no sign or signal shall be in the centre of an undivided highway, unless it is crashworthy (breakaway, yielding, or shielded with a longitudinal barrier or crash cushion) or unless it is placed on a raised island. Instances where the use of frangible poles should not be used include using the breakaway devices for the supporting posts for overhead structures or cantilevered arms that support overhead flashing-light signals.

3.3.3. Placement of utility poles in proximity to other road restraint systems

Road safety equipment and how it is used under different road and traffic conditions influences its functionality and safety. Safety barriers, for example, are active road safety devices and used if the consequences of a crash or accident were greater than those caused by crashing into a barrier. To ensure that barriers are effective, these devices need to be designed to successfully handle vehicle impact and to protect road and roadside users from fatal injury (Budzynski 2019).

Utility poles in proximity to other road restraint systems such as guardrails may hamper guardrail's ability to safely contain and redirect, the colliding vehicle and may constitute an additional obstacle that can further the stability of the barrier as well as the vehicle. It is therefore important to crash test (MASH or EN 1317:1998) structures in relation to other roadside furniture to determine the correct offset.

3.3.4. Crash tests for breakaway support

Breakaway supports meeting the crash test criteria have been required on all Federal-Aid Projects since 1990.

The original crash test criteria were developed as part of the 1985 with the publication of the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals. The 1993 NCHRP Report 350 incorporated *the same test and evaluation criteria* in metric form. Because the metric conversion in Report 350 resulted in tests that were slightly more liberal than the 1985 Specifications, all breakaway testing done between 1985 and 1993 is considered acceptable under NCHRP Report 350. The 2009 MASH adds the pass/fail criteria for windshield damage and roof crush, and requires testing with the 5000# pickup truck, but maintains test and velocity change evaluation criteria for the small car equivalent to that adopted in 1985.

Dinitz (2014) highlight that breakaway devices are tested at critical angles:

- Slip bases between 0 - 25 degrees
- Frangible bases between 0 - 90 degrees
- Frangible coulings between 0 - 90 degrees

The National Cooperative Highway Research Programme (NHRCP) 350 and the Manual for Assessing Safety Hardware (MASH) recommend breakaway poles for mounted signs and luminaires if (Dinitz 2014):

- The change in velocity is less than 22 km/h.
- The height of the break-away part is no more 100 mm.
- The wind load design 210km/h
- Spacing between objects is 2.1 m.

Breakaway devices should have a structural load capacity, which means they should be able to withstand elements of nature such as wind. In addition, devices should be designed to carry the heaviest/ largest pole.

The *Guide to Road Design – Part 6* (Austroads 2010a) provides guidance on the use of frangible road signs. Small road signs are usually supported by small diameter and thin-walled metal conduits that are frangible under vehicle impact. Larger signs require more substantial supports and should be provided with frangible mechanisms at the base of the supports (e.g., weakened timber, slip-bases with hinge points just below the sign). In urban areas, frangible bases may not be suitable, so the support should be located as far as possible from the carriageway. Alternatively, large signposts should be shielded by a road safety barrier or crash attenuator (C. S. Jurewicz 2014).

3.3.5. Yielding designs

Frangible poles have the potential to reduce the risk and severity of injuries in accidents. Extensive international crash testing and research has led to the development of "softer" roadside options such as frangible lighting poles and signposts, impact attenuators, rigid, semi-rigid and flexible safety barriers, flattened slopes (Jordan 2019). Frangible poles are designed to break or yield upon impact, thereby reducing the severity of crashes involving vehicles.

This design is crucial in areas with high pedestrian and vehicle traffic. The materials used, such as lightweight metals or composites, and the engineering design principles that allow these poles to break away or absorb impact efficiently, are central to their effectiveness (Jordan 2019).

The effectiveness of the frangible poles is measured in terms of:

- injury severity reduction
- vehicle damage
- overall accident rates.

Frangible poles offer significant safety benefits, but there are additional challenges such as higher costs compared to traditional poles, potential maintenance issues, or limitations in certain environmental conditions.

Austroads (2011) reported on the replacement of roadside hazards with frangible options (slip-base and impact-absorbing), the use of point hazard barriers and the review of engineering standards, guidelines, and product approvals (Jurewicz, 2014). Previous Austroads publications recommended that a risk analysis be conducted to examine the need for frangible poles since:

- Some types of impact-absorbing poles are unsuitable for use in cyclone-prone areas where (Jurewicz, 2014).
- Slip-base poles are considered ineffective in uneven roadside environments due to their reduced frangibility when hit above normal design height or when buried too deeply.
  Slip-base poles should be carefully installed to ensure that the pole stem will break away from its foundation upon impact. The structures should be checked regularly by qualified people to ensure they are free to slip on impact and the bolt tension is correct, as wind vibration can cause movements and jamming of the bolts. Regular inspection and maintenance were recommended to ensure that slip-base poles perform as designed (Jurewicz, 2014).

