Road Traffic
Management Corporation

UPDATE OF THE SOUTH AFRICAN ROAD SAFETY AUDIT MANUAL

Deliverable 1: Literature review

31 January 2021

Prepared for: Mr. Deon Roux
Road Traffic Management Corporation
General Manager: Research, Innovation and Engineering
Email: DeonR@rtmc.co.za

Prepared by: CSIR Smart Mobility Unit
Transport Systems and Operations

Contact person: Mr. Michael Roux
Contact details: Email: mproux@csir.co.za.

Project team
Mr. M. P. Roux (Pr Eng) - Project leader
Mr. S. E. Groskopf (Pr Eng)
Mr. F. J. J. Labuschagne (Pr Eng)
Mr. S. Ndungane
Mr. M. Nkosi
Mrs. L. Kemp
Dr. K. Venter

Disclaimer: This Literature Review is published as a public service by the RTMC. It is the result of a specific research project for the RTMC and is based on a desktop search and analysis of existing Internet searchable publications. This literature review does not purport to represent the views or the official position of any South African Road or Local Authority, the RTMC and the CSIR or any of their respective employees, or any of the individual project team members. The structure and content of the literature review report are not presented to be complete or exhaustive on the themes relevant to road safety reviews, nor as a contextually accurate analysis of references or of any collation of information abstracted from the references referred to. Any inferences made from this literature review by any user, or reliance on the information published herewith for whatever purposes is solely at the user's own risk. Under no circumstances shall we have any liability for any loss or damage of any kind (including consequential damages) incurred because of the use of or reliance on this information or related to it.

UPDATE OF THE SOUTH AFRICAN ROAD SAFETY AUDIT MANUAL

RTMC REQUISITION: 1004535

Report 2: Literature review

Document Ref.

Revision 00

January 2021

Authorised Use:

This document has been prepared specifically as Report 2: Literature review in support of the Update of the South African Road Safety Audit Manual study and remains the intellectual property of the CSIR.

The contents of the report must only be used for the Update of the South African Road Safety Audit Manual study for which it was commissioned under licence and shall not be reproduced or used in full or in part outside of this application without the authorisation of the CSIR.

Record of Issue:

Rev	Status	Author	Date	Reviewed/ Authorized	Date
00	For Review	CSIR Project Team			
01	Project management team				
02					

ABBREVIATIONS

AAAA	Addis Ababa Action Agenda
AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ABS	Anti-Break Locking Systems
AMFs	Accident Modification Factors
ANRAM	Australian National Risk Assessment Model
ASANRA	Association of Southern African National Road Agencies
ADB	Asian Development Bank
ADM	Abu Dhabi Municipality
AfDB	African Development Bank
ADMRN	Abu Dhabi Municipality Road Network
AIP	Accident Investigation and Prevention
BRT	Bus Rapid Transport
BSM	Blackspot management
CAREC	Central Asia Regional Economic Cooperation
CMFs	Crash Modification Factors
CRFs	Crash reduction factors
CSIR	Council for Scientific and Industrial Research
CSCRS	Collaborative Sciences Centre for Road Safety
COTO	Committee of Transport Officials
COLTO	Committee of Land Transport Officials
CPD	Continues Professional Development
DoRA	Division of Revenue Act
DoT	Department of Transport
EB	Empirical Bayesian

ECE	Economic Commission for *Europe*
ECSA	Engineering Council of South Africa
ESC	Electronic Stability Control
ETSC	European Transport Safety Council
FHWA	Federal Highway Administration
GDP	Gross Domestic Product
GRSF	Global Road Safety Facility
GRSP	Global Road Safety Partnership
GSRRS	Global Status Report on Road Safety
IFIs	International Finance Institutions
IHSDM	Interactive Highway Safety Design Model
IRAP	International Road Assessment Program
ITPs	Integrated Transport Plans
ISO	International Standard Organisation
ITS	Intelligent Transport Systems
LMICs	Low- and Middle-Income Countries
MDBs	Multilateral Development Banks
MECs	Members of the Executive Council
MMIRE	Model Minimum Inventory of Roadway Elements
MMUCC	Model Minimum Uniform Crash Criteria
NCHRP	National Cooperative Highway Research Program
NATMAP	National Transport Master Plan
NCHRP	National Cooperative Highway Research Program
NDP	National Development Plan
NEMA	National Environmental Management Act (NEMA 107 of 1998)
NLTA	National Land Transport Act
NLTSF	National Land Transport Strategic Framework

NMT	Non-Motorised Transport
NRSS	South African National Road Safety Strategy
NRTA	National Road Traffic Act (93 of 1996)
NSM	Network Safety Management (NSM)
NSR	Network Safety Screening
OECD	Organisation for Economic and Cooperative Development
PET	Post-Encroachment Time
PIARC	World Road Association
PLTF	Provincial Land Transport Framework
PRMG	Provincial Road Maintenance Grant
PSD	Passing Sight Distance
RAMS	Road Asset Management System
RIA	Road Impact Assessment
RIFSA	Road Infrastructure Strategic Framework for South Africa
RISM	Road Infrastructure Safety Management
RSA	Road Safety Audit
RSI	Road Safety Inspection
RSIA	Road safety impact assessment
RSSAT	Road Safety Screening and Appraisal Tool
RTI(s)	Road Traffic Injuries
RTMC	Road Traffic Management Corporation
RTSMS	Road Traffic Safety Management System
RTM	Road Transport Management
RSSAT	Road Safety Screening and Appraisal Tool
SALGA	South African Local Government Association
SANRAL	South African National Roads Agency Limited
SARSM	South African Road Safety Manual

SATC	Southern African Transport Conference
SER	Self-Explaining Roads
SDG	Sustainable Development Goals
SIPs	strategic Infrastructure projects
SIPDM	Standards for Infrastructure Procurement and Delivery Management
SPF	Safety Performance Function
SPLUMA	Spatial Planning and Land Use Management Act
SSA	Safe System Assessment
SSAF	Safe System Assessment Framework
SSD	Stopping Sight Distance
SSM	Safety Surrogate Measures
TER	Trans-European Railway
TMH	Technical Methods for Highways
ToR	Terms of Reference
TTC	Time-to-Collision
TTCD	Temporary Traffic Control Devices
TRACECA	Transport Corridor Europe-Caucasus-Asia
TRH	Technical Recommendations for Highways
TSM	Transportation System Management
UN	United Nations
US	United States
TAH	Trans-African Highway
TEM	Trans-European North-South Motorway Project
TEN	Trans European Road Network
TEV	Total Entering Vehicles
UK	United Kingdom
US	United States

USA	United States of America
UNECA	United Nations Economic Commission for Africa
UNECE	United Nations Economic Commission for Europe
UNGA	United Nations General Assembly
UNRSC	United Nations Road Safety Collaboration
VRUs	Vulnerable Road Users
WB	World Bank
WHA	World Health Assembly
WHO	World Health Organisation
WZRSA	Work Zone Road Safety Audit

TABLE OF CONTENTS

List of tables

List of figures

1. INTRODUCTION

1.1 Background

Road deaths and trauma is a global public health problem. This is also true for South Africa, where depending on the year, the loss of lives on South African roads varies between 24 - 26 people per 100 000. This is an enormous socio-economic burden placed on a developing low- and middle-income country.

Through the years several approaches have been employed to address the road safety crisis. Traditionally road safety management approaches centred around individual aspects of the road transport system. Thus, previous road safety approaches addressed the road user (education/enforcement), the road/environment (engineering standards and guidelines), or aspects of the vehicle (standards/ enforcement).

In the last decade or two, this thinking has changed, as now there is acknowledgement that humans make mistakes and are vulnerable to injury and death in traffic. The focus shifts from the individual, to addressing the road traffic system as a unit, rather than only parts of the sum. This shift in thinking emphasises that the various role-players have a responsibility to ensure that the road and traffic system is designed in a manner that do not result in serious injuries, disabilities, or death. This approach is called the Safe System.

The Safe System forms the basis of the United Nations Decade for Action (UNDoA), to which South Africa became a signatory in 2010. Safer roads and infrastructure, the second Pillar in the UNDoA, list activities that aim to improve road safety by improving and providing safer road and infrastructure.

This includes the design and provision of self-explaining and inherently safe roads. A self-explaining road guides and encourage the road user to make the correct decisions, consistent with the design and function of a road, to ensure safe travel from one point to another. Inherent safety ensures 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).

Road safety engineering is thus a key component of the Safe System, ensuring that the road and road environment is designed, constructed, and maintained for safe road and traffic operations. Road safety engineering encompasses a range of activities including the use of road safety audits, inspections, and reviews to guarantee that safety is considered during all stages of the road project.

Road Safety Audits (RSAs) is considered a proactive road safety engineering tool and has proved to be one of the most cost-effective tools as it considers safety from inception to completion of the road project. Safety is "built into" the new road. In addition, the road safety audit process makes provision for road safety reviews/assessments/appraisals to be conducted periodically on existing roads, again ensuring that road safety is addressed throughout the lifecycle of the road. However, indications are that even though the utmost care is taken to construct and maintain safe roads and environments, no road can be considered perfectly safe. As such provision is also made for the screening of road networks to identify specific locations or sections of the road where sub-optimal road safety performance needs to be addressed.