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Collapsible impact-absorbing power poles which fracture/crumble upon impact was investigated consist of two fibreglass sections which are joined together to create a solid tubular pole, which crushes on impact. The investigation revolved around opportunities to improve safety by undergrounding power lines, or installation of flexible barriers around poles with a crash history. Collapsible poles were investigated but were not deemed feasible, as a mechanical and electrical hazard would be created by overhead power lines lying on the road after a crash. Also, due to the reduced strength of fibreglass poles compared to their wood counterparts, the poles need to be spaced more closely together. This would increase the number of poles near the road and become uneconomical (C. S. Jurewicz 2014).

A utility pole has an above ground length (figure 9), and when struck at height (above ground level) this collision takes place at around 0.5 - 0.6 meter and the base shear strength will be exceeded at some stage of the vehicle impact and that the pole therefore ruptures in shear (Milner 2001).

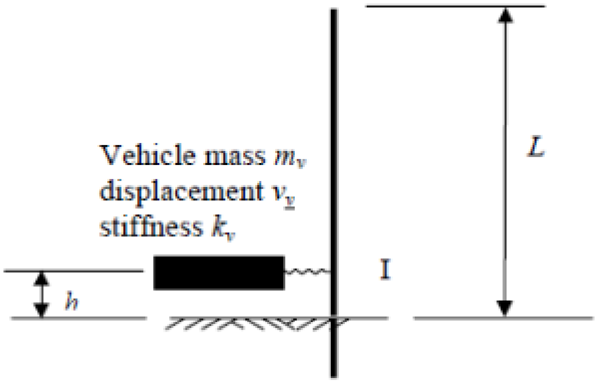

Figure 9: Forces of impact during collision with a utility pole (Milner 2001)

In the pre-rupture phase, it is assumed that the pole acts as a rigid object. This is not completely correct as the soil would deform slightly but should not have a significant impact on vehicle decelerations. The effect of soil deformation can be added easily to the analysis but choosing an appropriate value introduces several imponderables.

There are two complications associated with analysing vehicle-pole impacts (Milner 2001):

- Pre-rupture pole dynamic effects are negligible and ignored but post-rupture pole dynamics become dominant.
- The rupture of the pole changes the physical system.
- the nature of vehicle response to impact changes sharply during the impact event since the post rapture involves the vehicle crumpling and cushioning the impact. Once the pole penetrates the vehicle more than approximately 400 mm the vehicle becomes much stiffer due to contact with the engine and stiffer parts of the vehicle, leading to rapidly increasing vehicle decelerations (figure 10).

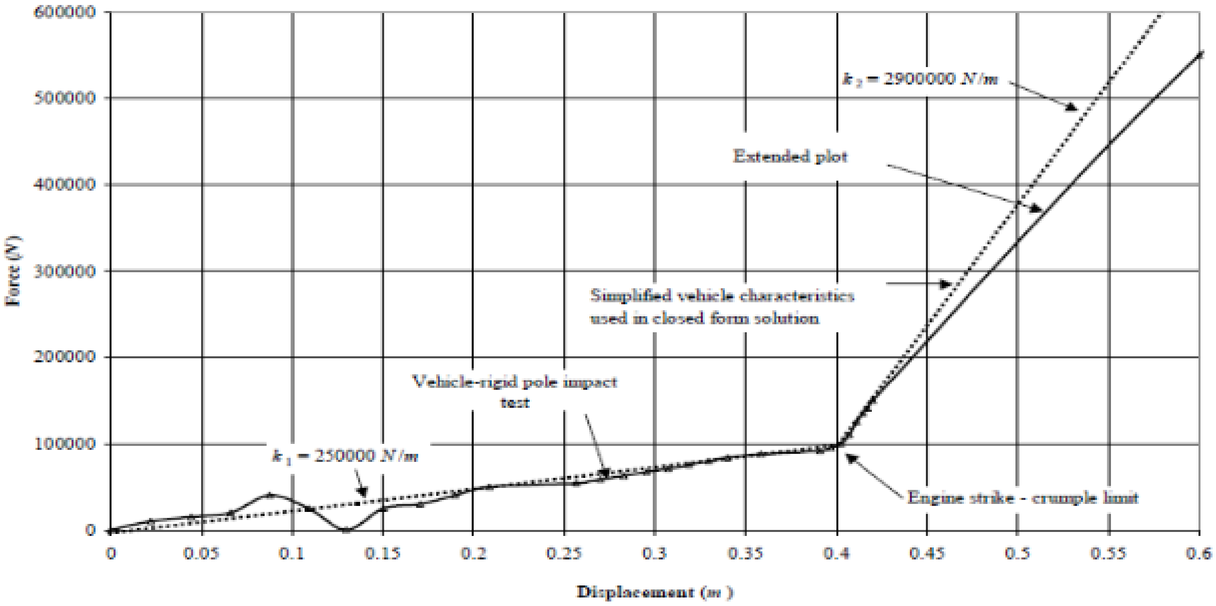

Figure 10: Vehicle deformation upon impact with a utility pole (Milner 2001)

When a pole must remain in place, it can be modified to break upon impact and swing out of the path of the vehicle, reducing the severity of an accident. Unlike the previous countermeasures, use of a yielding breakaway design is intended to reduce the severity of an accident rather than the accident frequency (Milner 2001).