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) 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 South African Road Safety Audit Manual 2012 (SARSAM 2012) is currently used by road authorities in the design, construction, and maintenance of roads in South Africa. Although there is legislation that makes provision for road authorities to conduct RSAs, there are no requirement to recognise recommendations, and the actions thereof as legal duty.

Past South African road safety engineering practices do include the use of RSAs and reviews. However there seems to be no consistency/agreement as to how or when these tools are employed. Indications are that different road authorities and engineering practitioners also have different ideas regarding success of using road safety audits and reviews in support of safe road design and maintenance.

1.2 Project description

The Road Traffic Management Corporation (RTMC) appointed the Council for Scientific and Industrial Research (CSIR) in September 2020 to provide technical assistance to review and update of the SARSAM 2012.

The purpose of this project is to review international and local road safety engineering research and practices, with respect to the foundational development of contemporary road safety audit and appraisal best practices. The focus is on the period since the publication of SARSAM 2012. The review will include experience gained in local RSA application to provide, as may be required, a more pragmatic approach for road safety audits, reviews/appraisals/assessments in South Africa. In addition, the project aims to develop a network road safety screening methodology to be used by road authorities in South Africa.

The project objectives are:

- To update the existing SARSAM 2012 into a document that would be appropriate for use on the road network in South Africa; and
- To update and publish a revised SARSAM manual for national use – i.e., the South African Road Safety Audit Manual 2021 (SARSAM 2021).

1.3 Motivation for the project

The first edition of the SARSAM was published by the RTMC in 2012. SARSAM 2012 was developed at the onset of the first United Nations Decade of Action for Road Safety, 2011 to 2020 (UNDoA1). At the time, the SARSAM 2012 was considered a comprehensive guideline that describes the formal RSA process of road design before construction, upgrades, or rehabilitation takes place and provided guidelines for the road safety audit of existing roads (road safety appraisals).

The aim of SARSAM 2012 was to provide practical guidance to road safety engineering practitioners on the RSA process as well as providing motivation why road safety auditing is a meaningful action in the road life cycle. SARSAM 2012 included reference to legal precedent in South Africa related to the lack of appropriate attention to road safety during the life cycle of the road network elements. Although the RSA procedures were already documented in the South African Road Safety Manual in 1999, road safety auditing was still a developing discipline and not widely used in South Africa at the time of first publication. As such, SARSAM 2012 was envisaged to be a living document that would be updated periodically to remain current.

SARSAM 2021 is intended to coincide with the United Nations 2nd Decade of Action for Road Safety, 2021-2030 (2ndUNDoA). It is also in line with the South African National Road Safety Strategy (NRSS), 2016-2030 which provides for RSAs to be made compulsory. The revision of SARSAM 2012 aims to support the South African signatory of the United Nations Decade of Action for Road Safety 2011- 2020, and the South African Road Safety Strategy 2016-2030. By inference this revision of SARSAM 2012 also supports the 2ndUNDoA, the Stockholm Declaration 2020 approved at the 3rd Global Ministerial Conference on Road Safety, held in Stockholm on 19 and 20 February 2020 and the UN General Assembly Resolution 74/299 Improving Global Road Safety, dated 31 August 2020.

1.4 Overview of the literature review (this report)

1.4.1 Purpose of the literature review

The goal of writing a literature review is to reconstruct the amount of accumulated knowledge, in a specific science or domain (Vom Brocke 2009). The purpose of a literature review is to (Lau. 2017):

- identify what has been written on a subject or topic.
- determine the extent to which a specific research area reveals any interpretable trends or patterns.
- aggregating empirical findings related to a narrow research question to support evidence-based practice.
- generating new frameworks and theories; and
- identifying topics or questions requiring more investigation (Paré, Trudel, Jaana, & Kitsiou, 2015).

Since the publication of SARSAM 2012, extensive developments have taken place in the science and practice of road safety auditing, also including developments in the greater socio-political environment where many countries formally adopted the RSA process as an integral part of the road design, build and operate life cycle.

1.4.2 Methodology

Literature reviews can serve two purposes. A “literature review” or “background” section review synthesizes the extant literature and identifies the gaps in knowledge that the empirical study addresses (Vom Brocke 2009). Secondly, a review article constitutes an original work of research that provides a base for a solid starting point for all members of the community interested in a particular area or topic (Lau. 2017). Review articles represent powerful information sources for practitioners looking for state-of-the art evidence to guide their decision-making and work practices (Paré G. 2015). A review article enables the reader to have an overview, if not a detailed knowledge of the area in question, as well as references to the most useful primary sources (Lau. 2017).

This SARSAM literature review collates the existing literature (best practices, lessons learned, guidelines and so forth) since publication of the SARSAM 2012 and where relevant considers earlier publications. The information presented in the literature review will be collated in support of the development of a position paper that will guide and direct the development of the SARSAM 2021 which will include network level screening and road safety inspections on existing roads.

1.4.3 Scope of review

During the past eight years, since the publication of SARSAM 2012, extensive development within the road safety discipline has taken place. Developments include the further development of the Safe System approach to road safety, Vision Zero, lessons learned during UNDoA1 and the numerous manuals on RSA that have been developed by several countries. The review focuses on international practice and local experience, to update SARSAM 2012 into a practical document ready for use on the South African road and street network.

Considerations include:

- RSA subject matter contained in reputable RSA manuals, including definitions of road safety inspection or road safety audit related terminology.
- RSA management procedures, including RSA briefs, interaction between RSA Team and Project design team, conclusion, and close-out of road safety audit projects.
- Monitoring and evaluation of RSA projects.
- Training and certification of road safety auditors.
- Road network safety and condition assessment; road safety management systems, road safety improvement approaches; practical road safety auditing.

This literature review entailed a search for scientific/peer reviewed publications as well as best practice guidelines and popular articles (grey literature) published on the topics related to road safety audit, road safety reviews/assessments/appraisals and network (safety) screening methodologies.

1.5 Terminology and definitions

1.5.1.1 Crashes vs. accidents

The Safe System Approach reiterates that humans make mistakes, and that from an ethical and moral point of view, should not be killed, maimed, or seriously injured because of road traffic accidents (RTAs). Designers and planners of the road traffic system therefore has a responsibility to design the system in a manner that prevent this road related trauma.

The term 'accident' is entrenched in the South African National Road Traffic Act, 1996, Act 93 of 1996 (NRTA). The word 'accident' is defined by Merriam-Webster online dictionary as:

- an unforeseen and unplanned event or circumstance
- lack of intention or necessity: chance
- an unfortunate event resulting especially from carelessness or ignorance.
- an unexpected and medically important bodily event especially when injurious

This linguistic definition resonates well with the road traffic incidents, that also equate to transport system failures, that causes damage, injury, death, grievance and other personal and economic hardships.

Although SARSAM 2012 refers to crashes, the intent is that RSA becomes a regulated function. It will be tied to the NRTA and the South African Development Community and South African Road Traffic Sign Manual (SADC- and SARTSM). SARTSM Volume 2, Chapter 22 was recently so aligned with the use of "accident". The recently updated TMH 16 also use the term "accident".

For this literature review the term 'accident' is used consistent with the meaning imparted in the NRTA unless an alternative term (collision/crash) is part of direct quotation or a reference to literature. This linguistic definition resonates well with the road traffic incidents, that also equate to transport system failures, that cause damage, injury, death, grievance, and other personal and economic hardships.

1.5.1.2 Road safety engineering definitions

From the initial literature survey, the following are precursory definitions of various road safety investigations and reviews.

From the initial literature survey, the following are precursory definitions of various road safety investigations and reviews.

1.5.1.2.1 Road safety audit

RSA is a formal and systematic examination of a future road or traffic project or an existing road, in which an independent, qualified team reports on the project's accident potential and safety performance (Austroads 2019).

SARSAM 2012 defines an RSA as a formal examination of a new or upgrading project where interaction with road users takes place, in which an independent and qualified team identifies potential road safety problems and suggest measures to mitigate those problems (Corporation 2012).

1.5.1.2.2 Road safety audit review (appraisal or assessment)

A road safety audit review (RSAR) refers to the road safety audit process, as applied to an existing road (Jrew, 2002). RSAR is defined as "an evaluation of an existing roadway section by an independent team, focusing solely upon safety issues" (Jones 2013).

SARSAM 2012 refers to a Road Safety Appraisal as **a** systematic examination of an existing road location, in which an independent and qualified team reviews on-site conditions and historical evidence to identify existing or potential road safety problems and suggest measures to mitigate those problems (Road Traffic Management Corporation 2012).

1.5.1.2.3 Road network (safety) screening

Road network screening is part of the road network safety management process and defined as a process by which the road network is screened to identify potentially hazardous sites (Ambros Sedoník, Křivánková, 2017).

SARSAM 2012 defines a road safety engineering assessment as a screening process to establish the road safety status of sections of an existing road network. It is a network-based process performed on selected sections of the road network using a set of pre-defined key indicators to determine the feasibility of safety improvement of such a section. The road safety engineering assessment process provides a list of prioritised locations that should be further investigated (Road Traffic Management Corporation 2012).

1.5.1.2.4 Road safety inspections

Road safety inspections (RSIs) comprises a routine, programmed and systematic field survey which is undertaken proactively on existing roads to identify risk factors and to achieve enhanced safety (African Development Bank (b) 2014). The RSI is compared to the RSA pre-opening phase of newly constructed roads (Volpracht et al., 2018).

1.5.1.2.5 Accident investigations

According to the RTMC Crash Investigation Unit (https://www.rtmc.co.za/index.php/what-we-do/crash-investigation), accident investigation is to perform technical investigations of all major, fatal and serious injury accidents that happen within the roads of South Africa. Investigations are conducted with the usual purpose being to look at understanding the incident and the measures to prevent possible future occurrences. The recommendations for the investigation are aligned with road traffic safety education and engineering, law enforcement interventions, as well as monitoring and evaluation.

The criteria for the investigation is as follows:

- five (5) or more people died;
- accident involving vehicles carrying dangerous goods or hazardous chemicals where there is a fatality and a spillage of the dangerous goods or hazardous chemicals;
- an accident that the Corporation deems necessary to investigate, especially for research purposes.

1.5.1.2.6 Traffic Impact Assessment

Traffic Impact Assessments (TIA) focus on estimating the volume of traffic associated with a land development project and the impacts that traffic will have on the operation of the adjacent street and road network in terms of capacity and levels of service (FHWA 2006).

The South African Traffic Impact and Site Traffic Assessment Manual TMH 16 Volume 1 defines a TIA as the assessment of the impact of a proposed change in land use on the transportation system. A Site Traffic Assessment in terms of TMH Volume 2 may be ordered to address road safety concerns and a road safety assessment (or audit) must be undertaken with the purpose of identifying possible locations where the heavy good transport could significantly affect road safety. Only the specific impact of heavy good transport is required to be evaluated.

1.5.1.2.7 Road safety impact assessment

Road safety impact assessment (RSIA) can be regarded as a proactive effort. Estimating explicitly the impact on road safety that results from building new roads or making substantial modifications to the existing road infrastructure that alter the capacity of the road network in a certain geographic area is of crucial importance if road safety is not to suffer unintentionally from such changes (ETSC, 1997). Other schemes and developments that have substantial effects on the pattern of road traffic needed to be regarded similarly. RSIA is the procedure designed for this purpose (Wegman et al, 1994). It is intended to be applied at the planning stage, often proceeding to a definite design for the scheme. Safety impact assessment thus precedes and complements the eventual safety audit of any specific design for the scheme. A parallel to these two procedures can be seen in the Strategic Environmental Impact Assessment and the ordinary Environmental Impact Assessment (OECD, 1994). The two procedures together first provide an estimate of the impact of schemes on safety for an entire geographic area at the strategic level and then follow this with an audit of the safety of the specific design of the chosen scheme. For smaller schemes, the two procedures can be combined by extending the feasibility stage of the safety audit to include the effects of the scheme on accident occurrence in the surrounding network.

1.6 Overview of chapters/structure of the report

The rest of the report is structure as follows:

Chapter 2 provides background information and contextualise the road safety problem in low-and-middle income countries including South Africa. In addition, Chapter 2 highlights several approaches that have been implemented in response to addressing the road safety problem. Chapter 2 provides a brief overview of the Vision Zero and Sustainable Road Safety principles which informed the development of the Safe System approach, which in turn forms the basis of the United Nations Decade of Action.

Chapter 3 gives an overview of road safety as a key element of the transport and traffic management system. Furthermore, Chapter 3 highlights the need to proactively manage road safety. ‘Safer roads and the mobility’ is one of the five pillars of the UN Global Plan for the Decade of Action for Road Safety.

Chapter 4 provides background information pertaining to international and regional directives, that stipulate that RSAs should form part of new and existing road projects and considers international best practices in relation to RSA purpose, lifecycle stages, Safe System auditing and so forth.

Chapter 5 provides an overview of road network screening methodologies.

Chapter 6 details the practice of RSAs and network screening in South Africa.

Chapter 7 provides a summary of key findings that will be relevant to the drafting of the Position Paper on the development of the ‘Road Safety Audit’ and ‘Network Screening and Road Safety Inspection’ manuals – collectively the SARSAM 2021.

2 ROAD SAFETY: CONTEXT AND INTERNATIONAL RESPONSE

2.1 Introduction

The road safety pandemic was brought to the world centre stage, by the World Health Organization (WHO) in 2003. In 2004 the global "Road Safety is no accident campaign" was launched. In 2009, the WHO and the World Bank (WB), published the 'Global Status Report on Road Safety – Time for Action' highlighting the growing public health burden of road deaths in especially the developing world (and its current and future impact on national economies and resources) and made a powerful case for urgent measures to address the problem as a global development priority (World Health Organization 2009).

The Global Status Report on Road Safety report showed that low- and middle-income countries have higher road traffic fatality rates (at the time 21.5 and 19.5 per 100 000 population respectively) than high-income countries (at the time 10.3 per 100 000). Half of those that die in road accidents are vulnerable road users (VRUs) and the proportion of VRU deaths is higher in the poorer countries of the world. (World Health Organization 2009).

The report resulted in the United Nations General Assembly (UNGA) proclaiming the period 2011 to 2020 as the Decade of Action for Road Safety (UNGA resolution 64/255 on improving global road safety), "with a goal to stabilise and then reduce the forecast level of road traffic fatalities around the world by increasing activities conducted at the national, regional and global levels" (United Nations General Assembly, 2010).

Efficient and effective implementation of the World Report's recommendations and a requirement that countries must work in partnership with the international development community to scale up, refocus and harmonise their road safety activities, with an emphasis on managing for results. As an overarching priority, institutional capacity building at global, regional, and country levels must underpin this endeavour if improved country road safety performance is to be sustained in the longer term.

Since the publication of the 'Global Status Report on Road Safety – Time for Action" in 2009, and the onset of the UNDoA 2010-2020, the UN invited the WHO to publish an annual update to measure progress towards halving the number traffic deaths around the world, employing a methodology to obtain information about a variety of road safety indicators from a multisectoral group of experts in countries (Toroyan, Peden and Laych, 2013).

The most recent Global Status Report on Road Safety (GSRRS) was published in December 2018 and unfortunately indicating that the global road safety outlook seems to look the same than in 2009 with 1.35 million traffic related deaths per year, the eight-leading cause of global deaths, of which pedestrians, cyclists and motorcyclists seem to continue to bear the brunt (World Health Organisation 2019). This led to a renewed dedication and commitment to address road safety at as a matter of urgency.

2.2 Road safety in low- and middle-income countries

2.2.1 African road safety context

Internationally, many developed countries have succeeded in controlling traffic accidents. The measures implemented include making infrastructure safer, improving the safety of vehicles, and executing several other interventions recognised to be effective at reducing road traffic injuries. Quality data to monitor the impact of these efforts is critical (Yannis, Gittelman, Papadimitriou, and Hakkert, 2018).

Developing and less-developed countries have not yet achieved this level of success. Africa, with a low level of motorisation and road density, experiences the highest per capita rate of road fatalities (United Nations 2017). The characteristics of victims of road traffic accidents in the region, signifies that over 75 % of the casualties are of productive age between 16-65 years; and the vulnerable road users constitute over 65 % of the deaths. Indications are that road traffic accidents costs African countries between one and five per cent of the respective Global Domestic Product (GDP) every year. These figures show that road traffic deaths and injuries have a direct link to worsening poverty in Africa (African Development Bank (b) 2014).

Regional features such as road network expansion and improvement, rapid motorisation, population growth, urbanisation, unsafe vehicle fleets and mixed traffic, according to the African Development Bank (2018) inevitably will worsen road accident deaths and injuries unless African countries invest in road safety. In response, the African Development Bank (AfDB) is investing in road infrastructure that can enhance competitiveness and realise sustainable development (African Development Bank (b) 2014). In addition, the AfDB states that the bank is actively involved in skills and knowledge transfer in support of addressing road safety on the continent.

Despite these intentions indications are that road traffic injuries are not properly prioritised as road safety efforts must compete with other more pressing (prioritised) health problems such as for example Tuberculosis, HIV AIDS, and Malaria deceases (Bekefi, 2006) and more recently the Coronavirus disease (COVID-19) pandemic (Transformative Urban Mobility Iniative 2020). Road safety is not prioritised and as a result the design and implementation of preventative road safety programmes seem to suffer.