Breakaway support, in contrast to a rigid support means a fixed object can be hit when running off the road, and the object yields on impact and reduces the deceleration of the vehicle and its occupants. The difference between frangible and rigid pole collisions are illustrated in the figure 6 below.

Sequence 1 (infrangible poles) is associated with:

- Stage 1-2 where initial impact occurs and continues until the vehicle has fully crumpled (engine strike)
- Stage 2-3 where the force resistance suddenly rises until rupture of pole occurs.
- Stage 3-4 where the force continues to rise because the vehicle continues to interact with the severed pole trying to overcome the pole’s inertia.

Sequence 2 (frangible poles) is associated with:

- Stage 1-2 where initial impact and some crumple occurs up to the moment the pole ruptures.
- Stage 2-3 where vehicle crumpling is completed (engine strike) as it continues to interact with the severed pole and its inertia.

- Stage 3-4 where the force suddenly rises on completion of vehicle crush and it then continues to interact with the severed pole's inertia, i.e., trying to accelerate the pole (figure 11).

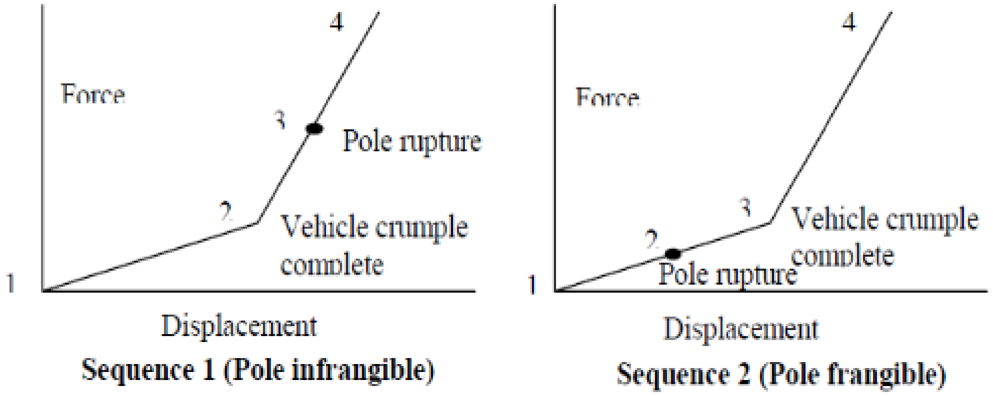

Figure 11: Impact sequence for infrangible and frangible poles (Milner 2001)

The use of breakaway support for all signs, luminaire and traffic signal supports aims to reduce the severity of crashes (SARRSM, 2022). If fixed objects are made to yield, they can be placed in an obstacle-free zone without safety barriers. The use of frangible poles may effectively reduce the severity of pole-related crashes if pole removal or relocation is not feasible. These poles are designed to collapse or break away on impact, thereby reducing the severity of injuries to the occupants of an impacting vehicle compared to those that would occur if the pole were rigid (SARRSM, 2021).

Several breakaway designs have been successfully crash-tested, have demonstrated satisfactory in-service performance, and may be feasible for poles in vulnerable locations that cannot economically be removed or relocated. The term breakaway support refers to all types of signs, luminaire, and traffic signal supports that are safely displaced under vehicle impact, whether the release mechanism is a slip plane, plastic hinges, fracture elements, or a combination of these.

Energy absorbent material

An impact absorbent pole is designed to collapse progressively, absorbing the force of an impacting vehicle by wrapping itself around the vehicle and decelerating it to a controlled stop. The pole remains attached to the base, and is therefore most suited to locations where vehicle speeds are lower, or pedestrian and development activity higher (Jurewicz 2014).

To increase energy-absorbance materials with low stiffness. Wooden poles is used posts should be avoided. Poles made of fibreglass that absorb energy over their entire length are a good compromise between energy-absorbance and safety. The poles crack without having a predetermined breaking point. Impact absorbing poles are suitable for areas with lower speeds and more non-motorised transport user activity.

Splicing

If the predetermined breaking points are not correctly located in the pole or post this can result in vehicle snagging and flying parts. To achieve a safe breakaway, splices should be kept close to the ground.