A key concern highlighted was that even in African countries where national action plan/programmes exist, the plan/programmes is not translated into achievable and measurable targets for all road safety stakeholders (Forjuoh, 1998; Bekefi, 2006). Additionally, there is a lack of sufficient financial and human resources to achieve the targets (Bezabeh, 2013; Small et al., 2014).

Governments of developing countries find it challenging to share and implement road safety policy lessons, technologies and institutional innovations that underpin the success of developed countries (Bekefi, 2006). Weak institutional leadership, weak relationships between stakeholders and uneven distribution of funding complicate matters even more (Vogel 2015). Although indications are that some African countries may have advanced in terms of improving road safety, these countries often do not have specific road safety policy frameworks, or where they do have policies, they do not implement them. Adolehoume (2017) reiterates that it is essential for African countries to define a road safety policy and to develop a subsequent road safety strategy and action plan. The road safety action plan needs to prioritise road safety activities in the short, medium, and long term.

2.2.2 South African road safety context

South Africa continues to have one of the highest road traffic fatality rates in the world. Recent indications are that about 25 people per 100 000 population (2016 - 25.2 compared to 2018 - 24.4 per 100 000) people on average lose their lives on the country's roads compared to middle-income country averages which vary between 17.4 and 18.4 people per 100 000 (Department of Transport, 2015; Road Traffic Management Corporation 2016).

According to the 2019 outlook for South Africa, reported yearly by the Road Traffic Management Corporation to the International Road and Traffic Data Analysis Group (IRTAD), the trend for road fatalities in South Africa has been upward (International Road Traffic and Data group (IRTAD) 2019). Between the year 2000 and 2018, the number of road deaths increased by 52 % and during the same period, the number of traffic deaths per 100 000 inhabitants in South Africa increased by 18 %. Despite interventions implemented in 2018, 22.4 traffic deaths per 100 000 inhabitants were recorded which in comparison to for example the European Union's 4,9 deaths per 100 000 inhabitants in 2018, is quite high. Recent estimates have placed the cost of accidents in South Africa between 3,4 and 3,5 % of the Global Domestic Product (Labuschagne, Roux, De Beer and Venter, 2017; International Road Traffic and Data group, 2019).

In 2018 human factors accounted for 89,3 % of accidents followed by 4,2 % vehicle factors and 6.5 % environmental factors (Road Traffic Management Corporation 2019). However, with the move towards implementation of the Safe System Approach, on which the new National Road Safety Strategy 2016 - 2030 hinges, humans are considered fallible, prone to error and as such the road environment needs to be designed in a manner that absorbs these failures so that it does not result in serious harm or death. Although road users are still responsible for their actions, the Safe System approach that underpins the NRSS 2016 - 2030 emphasises the responsibility that road authorities must plan, design, construct and maintain a safe road network, to protect the public investment in the road infrastructure, to ensure the continued functionality of the transport system, and to promote the safety of traffic on the road network. Authorities also have the obligation to provide a reliable, effective, efficient, and integrated transport system that supports the sustainable economic and social development of the country.

Roads, at least in low- and middle-income countries (LMIC) countries such as South Africa, will continue to be the backbone of the land transport road network providing accessibility for the required mobility, to support economic growth and promote social activities. However, the potential adverse impacts of road development have also grown in magnitude, especially when proper planning, design, construction, or management is not carried out (Fwa 2006).

2.3 Response in support of road safety improvements

Through the years, several measures and programmes have been developed to address and reduce the number of casualties on the roads. Institutions such as the UN, WHO, Multi-Lateral Development Banks (MLDs), and non-governmental organisations (NGOs) represent stakeholders aiming for global road safety improvements (A. J. Ross 2016). The Global Road Safety Facility Strategic Plan (GRSF, 2012) states that traditional planning approaches, to reduce the risk of traffic injuries, considered road users, vehicles, and the environment as separate entities rather than as components of the road traffic management system. Traditional injury prevention efforts (e.g., targeted high-visibility enforcement or spot engineering treatments) may be effective at reducing the magnitude of accidents and mitigating significant risks at particularly dangerous locations, however, these approaches often thrust the problems to other areas of the system (Kumfer et al., 2019).

Yannis et al (2018), however, highlights that to address the problem there is a need for dedicated action from multiple ministries, most notably law, planning, transport, education, public information, and health. Approaches and measures to ensure road safety includes improving the built environment (e.g., safer road design, regulating sidewalks and traffic lights, introducing safe bicycle lanes), law enforcement and education, e.g., to increase seatbelt use and helmet wearing, reducing speeding and drink driving, better vehicle standards, and improved post-accident response. Road safety measures that provide safer, more sustainable public transport options can support synergies between health, transport, and carbon emission reduction targets (Yannis et al., 2018).

2.3.1 Road safety directives

2.3.1.1 United Nations Sustainable Development Principles in relation to road safety

Sustainable transport and high-quality infrastructure are of cross-cutting importance for increasing economic growth and attaining the sustainable development goals (Horn and Jannsen, 2000; United Nations, 2017).

With respect to transport infrastructure, the United Nations Secretary General's Special Envoy for Road Safety observed that it had been estimated that 50 per cent of casualties occur on around 10 per cent of the road network (UNECE, 2016). Therefore, international efforts need to be "reinforced to ensure greater road safety for all road users through proper planning, design, building and maintenance of high safety performance standards of road networks" (United Nations 2017).

The 2030 Agenda on Sustainable Development Goals (SDGs) for the first time in 2015, explicitly included road safety as part of the global development agenda, and this puts road traffic safety on the same level of global criticality as climate, health, and equity issues, and means that road safety can no longer be traded off to promote other needs. Inclusion among the SDGs also means that road safety is the responsibility of a wide range of stakeholders, both public and private (Academic Expert Group for the 3rd Ministerial Conference on road safety 2019). SDG targets three and eleven are directly associated with road safety: halving the number of global deaths and injuries from road traffic accidents and improving road safety in cities, notably by expanding public transport (United Nations Economic Commission for Europe 2018). Road safety thus become an important sustainable development issue and the targets are (United Nations 2017):

- SDG 3.6 - aiming for the reduction of global road traffic deaths and injuries by 50 per cent by 2020; and
- SDG 11.2 – aiming to provide access to safe, affordable, accessible, and sustainable transport systems for all by 2030.

A total of 10 UNGA resolutions have been adopted on improving global road safety. In these resolutions, the General Assembly:

- seeks to raise awareness of the road safety problem.
- urges governments to continue to enforce traffic laws.
- provides policy recommendations.
- calls for accession to the United Nations road safety legal instruments administered by UNECE; and
- calls for actions to increase international efforts to address road traffic fatalities and injuries.

Within this framework, the UNGA invited the WHO in close collaboration with UN Regional Commissions, to work as an international coordinator on road safety. Several UN legally binding instruments provide a harmonised legal framework across countries that relate to road, aviation, and maritime safety. It provides a framework for establishing national legislation and technical standards. One key area in which these instruments are highly relevant is road safety (United Nations Economic Commission for Europe, 2018).

UNECE administers seven core global UN conventions on road safety and several other related legal instruments. These conventions include:

- uniform traffic rules, a uniform system of signs, signals, symbols, markings, and technical regulations
- harmonised vehicle regulations and rules for the inspection of vehicles,
- rules for the transport of dangerous goods.

UNECE administers an agreement concerning technical safety prescriptions for wheeled vehicles, equipment, and parts, known as "UN Vehicle Regulations," which determines a common set of technical prescriptions and protocols for the approval of vehicles and their components. In turn, the Convention on Road Traffic establishes uniform rules for road traffic and sets up requirements for admission of vehicles in traffic and for drivers of these vehicles (Sustainable Mobility for All (TM) 2018).

Transport safety is also addressed in documents from:

- UNESCAP, which provides a guideline for policy formulation and implementation as part of the Regional Road Safety Goals.
- ICAO, calling for robust and sustainable regional and state civil aviation safety systems, through the Global Aviation Safety Plan (GASP), supported by regional safety activities coordinated by the regional aviation safety groups.
- UN-Habitat, underlining the importance of protecting vulnerable road users, including pedestrians and bicyclists, and promoting legislation and policies on motorcycle safety with the New Urban Agenda.

2.3.1.1.1 Legal and regulatory framework (United Nations 2017)

The UN recommended that countries worldwide, and particularly developing countries, should consider acceding to and fully implementing the latest relevant versions of the United Nations legal instruments on road safety, as appropriate, since these reflect additions and updates to the international rules and requirements for road safety (United Nations 2017). Developing countries should strengthen their national road safety legislations, establish regional instruments and regulations, as appropriate, and work towards achieving greater consistency between those and the relevant international instruments. Collaboration among multiple stakeholders, including through regional and subregional organisations and institutions, should be strengthened. Key recommendations include (United Nations 2017):

- Infrastructure investment plans should continue to become a part of national sustainable development strategies.
- The intent is to achieve safer roads through the implementation of various road infrastructure agreements under amongst other the UN framework for road infrastructure assessment and improved safety-conscious planning, design, construction, and operation of roads (WHO, 2011).

The RSA and RSI are part of road safety management (on an institutional level) and of Safer Roads and Mobility pillars, but procedures must consider all parts of the Safe System approach (United Nations Economic Commission for Europe 2018). International organisations could potentially contribute to creating an enabling domestic environment in developing countries, by providing technical support to translate plans into concrete projects and implement them. Road infrastructure safety elements and considerations should be included in these infrastructure projects. International organisations could also contribute with capacity building and skills development to ensure safe road design, road safety audits, and impact assessments (United Nations Economic Commission for Europe 2018).

In view of the high urgency and sensitivity of the issue, governments of developing countries as well as their development partners, should integrate and mainstream road safety elements and considerations in support of the relevant sustainable development goals and targets, including target 3.6 and 11.2 of the 2030 Agenda for Sustainable Development, in relation to their infrastructure planning and projects (United Nations 2017). In this context, it is important to integrate climate considerations to enhance climate change adaptation and resilience for transport infrastructure. As such, governments and other stakeholders should embrace actions known to be effective in reducing road safety risks, such as making cycling and walking safe and reducing the risks of motorised two-wheelers; as well as prioritise safety when adopting modern technologies such as autonomous passenger cars or automated traffic control systems (United Nations 2017).

2.3.1.1.2 Concepts related to sustainable development.

In addition, related sustainable development concepts include:

- **Justice in Transport:** The focus has for many years been on maximising the efficiency of getting from point A to B with the onus on the performance of the system, rather than on the needs of the people who use it (Martens and Golub, 2018). Given the importance of mobility in current society, the suggestion is to replace current demand-based approaches by transport planning that is based on the principle of need (Martens 2006).

- **Universal access design:** Universal access is an approach to create an environment that meets the needs of all potential road users to the greatest extent possible. The concept emphasises inclusive design that allows participation and access for all, especially the mobility impaired.
- **Shared space concept:** Shared Space refers to a road design involving desegregation of different road users. This concept contrasts with the traditional way of thinking where vulnerable road users are separated from motorised traffic. (Edquist and Corben, 2012).
- **Last mile/ first mile concepts**: The Last Mile refers to the difficulty in getting people from a transport hub or intermodal facilities (railway stations and bus depots) to their destinations. When users have difficulty getting from their starting location to a transport network, the scenario may alternatively be known as the "First Mile" problem. These issues are, especially, acute in countries where land-use patterns have moved more jobs and people to lower-density suburbs that are often not within walking distance to existing public transport options. Public transport use in these areas is often less practical as the difficulty in reaching end destinations promotes a reliance on private vehicles, resulting in more traffic congestion, pollution, and urban sprawl (European Environment Agency 2020).
- **Modal hierarchy:** Modal hierarchy is "the ranking of the relative importance of travel modes, determined in the initial phase of a roadway project, to clearly establish and state priorities for accommodation in design" (City of Illinois 2015). Each mode is ranked according to overall community goals such as mode-shift, safety, and community liveability (figure 2-1).

Figure 2-1: Modal hierarchy (City of Illinois, 2015)

By determining a mode hierarchy at the inception of a project, the hierarchy will provide guidance to what decisions should be made in favour of safe plans and designs, in a manner that will optimise roadway design measures, taking cognisance of important aspects such as capacity and Level of Service (LOS).

2.3.1.2 United Nations Decade of Action for road safety (UNDoA)

In 2010 Ministers from around the world signed the Moscow Declaration, pledging to half the number of fatal accidents by 2020. In 2020, with advent of the new decade, the Stockholm declaration was signed, with renewed commitment to address road safety on an international scale (United Nations Economic Commission for Europe 2018).

2.3.1.2.1 UNDoA1 2011-2020 Moscow Declaration 2010 – 2020

The WHO and WB findings and recommendations contained in the 2009 GSRRS provided a consensus-based blueprint for country, regional and global action and were subsequently endorsed by the UN General Assembly Resolutions 56/289, 60/5 and 62/244 (Improving Global Road Safety) and World Health Assembly (WHA) Resolution 57/10 (World Health Organization 2009).

This resulted in a global commitment to address road safety, with the UN declaring the period 2010 -2020 a Decade of Action for Road Safety (UNDoA). It was considered crucial to involve various stakeholders, such as civil society and the private sector, in the road safety agenda (United Nations Economic Commission for Europe 2018). The UNDoA calls upon Member States to commit to implement road safety activities, "particularly in the areas of road safety management, road infrastructure, vehicle safety, road user behaviour, including distractions in traffic, road safety education and post-accident care" (United Nations 2017).

Regional action programmes were adopted along with the Global Plan, listing priority areas and concrete road safety measures, the implementing process and the organisations and other stakeholders involved (United Nations 2017). In addition, national road safety strategies have been formulated, setting clear and concrete targets for road safety policies, and establishing action plans containing selected concrete measures that can be transformed into actions, considering the specific situation in the country and best practices from other countries. To ensure progress, the development and implementation of these measures is continuously monitored and their effects on road safety evaluated.

2.3.1.2.2 Brazil Declaration on Road Safety and ways to halve road traffic deaths by the end of the decade.

The Second Global High-level Conference on Road Safety, held on 18 and 19 November 2015 with the title "Time for Results", adopted the Brazil Declaration on Road Safety, in which the participants affirmed their willingness to meet the Sustainable Development Goal (SDG) target to halve road traffic deaths by 2020. In the Brazil Declaration, a comprehensive approach involving multiple sectors was reiterated (Economic and Social Commission for Asia and the Pacific, 2017):

- strengthening road safety management and improving legislation and enforcement
- promoting safer roads and the use of sustainable modes of transport
- protecting vulnerable road users
- developing and promoting the use of safer vehicles
- increasing awareness and building the capacity of road users
- improving post-accident response and rehabilitation services, and
- strengthening cooperation coordination towards global road safety.

2.3.1.2.3 UNDoA2 2020 -2030 Stockholm Declaration

An Academic Expert Group convened by the Swedish Transport Administration created a set of recommendations for a decade of activity by the public and private sectors that would lead to a reduction of worldwide road deaths by one-half by 2030 (Academic Expert Group for the 3rd Ministerial Conference on road safety 2019).

The recommendations were made in the context of a Third High-Level Conference on Global Road Safety to be held in Stockholm in February 2020 and are offered for consideration by conference participants and leaders from business, corporations, governments, and civil society worldwide. These conclusions are based on the workshop and discussions in the international Academic Expert Group meeting held in Paris on 26–28 February 2019.

The UNDoA1 has raised global awareness of road safety among governments, business, and civil society. It has produced measurable and effective safety improvements. It has also attracted new funding and new partnerships and brought road safety closer to the global public health arena. Target-setting is now widespread practice across a range of sectors of society as a means of managing progress toward ambitious goals, and in some cases the practice has developed from simple targets to complex sets of sub-targets, indicators, and action plans.

A significant achievement of the Decade of Action for the long-term has been the inclusion of road safety as a specific target – Target 3.6 – in the Sustainable Development Goals (SDGs). Integrating the Decade of Action target into Target 3.6 was a remarkable accomplishment with far-reaching implications. The 2030 Agenda states clearly that the 17 SDGs and 169 associated targets "are integrated and indivisible". This recognition places road safety at the same level of criticality as other global sustainability requirements and clearly indicates that sustainable health and wellbeing cannot be achieved without substantial reductions in road deaths and injuries. While this integration with other SDGs has yet to be realised at global level, opportunities are now emerging for new partnerships, and the potential benefits that could stem from such integration are compelling.

At the meeting in Paris on 26–28 February 2019, the Academic Expert Group discussed the importance of target-setting and carefully considered options. A strong consensus was reached on the following points. It is crucial that a specific road safety target is retained and kept up to date in the Sustainable Development Goals.

Proposed wording for Target 3.6: "Between 2020 and 2030, halve the number of global deaths and injuries from road traffic accidents, achieving continuous progress through the application of the Safe System approach."

The Academic Expert Group recommended the following:

- Operational targets should be set by individual global regions (consistent with the ambition of Target 3.6, but taking account of local developments, conditions, and resources).
- Regional targets should include fatalities and severe injuries.
- Targets should include numbers of deaths and non-fatal injuries because this is most relevant to our mission. However, identifying appropriate casualty rates is also desirable. The optimal measure of fatal and non-fatal injury rates has yet to be determined.
- Linkages and collaborations should be established among the constituencies associated with the range of other SDGs affected by and associated with road safety.

The most promising means of achieving continuous progress is by mobilising traditional and new road safety partners to use the tools identified in the Safe System's five road safety pillars.

2.3.2 Strategies and frameworks aimed at addressing road safety.

In a scoping review conducted by the authors highlight that several road safety approaches have through the years received attention (Safarpour et al., 2020). The most notable schools of thought can be classified into three themes:

- The traditional approach focuses on changing the road users' behaviours and to through enforcement and education reduce human errors. Traditional approaches assume that there is a limit to safety determined by the point at which the costs of an intervention exceed the benefits. The problem with this approach is that road traffic accidents (RTCs) are regarded as separate issues and not as part of the public health problem (Safarpour 2020).
- The sustainable safety (or according to Safapour et al., 2020) systematic approach considers the functionality of the road, the homogeneity of the road users (separation

of traffic) and place emphasis on encouraging correct road user behaviour through predictable road design.