Slip-base poles

A slip base lighting column is designed to break away at the base when struck by a vehicle. This type of column can often be reused after a collision, with only minimal repairs. A characteristic of slip base poles is that when impacted at normal operating traffic speeds, they are dislodged from their original position. This enables the pole to slip at the base and fall if a collision occurs. The electrical connections also break away and are easily reconnected. Slip base columns are mostly suitable for locations where vehicle speeds are greater than 80 km/h, areas with little or no non-motorised transport activity. The use of slip-based poles is not recommended for areas where there is high pedestrian activity, or lots of parked vehicles (Jordan 2019).

The correct failure mode of this type of pole is straightforward but needs attention to detail in practice. Common faults with the installation of slip-base poles include:

- incorrectly tightened hold down bolts. If the bolts are too tight the pole acts a rigid pole and the safety features are lost, too loose and the pole can be knocked over by the forces of excessive wind loading.
- base section set too low so that the surrounding ground impedes the free movement of the pole during impact.
- base section set too high so that it will snag an impacting vehicle.
- pole placed too close to bottom of cut batters again impeding free movement.
- hold down bolts concreted in position so that collapse mechanism is inoperable - again creating a rigid pole.
- base plate not aligned correctly to direction of traffic flow.
- circular washer broken at bolts enabling the slip-based pole to "move" off the base under wind load.
- use in low-speed locations e.g., at roundabouts, parking areas, where the striking vehicle does not have sufficient speed to satisfactorily clear the falling pole.

Breakaway transformer base

Breakaway connectors are fused or unfused connectors in the base of poles. A transformer base, commonly made of cast aluminium, is bolted to a concrete foundation. The bottom flange of the pole is bolted to the top of the transformer base. The aluminium is heat-treated to make it 'frangible', so that the pole can break away from the base when struck by a vehicle.

When breakaway poles are used, the electrical conductors must also be designed to break away. This is accomplished by using special pull-apart fuse holders (breakaway connectors). In the case of breakaway poles, the neutral must also have this breakaway connector but should be unfused.

3.3.6. Placement of traffic control devices

In South Africa, road traffic signs must comply to the requirements of the South African Road Traffic Signs Manual (SARTSM), Volumes 1 to 4. According to the SARTSM Volume 1 Figures, 1.5 to 1.9 shown in Appendix A the lateral distance for the placing of road signs ranges from 750mm to 4000mm. Thus, SARTSM dictates that road signs should be well within the 'clear zone' to effectively serve their purpose.

Signs need to be seen - and for this they need to be placed near the roadway. This can itself cause conflict. In general, most sign supports should be fully collapsible e.g., small bore galvanised pipes for small signs, break-away or slip base for larger signs or protected by some type of safety barrier. In South Africa, the National Roads Agency uses timber poles. Where diameter of poles exceeds 125 mm, two breakaway holes must be drilled.

Vandalism however creates a significant problem and measures to combat it should be implemented. These may include using rods or vanes at the bottom of posts to prevent rotation or removal (SARTSM, 2012.p1.10.4). This specific measure of preventing vandalism may pose a danger to errant vehicle that collide with these signs and therefore breakaway poles may be a suitable fixed object in some instances.

Most traffic signal poles are not frangible and are not protected. These poles are designed with the strength to support the necessary traffic signal apparatus/signal heads and road lighting hardware (particularly under wind loading), so the provision of barriers to shield these poles is usually impracticable or would lead to reduced overall safety. Most importantly, traffic signal systems provide significant net road safety benefits, despite their supports being expected to endanger errant vehicles (SARRSM, 2022).

Designed steel breakaway poles typically for larger signs have not found favour in South Africa. This may be due to low crash rates or the absence of claims against the road authorities. They should be considered in high-risk areas as an alternative to shielding (SARRSM, 2022: p54).

3.3.7. Placement of advertising signs

Other signs that are not essential to the control of traffic except for street name signs and suburb name signs (SARTSM, 2012) are not permitted to be positioned within the road reserve. However, in South Africa it is a common occurrence for other signs, often illegal advertising signs to be placed within the road reserve with some being close to the roadway. Often many advertising signs are placed within the road reserve without the involvement of qualified traffic engineers or traffic officers as required by the South African Road Traffic Signs Manual. As indicated earlier, this issue is address in the Guidelines for Outdoor Advertising which is under review and will be published in South African Road Traffic Signs Manual Volume 2 Road Traffic Sign Applications Chapter 22 Outdoor Advertising.

3.4. Considerations pertaining to the placement of frangible poles.

The adoption of frangible poles in urban and traffic planning involves a complex interaction of various factors that can influence the decision to implement frangible poles and these factors also affect the overall effectiveness and cost-efficiency of the frangible poles. Key considerations are summarised in the section below.