- The Safe System approach has three dimensions namely ethics, responsibility, solutions. This approach has at the core of its philosophy, a stipulation that planners and designers have an ethical and moral responsibility to design and construct roads that are inherently safe, and that if humans make mistakes, can absorb these mistakes without the human dying or being seriously injured. Deaths and serious injuries are preventable and as such need human life and health are prioritised within all aspects of transport systems. Initiatives to improve road safety should focus on systems-level changes before strategies that influence individual behaviour. Lastly within this paradigm, speed is recognised and prioritised as the fundamental factor in road traffic accident severity (Kumfer 2019).

2.3.2.1 Sweden Vision Zero

In 1997, 'Vision Zero' became Sweden's new road safety policy (Johannson, 2009). The Vision Zero focus is the elimination of serious injuries and deaths associated with accidents, based on the underlying principle that humans make mistakes and that the traffic system needs to accommodate these human limitations.

Vision Zero emphasises that the responsibility for road and traffic safety lies with the planners and designers of the road transport system, while road users are responsible for adhering to the traffic rules and regulations that guide them within this system. If road users do not obey the rules due to a lack of knowledge, acceptance, or ability, the system needs to be accommodating and prevent serious harm to the users (Johannson, 2009).

During a 2013 conference the keynote address stated that the "real strength of Vision Zero" is that it gives a common goal for all stakeholders. Secondly that it needs authorities to set clear targets and performance indicators to manage road safety. And lastly that Vision Zero provides an opportunity to find synergies between safety, the environment and mobility to plan and organise resources so that these resources can be sued in the most effective way (Tidström 2013).

2.3.2.2 Netherlands Sustainable Road Safety Principles

The 1992 Netherlands Sustainable Safety vision specifies that safety should be a design requirement in road and traffic system and advocates for a proactive approach to road design using human characteristics (physical and cognitive capabilities and limitations).

Table 2-1 provide an overview of the Sustainable Safety Approach. This approach has five guiding principles that aims to facilitate recognition and behavioural adaptation in traffic (Wegman and Aarts, 2006).

Table 2-1: Sustainable safety principles (**Wegman and Aarts,** 2006)

Road function	Ensure monofunctional properties of through roads, distributor, and collector roads
Homogeneity of: • traffic load • Speed • Direction of travel	Ensure equality in speed, direction, and mass at medium and high speeds
Forgiving roads	Limit injuries through a forgiving road environment that anticipate road user behaviour

Predictability of road and road user behaviour by recognisable designs	Design road environment that anticipates and facilitate safe road user behaviour through consistency and recognisable designs
Take cognisance of the state of awareness of the road user	Consider the road users' ability to manage the driving task adequately and safely.

Roads are categorised according to their function and should as far as possible be self-explaining (Theeuws 2012). Roads need to be designed in a predictable manner that facilitates the expectations of the road users, to limit mistakes and errors (Ahmed 2013).

2.3.2.3 Safe System approach

The Safe System evolved from the two concepts described above namely "Vision Zero" and the "Sustainable Traffic Safety approach." The Safe System approach is a comprehensive view on road safety that acknowledges that human error within the transport system is inevitable, and that when it does occur the system makes allowance for these errors to minimise the risk of severe injury or death. In terms of death and injury, there are limits to the kinetic energy exchange which humans can tolerate before severe injury or death occurs. As such the road system need to be designed and take account of these errors and vulnerabilities so that road users can avoid severe injury or death on the road.

The typical "blame the road user" view is thus replaced by the one that considers providers and enforcers of the road transport system, responsible to citizens, guaranteeing their safety in the long term by providing inherently safe and self-explaining roads (Theeuwes 1995; Wegman and Aarts, 2006).

In a Safe System, road safety problems are treated by considering the interaction of several components of the transport system, rather than by implementing individual countermeasures in relative isolation. This means that the full range of solutions, infrastructure, traffic and speed management, vehicle standards and equipment and road user behaviour need to be addressed (Bliss and Breen, 2012). Therefore, the Safe System Approach is not focusing anymore on single elements of the transport system but on their interfaces, especially on the human factors and the interface between road users and the road which must be adapted to road users' abilities and limitations (A. J. Ross 2016).

The Safe System approach is seen as the most appropriate method in guiding the management of road safety as it recognises that humans as road users are fallible and will make mistakes. In (IRAP Toolkit, 2010; Buttler 2014). A Safe System has the following characteristics (IRAP Toolkit 2010):

- It recognises that prevention efforts notwithstanding, road users will remain fallible and accidents will occur.
- It stresses that those involved in the design of the road transport system need to accept and share responsibility for the safety of the system, and those that use the system need to accept responsibility for complying with the rules and constraints of the system.
- It aligns safety management decisions with broader transport and planning decisions that meet wider economic, human, and environmental goals.

The Safe System takes a holistic view of all factors in road safety and encourages a better understanding of the elements (road users, roads and roadsides, vehicles, and travel speeds) and their interaction (figure 2-2).

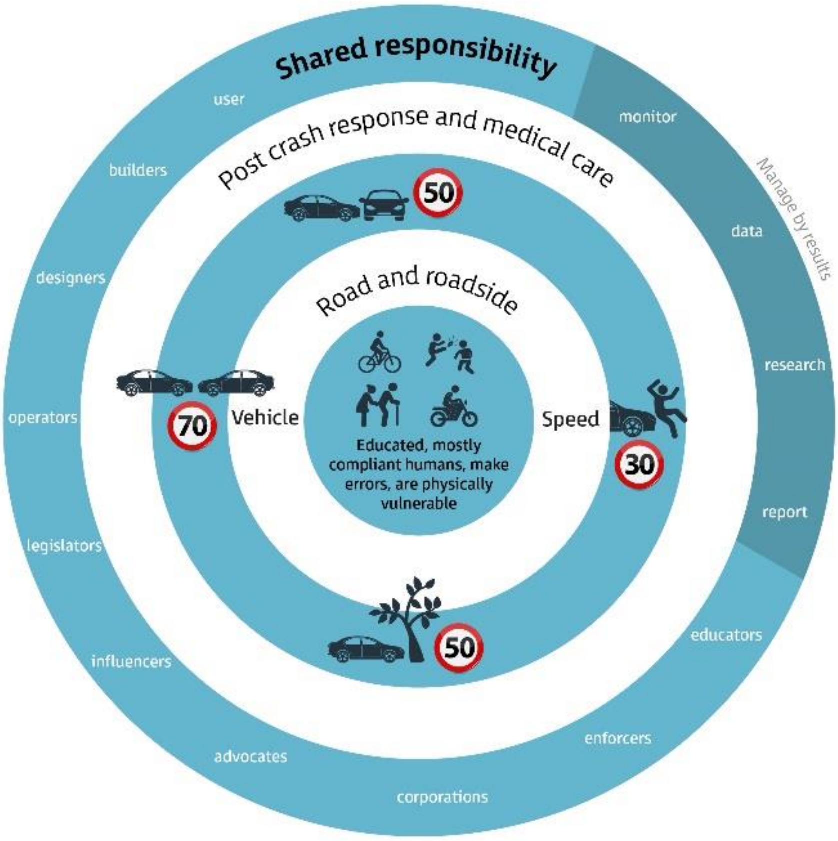

Figure 2-2: Safe System approach (Austroads 2019)

2.3.2.4 Safe System and UNDoA1 Pillar approach

The Safe System is the basis for the supporting actions for the UNDoA 2011-2020 (Buttler, 2014). The UNDoA1 strategy aimed to stabilise the growing number of RTIs and to reduce the number of fatal accidents by half over a ten-year period.

The five pillars of the UNDoA facilitate the design and implementation of interventions that will build capacity for road safety management (pillar 1) improve the safety of traffic-related infrastructure (pillar 2); improve the inherent safety of vehicles through better designs (pillar 3), as well as enhancing the behaviour of road users (pillar 4) and pillar 5, improving post-accident care (Buttler, 2014).

National activities				
Pillar 1 Road safety manageme nt	Pillar 2 Safer roads and mobility	Pillar 3 Safer vehicles	Pillar 4 Safer road users	Pillar 5 Post crash responses
International coordination				

Figure 2-3: UNDoA1 pillars for road safety (2011-2020)

The UNDoA1 is an implementation/action plan with specific road safety pillars of which (Figure 2-3):

- Pillar 1 focuses on Road Safety Management - strategic direction, dedicated funding for research and programmes as well as constant monitoring, evaluation and learning from mistakes.
- Pillar 2 entails safer roads and infrastructure.
- Pillar 3 focus on initiatives to enable safer road usage,
- Pillar 4 entails safer vehicles and encourages programmes such as new car assessment programs (rating of the safety of new car models to assist fleet and car buyers using state of the art accident tests and protocols, product liability legislation and manufacturing initiatives which make a substantial contribution to road safety (Sustainable Mobility for All, 2018).
- Pillar 5 is concerned with post-accident care that when an accident has taken place, that there measures to facilitate quick and efficient access to care.