3.4.1. Frangible pole placement at hazardous locations

Existing utility poles must be monitored to determine if there is a high concentration of crashes at a particular location (Gagne 2008). The location and spacing of frangible poles, which are critical for maximizing their safety benefits. Poles placed near pedestrian-heavy areas, school zones, or sharp curves can significantly reduce the risk of severe injuries in crashes. The height and angle of installation also play a role, as they need to be optimized for impact absorption while maintaining their functional purpose (like supporting streetlights or signs).

3.4.2. Road type and function

Different road types have varying requirements for pole design and placement. Freeways, with high-speed traffic, might need poles that can break away easily to minimize the impact on vehicles whereas on urban streets with lower speed limits poles that protect pedestrians or other vulnerable road users should be prioritised. The type of road also influences the frequency and spacing of poles, with densely populated urban areas possibly requiring more poles than rural roads (AASHTO, 2011). Areas with high traffic volumes may benefit more from frangible poles due to the higher likelihood of vehicle-pole collisions (AASHTO, 2011). However, the cost-benefit analysis in these areas must also consider the frequency of replacements or repairs due to more frequent impacts (AASHTO, 2011). In contrast, less busy roads might not see as much direct safety benefit from frangible poles, but when accidents do occur, the poles can significantly reduce the severity of outcomes.

3.4.3. Environmental considerations

The local climate and environmental conditions play a significant role in the selection and maintenance of frangible poles. Frangible poles in areas with harsh weather conditions (like extreme cold, heat, or coastal salt air) need to be made of materials that can withstand these conditions without compromising their frangibility. Additionally, environmental factors like the likelihood of wildlife collisions or the presence of natural obstacles can influence the decision to install frangible poles.

3.4.4. Technology and material development

The development of new materials and designs that improve the effectiveness and reduce the cost of frangible poles can also drive their adoption. As technology evolves, more efficient and cost-effective solutions may emerge, making frangible poles an increasingly attractive option for road safety.

3.4.5. Alternative measures to address roadway departure crashes.

Assist the driver to stay on the roadway.

Positive guidance to drivers by for example, using pavement markings, advance warning signs, delineators, and other visual cues to tell the driver what to expect and to provide a visual path through a site.

Physical enhancements such as improving the skid resistance of the pavement, widening the pavement travel lanes, widening, or paving shoulders, straightening sharp curves, decreasing the speed of vehicles, or adding lighting in areas where accidents frequently occur at night may also diminish accident potential by decreasing the number of vehicles that accidentally leave the travel way (Gagne, 2008; Scott, 2019).

Warn motorists.

The number or severity of accidents may be decreased by warning motorists of the presence of poles adjacent to the roadway. This may be done by placing reflective paint, sheeting, or object markers on utility poles. Poles close to the travelled way, on the outside of a horizontal curve, where a lane becomes narrow, at the end of a lane drop, or in other locations where vehicles are likely to travel close to them are candidates for such warning where more comprehensive treatments are not justified (Scott 2019).

Increase sight distance and visibility.

Locate utility poles so as not to restrict the drivers' sight. Suggestions for improving sight distance and visibility include (Joseph 2016):

- Keeping intersection sight triangles clear of any visual obstructions between 1 meter and 3 meters vertically.
- Placing trees and poles outside of established sight distance parameters for horizontal curves on ramps.
- Locating trees and poles where their presence will not obstruct regulatory, warning, or advisory signing.

Place new utility poles where they are less likely to be struck.

Lighting posts should be placed on the inside of curves, in the central reserve or on traffic islands at junctions rather than posts placed on the roadside.

Pole lines should be placed on the inside of horizontal curves where possible. Studies have shown there are many fewer off-road accidents on the inside of horizontal curves than on the outside. On winding roads, this placement may not be feasible, because the wires would have to cross the road each time sequential curves changed directions (Nillson, 1997).

Where ditches, retaining walls, guardrail, or similar features exist, pole lines should be placed behind them. Errant vehicles cannot travel past them to strike the poles (Gagne, 2008; Scott, 2019). In addition, rigid steel posts should gradually be exchanged for deformable and energy absorbing posts, which should be used when installing new road lighting (Nillson, 1997).

Moving utilities underground

By burying utility lines, poles can be removed, reducing accident potential. This alternative also saves the utility company the cost for removing and replacing a pole damaged in a collision and for repairing the utility line after an accident.