2.3.2.5 ISO 39001 - Road Traffic Safety Management System (REF ISO)

Bliss and Breen (2012) describe road safety management as a "production process" where institutional management functions produce interventions, which in turn deliver results (fewer accidents and injuries). All components of the Road Traffic Safety Management System (RTSMS) need to be in place to progress towards a Safe System (Bliss and Breen, 2009). The seven institutional management functions (of which result focus is the most important) form the basis of a Safe System and subsequently the UNDoA.

International Standard Organisation (ISO) Standard 39001 provides clear practical guidelines as to how any organisation, including government, private and civil society, can become result focused. The results, at the top of the pyramid (social costs, outcomes, intermediate outcomes, and outputs), reflect the current and past state of road safety affairs in a country at any given time (Bliss and Breen, 2012). These results inform the vision and actions needed to improve and monitor road safety. The results provide for the setting of process indicators (e.g., number of roadblocks held); safety performance indicators (e.g., seatbelt wearing rate); outcome indicators (number of accidents, deaths, and injuries) and lastly the cost of accidents to the country (direct and indirect costs). The middle of the pyramid refers to the actions (pillars) that is employed on the road network (Figure 2-4).

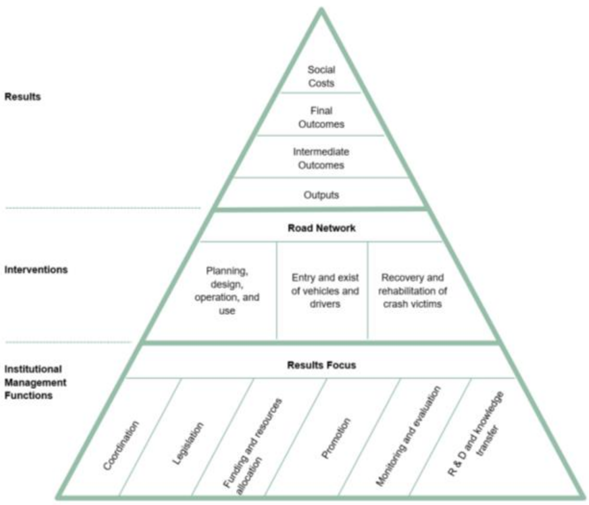

Figure 2-4: ISO 39001 - Road Traffic Safety Management System

3 ROAD SAFETY TRAFFIC ENGINEERING WITHIN THE TRANSPORT MANAGEMENT SYSTEM

3.1 Introduction

The road should be considered from the perspective of the broader transport, roads and road environment management regime and especially from the viewpoint of ‘transport system management’ as suggested in the ‘Guidelines for the Transport System Management Process (Draft UTG9, 1991). It defines Transport System Management (TSM) as follows:

“Road authorities at all spheres of government, as mandated by the Constitution have the sole responsibility for the management of the road transport system to deliver the mandated services at agreed service levels by applying appropriate systematic procedures that will ensure coordination of all respective activities, projects and programmes to achieve performance targets.”

The level of road safety is considered a performance indicator that shows how well the road transport network is being managed. Safety as an essential element of road and traffic engineering is influenced by a range of factors including road user characteristics, roadway characteristics, vehicle conditions, and weather. Road safety is an outcome (or function) of the interaction between these different components that make-up the road system. If any one of these components (user/vehicle/road) fail in its interaction with each other, the system collapses resulting in traffic accidents leading to deaths and road traffic injuries (RTIs).

UNDoA Pillar 2 emphasises the need to raise the inherent safety and protective quality of road networks for the benefit of all road users. This can be achieved through measures including improved safety-conscious planning, design, construction, and operation of roads. The activities under this pillar include encouraging governments to set a target to “eliminate risk roads by 2020”. Regular road inspections are considered an important measure that help to ensure the quality of roads and road surfaces, identify hazardous road locations or sections where excessive numbers or severity of accidents occur and take corrective measures; accordingly, and to promote the development of safe new infrastructure that meets the mobility and access needs through use of independent road safety audit findings in the design and other phases of new road projects. Yannis et al (2018) states that a smooth and good-conditioned road promises greater driving and road safety as compared to poor-conditioned roads which increase the probability of traffic accidents. Speed limits also play a key role in road safety and internationally intentions are to promote lower speed limits, to reduce the impact and trauma or force to the human body in incidences where accidents occur (Government of West Australia 2012)

The following section provides an overview of strategic road safety engineering approaches, globally recognised as best practices, which advocates for the use of RSAs in support of road and traffic management activities.

3.2 Transport, traffic, and road safety management

3.2.1 Transport system management

Transport System Management (TSM) entails the execution of management functions including planning, organising, directing or leading, co-ordinating, and controlling or monitoring of transport activities. TSM is multifaceted, multimodal and is used to coordinate the individual elements (infrastructure, modes, land use planning and human factors/users of the transport system) through investment, regulatory, monitoring, pricing, operating, and servicing policies to serve the system as whole (UTG 9, 1991; DeWar 2017).

TSM processes aim to optimally integrate and facilitate the functioning of the transport elements, ensuring an effective and efficient transport system (Karndacharuk 2017). TSM recognises transport as a unitary system where the four elements function interactively, needing to be organised and managed in an integrated manner. These four elements are briefly described below:

- **Transport infrastructure:** Planning for transport infrastructure need to include planning for integrated road network, traffic management, fleet management (public transport, heavy vehicles, rail and aviation) and make provision for right of way and rolling stock. Provision of transport infrastructure elements should not be seen in isolation and there is a need to at an institutional level, plan for the road environment in a way that link and integrate the different transport infrastructure elements (DeWar 2017).
- **Transport modes and users:** A well-balanced and multi-modal transportation system is vital to efforts that aim to sustain and enhance quality of life. Achieving such a system requires integrating land use and transport, and implementing a range of improvements that enhance connectivity, liveability, and vitality. Planning and provision of transport infrastructure should aim to cater for all modes in an integrated and sustainable manner (Steinmetz, Jurewitz and Taylor, 2015; Department of Transport, 2017).
- **Land-use patterns and planning:** Land-use patterns are an indication of existing land use; future zoning and rezoning as well as long-term planning for land use through structured plans. In addition, there is a need for coordination between different departments that provide social and spatial infrastructure, improving coordination by including different departments in the transport management process (Steinmetz et al., 2015; DeWar 2017).
- **Human factors:** To achieve a Safe System human factors need consideration early in the transport planning process. Human factors refer to human abilities and limitations (Borsos, Birth and Vollpracht, 2015).

3.2.2 Road (Land) Transport Management

Road Transport Management (RTM) entails utilising resources to optimise existing transport facilities. RTM includes organising the various land transportation modes (non-motorised transport, bus, taxi, car, rail) as well as the more recent interconnectivity of the various disciplines, Intelligent Transport Systems (ITS) and connected-autonomous vehicles (Karndacharuk 2017).

An RTM framework enables an integrated and harmonised approach to strategic planning, road network operations, road safety, asset management and land use planning (Karndacharuk 2017). A key objective of the RTM framework is to enable a safe, efficient, reliable, and sustainable road transport system.

Figure 3-1 below illustrates the RTM framework which is underpinned by 15 interrelated principles relating to mobility, safety, assets, and technology (Karndacharuk 2017). RTM principles are applied to integrate systemwide planning for the whole authority, city, or region with detailed planning at the transport network level (corridor, route, and link levels). The RTM framework can also be applied to the infrastructure asset life cycle from strategic and solution planning to design, construction, operation, and maintenance (Karndacharuk 2017).