The primary disadvantage of this treatment is the additional initial expense. Even with underground utility lines, there still may be a need for safety treatment of surface transformer pads, switching cabinets, and other associated hardware. Rock formations and similar site conditions may make underground treatment too expensive. It may also be difficult to handle unanticipated local growth, or it may be impossible to tap some underground facilities to add customers. Despite these and other difficulties, an underground installation is often the best design solution (American Association of State Highway and Transportation Officials 1994)

Increasing lateral offset

Obstructions are elements that have a vertical dimension and influence vehicle operations; the impact on safety is not considered in this design control. Safety impacts are considered when designing an appropriate clear zone, which is an important measure, but is not included as a design control due to the flexibility required for specific local conditions. If an inadequate lateral offset is applied, the obstruction may influence speed and lane position of vehicles, as well as vehicle access when on-street parking is allowed (Findley 2022)

Lateral offset reflects the vehicle position with respect to the lane centreline. It is the direct expression of the vehicle's lateral position. As a design control, the lateral offset to obstruction is concerned with the distance from the edge of the travel lane to a roadside obstruction and its influence on roadway operations (Findley 2022).

While lateral offset and the density of utility poles are major characteristics when determining the risk of a utility pole being hit, they are not the only factors which must be considered. Crashes do still occur in locations with large offsets or low densities And the road geometry impacts the likelihood of a run-off-the-road-crash occurring and consequently must be considered when determining the chance of a crash occurring with a utility pole. For instance, a pole placed on the outside of curve on a downgrade is more likely to be hit than a pole with the same lateral offset on a level, straight section of road. So even though it may not be possible to adjust the road's geometry when applying corrective measures, it is still important that the geometry be considered when identifying and prioritizing hazardous poles (Gagne, A. 2008). The minimum offset to diminish the impact of the obstruction on vehicles operations is 45,72 cm, while 137.16 cm is recommended (AASHTO, 2018):

- Decreasing the density of poles by increasing spacing between poles
- Using fewer poles by encouraging joint usage
- Installing breakaway devices
- Shielding utility poles with horizontal barriers and crash cushions
- Attaching reflectors to the poles

Relocate existing utility poles farther away from the roadway.

Both accident rate and accident severity will decrease when utility poles are moved farther from the travel way. Ideally, utility poles should be placed near the right-of-way line (i.e., beyond the 0.5-meter minimum offset or, desirably, behind the sidewalk in curb and gutter sections, and outside the clear zone in ditch sections). Vertical construction of the utility poles can sometimes be used instead of cross-arm construction to provide more lateral clearance.

The full effectiveness of moving poles away from the roadway cannot be achieved if other fixed objects are allowed to remain in the clear zone. A utility pole accident reduction program should be part of a comprehensive plan that removes all types of objects from the clear zone.

Reduce the number of utility poles.

One way to decrease utility pole accidents is to decrease the number of poles beside the roadway. There are several methods available:

- encourage joint use of existing poles, with one pole carrying streetlights, electric power, telephone, and other utility lines.
- place poles on only one side of the street
- increase pole spacing by using bigger, taller poles.

These larger poles will be struck less frequently because there are fewer of them. However, they may cause more severe accidents because of their larger size and thus cancel any savings that might have accrued because of the decreased number of accidents.

Before adopting any of these procedures, an engineering study should be conducted to determine whether the changes would be cost-effective and appropriate for the specific site. The study should be done per site considering the number of crashes, the number of poles with consideration as to the type of incidents and traffic.

Shield utility poles.

If it is not feasible or practical to place utility lines underground, relocate them, make them breakaway, or to provide any other of the previous countermeasures, then other treatments may be necessary. One acceptable treatment is to shield the fixed object. Roadside barriers perform this function by redirecting the vehicle away from the utility structure, allowing the driver an opportunity to recover control of the vehicle.

Research to determine the safe placement of a breakaway light pole with respect to guardrail placements were conducted through computer simulation and full-scale crash testing (Budzynski 2019). Recommendations from the research concluded that lighting poles typically should not be placed within the working width of a guardrail. Working width is defined as the farthest distance the barrier or vehicle extended laterally during impact, as measured from the original, undeformed front face of the guardrail. There are many instances where light poles are desired to be installed directly behind W-beam guardrail to provide adequate illumination along roadways. However, the placement of light poles near guardrail may affect the guardrail’s ability to safely contain and redirect vehicles. Interaction between a deflected guardrail system and a pole may create unwanted stiffening or hinging of the barrier system about the pole, which may cause pocketing and increased loading to the guardrail. Impacting vehicles may catch on the pole, which could increase vehicle decelerations and instabilities. There are instances in which a guardrail is not appropriate. One example is when there is not enough room between the guardrail and the fixed object for the guardrail to fully deflect during impact. Another way to shield a vehicle from striking a utility pole is to use a crash cushion. A crash cushion is normally used where there is an isolated fixed object hazard. If there are several objects, a guardrail is a better safety device (Scott 2019).

Criteria on roadside barriers in the AASHTO Roadside Design Guide are used to determine whether a barrier is an appropriate treatment and, if so, what design is suitable for site conditions (American Association of State Highway and Transportation Officials, 1994; American Association of State Highway and Transportation Officials, 1996).

Guardrail and crash cushions should not be used indiscriminately because they are expensive to install and to maintain, and they are closer to the road than the objects they are shielding. They are involved in more accidents than unshielded objects. They should be used only when they are warranted by the reduction in accident severity (Jones, 2016).

Public awareness and support for adoption

The acceptance and support of the local communities and stakeholders (like city planners, road users, and insurance companies) can influence the adoption of frangible poles. Public awareness campaigns highlighting the safety benefits can play a crucial role in gaining support for the adoption and implementation of fragile poles in support of roadside safety.

3.5. Kilometre markers

Kilometre markers are physical devices placed on the roadside to indicate or mark the longitudinal distance location of the road in relation to its designated starting point for a specific section of the road.

The following is uses of the kilometre posts:

- While undertaking road planning, design, and maintenance activities to refer to a specific road by route number, section of the road, distance location, and the direction of travel (i.e., side of the road).
- In emergency situations or when assistance is requested motorists (or emergency services) can use the device to identify their location on the road.
- Kilometre markers are placed 200m apart and on both side of the road (only on dual carriageways). The markers are blue and made of steel.

3.5.1. International practice

The use of kilometre markers follows the same principles with the main reason being to identify location and proximity on the road. The use of kilometres may slightly differ in that the letters and numbers on the kilometre may bear slightly varying messages or meaning as discussed in table 6 below.

Table 6: Description of kilometre marker functions in different countries

Country	Description of kilometre marker functions
Philippines	The distance location is with reference to the nations' capital and not the beginning of a specific road or road section. Furthermore, another distance location on the same marker states the distance from the next town or city. If the kilometre marker is on the right side of the road, that means driving away from Manila. In Philippines traffic drives on the right. If the kilometre marker is on the left, then you are heading towards the capital (Autodeal, 2017).
England:	Blakedale posts are installed at 100-meter intervals alongside the hard shoulder. The numbers on the posts, for which no units are given, are derived from the distance, in kilometres, of the post from a reference datum location such as a city centre, an administrative boundary or some other feature. Posts are used to • pinpoint road locations for maintenance • emergency purposes • show the direction to the nearest emergency roadside telephone. On motorways distance marker posts also bear an arrow pointing towards the location of the nearest emergency telephone. The number used on distance marker posts is also encoded into the numbers associated with motorway emergency roadside telephones for motorway control centre staff can pinpoint the telephone from which a call is being made (Highway Agency, 2010). Mobile phones required a government rethink regarding marker posts. This has led to the erection of driver location signs in England at about 500 metre (about 1/3 mile) intervals on many motorways. Driver location signs have three pieces of information: • The road identifier • The carriageway identifier • The location The location is identical to the location given on marker posts. The most used carriageway identifiers are the letters "A", "B", "J", "K", "L" and "M". • "A" normally denotes the carriageway in the direction of increasing location numbers (usually away from London), • "B" the carriageway in the direction of decreasing location numbers • "J", "K", "L" and "M" denote junction slip roads.
	Dutch hectometre markers are spaced at 100-metre intervals. Shows motorway number and location a carriageway identifier – Li for Links (Left) and Re for Rechts (Right). The carriageways are identified as being

	left-hand and right-hand as viewed by somebody looking in the direction of increasing location numbers. Dutch location numbers increase as one moves away from Amsterdam, or in the case of roads that do not originate in Amsterdam, location numbers increase as one moves eastwards away from the North Sea. Carriageway identifiers “a”, “b”, “c” and “d” are used to identify slip roads on and off the motorway. Another novel concept on Dutch hectometre markers is that speed limits are displayed on the marker boards when the speed limit is less than the (previous) national default of 120 km/h.
United States	United States except in California (discussed below), mileposts are placed on interstate highways (and other major routes in some states) at one-mile intervals that indicate the distance through a state. Mileposts normally start at the western or southern point of entry of the route into the state, or the southern or western terminus of the route within the state and increase heading north or east. Many states have added supplemental reference markers that indicate distance in fractional miles (tenth, quarter, half, etc.) in addition to mileposts for whole miles, either across the entire state or in select regions of the state.
California	California uses a postmile system on all of its state highways, including U.S. Routes and Interstate Highways. The postmile markers indicate the distance a route travels through individual counties, as opposed to mile markers that indicate the distance travelled through a state. Nevada and Ohio use similar county-based mile markers on non-interstates but use standard mileposts on interstate routes (https://en.wikipedia.org/wiki/Highway_location_marker)
New York	New York reference markers are plates 252 mm by 200 mm that have three rows of numbers. Since the lettering is small (60 mm, 2.4 in), they are designed for use by highway engineers rather than motorists. The first row displays the route number, the second row the NYSDOT Region, and the third row the control segment and distance from the segment start. The control segment has one digit while the distance from the start of the segment has three digits and is given in units of tenths of a mile.
	Malaysia has its own unique set of location markers in kilometre and hectometre (100-metre intervals). They include the route code, location number from the road starting point and sometimes direction of the carriageway. Green background is for toll expressways and blue backgrounds are for non-tolled highways (https://en.wikipedia.org/wiki/Driver_location_sign)

India	The Indian location markers carry several different distances. The marker illustrated carries the following information: • National Highway 58 • 180 kilometres from the start of the highway (in Delhi) • 24 kilometres to the next big city - Haridwar 352 kilometres to the last town on the route - Mana, India (which is close to Mana Pass on the Tibetan/Chinese border, the terminus of the route).Although the sign illustrated uses Latin script, several Indian location markers use the Indian official language Hindi or the predominant language of the state in which they are located.

An example of Malaysia kilometre markers are given below.

Driver location sign on tolled expressways every 1 kilometre

Driver location sign on tolled expressways every 100 metres

Driver location sign on non-tolled highways every 1 kilometre

Driver location sign on non-tolled highways every 100 metres

On the other hand, federal roads have marker which are placed every kilometre and includes the distance to primary destination and location number. Every five kilometres however the marker includes the route code, distance to primary destination, distance to secondary destination and location number.

Driver location milestone on federal roads every 5 kilometres

3.5.2. South African Practice

The study of the South African Road Traffic Signs Manual (SARTSM) Volumes 1 to 4 does not reveal any specific information regarding the use of kilometre markers. Thus, it is deemed that kilometre markers are not legislated in South Africa or the South African Development Community (SADC) region. Furthermore, based on personal experience kilometre marker are mostly observed on national routes (i.e., those under the authority of the South Africa National Roads Agency - SANRAL).

The most accurate location details can be obtained from the blue kilometre marker boards erected every 200 metres along the national road. This board displays the following:

- It is the N1 Route
- On section 21
- At kilometre 15,0
- On the Northbound carriageway

Figure 12: Example of kilometre markers along national rotes (Source: SANRAL)

As previously indicated other than being useful for SANRAL kilometre marker boards are valuable for the public, emergency services and what is termed 'On-Road Services' which provide the following services: Incident Response Units (IRU), Medical Response Units (MRU), Light Towing and Recovery Units (LTRU), and Heavy Towing and Recovery Units (HTRU).

Kilometre markers on provincial roads in South Africa are not standardised and each provincial authority applies different designs. In some provincial road authorities, more than one design is used.

Below images are examples of different (not standardised) kilometre marker designs.

4. RECOMMENDATIONS AND FURTHER RESEARCH

4.1 Kilometre markers

4.1.1 Standardised kilometre markers to be legislated to be mandatory and incorporated in national, provincial and municipal policies.

4.1.2 Existing roadside furniture such hazard markers, street names, stop signs, bus stops, etc. could have an added function as kilometre markers placing QR code or barcode sticker on them that could be read by a smartphone. The information displayed on the smartphone would include the location and could further include a feature to send back the user's location to an emergency control/dispatch centre.

4.1.3 Kilometre markers (and other road signs) could have a QR code or barcode engraved on them that can be scanned by a smartphone which would then reveal more information about sign including the location (or intended location)

4.1.4 The kilometre marker could display information on both sides of the metal plate.

4.1.5 The kilometre markers could be designed and manufactured with a reflective strip around the edges of the metal plate to make the kilometre sign identifiable at night.

4.1.6 There should be ongoing public awareness campaigns regarding the existence and understanding of the information on kilometre markers.

4.2 Break-Away/Frangible Poles

4.2.1 Further research should consider determining the suitability, effectiveness, and efficiency of frangible poles, in relation to the South African road environment, climate and environments as well as the investigation of types of material and the use of technology to improve designs suitable for the South African road environment.

4.2.2 To quantify and motivate for the use of frangible poles in support of safer roadsides there is a need for focused research to quantify the benefits of frangible poles in terms of lives saved, injuries prevented, and cost savings in terms of healthcare and vehicle repairs as well as to investigate the optimal placement and distribution of frangible poles in various South African road settings. In addition, there is a need for South African research to understand how frangible poles behave in real-world scenarios (considering local contexts, land use, traffic mix and so forth).

4.2.3 The cost of installation, maintenance, and replacement of frangible poles compared to traditional poles is important as frangible poles might be more expensive initially, their potential to reduce long-term healthcare and repair costs can make them a cost-effective choice. Economic analyses (possibly an addition to the Cost of Crashes methodology) or cost-benefit analysis should include a long-term view of these costs and benefits for improving roadside risk and safety.

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