1. Multi modal network operations planning
2. Functional road classification
3. Well connected transport infrastructure networks
4. Traffic control techniques and devices
5. Traffic calming and local area traffic management
6. Traffic incident management
7. Integrated transport and land-use planning
8. Lifecycle asset management
9. Parking strategy and management
10. Travel demand management
11. Safe System approach and principles
12. Electric connected and autonomous vehicles
13. Transport sustainability and resilience
14. Human factors and road user behaviour
15. Stakeholder engagement and collaboration

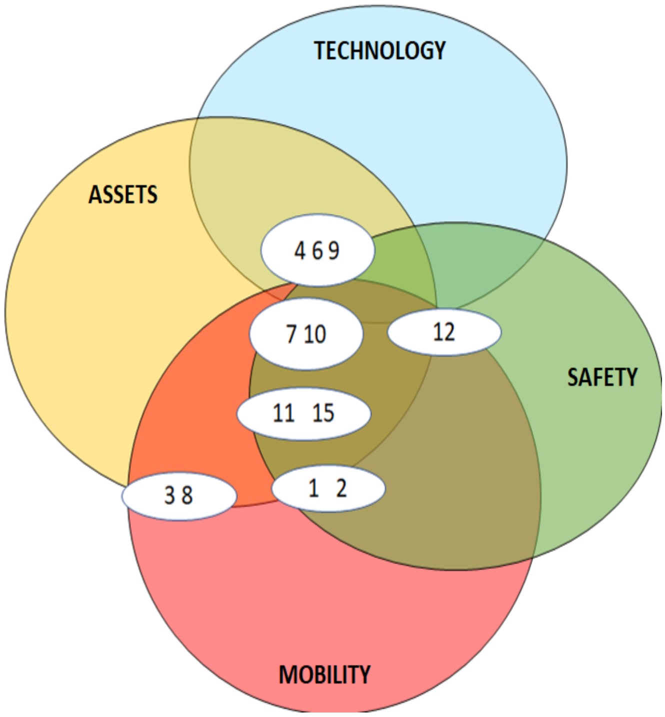

Figure 3-1: Road Transport Safety Management (Karndacharuk 2017)

3.2.3 Traffic Management

Traffic management as a component of the RTM framework (Figure 3-1) aims to provide not only the safe, orderly, and efficient movement of persons and goods, but to also, protect and where possible, enhance the quality of the local environment on and adjacent to traffic facilities (Underwood, 1990; Karndacharuk, 2017).

The discipline of traffic management links traffic control practices, within a defined policy framework, over a length of road or an area, to achieve specified objectives which may be set by national, provincial, or local governments in terms of individual or parallel functions (Austroads, 2006).

Traffic management is a function of the road authorities, responsible for managing the orderly and efficient movement of persons and goods on roads. These authorities have a responsibility to ensure that the road environment is designed in a consisted manner to guide road user behaviour. Use is made of guiding documents including (Austroads 2009):

- legislation standards (formal technical specifications based on agreed baseline practice).
- guidelines (technical guidance for practitioners based on consolidated experience and acknowledged best practice) as well as agreed upon codes of practice, supported by manuals with policy and procedures for implementing programs in accordance with standards, guidelines, and best practice.

The traffic management scheme is influenced primarily by the traffic volume, composition, and speed of the traffic either throughout the road network or in one or more parts of the road network (Austroads, 2009). Traffic management, in combination with the relevant planning, design, construction, and operational practices, is a valuable tool with which safety in the road and road environment can be addressed (Austroads 2009).

3.2.4 Road safety management

Road safety is a complex matter, requiring multi-sectoral collaboration and synergistic coordination of evidence-based programmes and countermeasures, headed by recognised leadership with elevated level political support and sustained funding (Gregoriades 2007). Factors that influence safety include road safety policy, traffic flow, vehicle condition and road characteristics, human behaviour and attitudes, travel conditions, environment (McCarthy 2011).

Yannis et al (2018) states that 'risk' is associated with the number of fatalities and known as a road safety outcome. "Risk" refers to the level of safety in transport systems by incorporating a measure of exposure, such as for example traffic flow. McCarty (2011) describes risk as "the measure of the probability and severity of adverse effects where probability is a mathematical construct and severity is the potential damage or unfavourable adverse effects arising from a road accident". The level of road safety is considered a primary performance indicator that illustrates the effectiveness and efficiency of the traffic management framework. Attributes of road risk have been studied extensively to inform the development of standards, guidelines and approaches to assess and manage risk on the road network (Persia 2016)

3.3 Safer roads and infrastructure (inherently safe and forgiving roads)

3.3.1 Pillar 2 Safer roads and infrastructure

The FHWA (2019) states that road safety is defined in terms of the injuries and fatalities that occur on the roadway system. Road safety definitions are therefore based on crash outcomes such as the number of accidents or accident consequences, by kind and severity, which are expected to occur on the road during a specific period.

Past sentiment was that the human element was the key causal factor of road accidents (PIARC, 2007). More recently, the influence of road factors in terms of infrastructural and environmental components have received attention (McCarthy 2011). As such, road safety management initiatives need to acknowledge that humans are vulnerable, make mistakes and has a low biomechanical injury tolerance which makes humans fallible and vulnerable (Ausroads, 2019). In line with international thinking, road safety should be managed with the Safe System principles in mind which entails a deliberate intention to divert from approaches that treat road injury factors as inherent factors to the road transport system (in other words there will always be a risk associated), to conceptualising and designing a system that is inherently safe for all road users (IRAP Toolkit 2010).

The UNDoA1, Pillar 2 – Safer Roads and Mobility, addresses safer roads and infrastructure including improved road design that caters for all users. As indicated earlier, working towards a Safe System starts from the acceptance, that humans make errors and thus the realisation that traffic accidents cannot be completely avoided. Traffic accidents do occur on all roadways (even top-quality roads), and it is therefore not possible to have a perfectly safe roadway. Hauer (1998) states that road safety is a matter of degree, and that highways can be built to be safer or less safe. Thus, road-traffic safety is a relative condition, and its assessment is due to a scale of degree (Hauer 1998) (AASHTO 2004).

Safer roads refer to roads that are self-explaining and forgiving of mistakes to reduce the risk of accidents occurring and to protect road users from fatal or severe injury (Ahmed 2013). Concepts such as the "Forgiving Roadside Design" and the "Positive Guidance" approach need to be integrated into the engineering design of roads to minimise the risk of road accidents (Ahmed 2013).

Within the Safe System paradigm, road authorities are responsible to ensure that the road network is safe. Road safety engineering makes use of specific principles and guidelines to improve the safety of the road environment and reduce the total cost of road in a cost-effective manner (Austroads 2019).

There are six activities listed under Pillar 2, including activities that promote safe operation, maintenance and improvement of existing road infrastructure by road authorities and developing safe new infrastructure that meets the mobility and access needs of all users, encouraging capacity building and knowledge transfer by creating partnerships, including with development banks, national authorities, civil society, education providers and the private sector, as well as encouraging research and development in safer roads and mobility.

The identification and removal or treatment of road elements which may contribute to accident occurrence or accident severity is a key component of the Safe System approach to road safety.

The Safe System approach in relation to road safety engineering related to (Australian Transport Council, 2006):

- designing, constructing, and maintaining a road system (roads, vehicles, and operating requirements) so that forces on the human body generated in accidents are less than those resulting in fatal or debilitating injury.
- improving roads and roadsides to reduce the risk of accidents and minimise harm: measures for higher speed roads including dividing traffic, designing ‘forgiving’ roadsides, and providing clear driver guidance. In areas with large numbers of vulnerable road users or substantial accident risk, speed management supplemented by road and roadside treatments is a key strategy for limiting accidents.
- managing speeds, considering the risks on various parts of the road system.

3.3.2 Reducing the severity of traffic injuries

Within the Safe System, the environment is addressed by applying guiding principles to provide road and traffic environments that guide behaviour based on road and traffic characteristics and that is inherently safe (Arson 2019). The Safe System considers the various elements of the road or the traffic system which include the interaction between the road user, the vehicle, and the road environment. The pillars provide a mechanism of through province can plan for actions to address safety in the road environment. Pillar 2 Safer Roads and Mobility aims to raise the inherent safety quality of road network for the benefit of all road users (African Development Bank (b) 2014). This is done through the implementation of road infrastructure assessment and improved safety planning, design, construction, and operation of roads.

3.3.3 Designing for road safety

A safe roadway is defined as “one in which none of the driver-vehicle-roadway interactions approaches the critical level at any point along its length” (FHWA, 2000). This critical level is rapidly reached unless the roadway has been designed taking safety in consideration. The concept of positive guidance entails the notion that the road acts as a contributing component in avoiding deficiencies of the road traffic system, thereby, in addressing safety in the entire system (Hauer 1998).

Wolhuter (2015) commences his introduction to Geometric Design of Roads by saying:

“Geometric design is defined as the design of the visible elements of the road. In effect, the geometric designer is the architect of the road. Geometric design includes a fair measure of art amongst the science. Road designers should be sensitive to the perceptions of the people who are using the road, whether they are drivers or passengers in a vehicle or outside vehicles” (Wolhuter 2015).

This statement from Wolhuter (2015) highlights the importance of inclusive designs that consider the road and traffic system in totality. Thought should be given to amongst other the fact that roadway and roadside design elements influence accident risk, as these elements directly affect how road users, including drivers and pedestrians, perceive the road environment.

In most countries, road design guidelines are applied to the construction of new roads (Ross, 2016). Austroads (2019) highlight that standards are an important starting point with any road design (Austroads, Guide to Road Safety Part 6A: Implementing Road Safety Audits 2019). According to Ivan et al (2000), road design standards, guidelines, and warrants are based on the opinion of experts and the basic principles of geometric design (Ivan, Ossenbruggen, Wang and Bernardo, 2000). A designer should be familiar with the relevant standards, attempt to comply with them and be aware of where any standard cannot be achieved. These designs should incorporate and address road safety issues, however, despite this, accidents still occur on new roads (A. J. Ross 2014). There are several reasons for this including that design standards often only contain minimum requirements regarding road safety and a combination of these elements can sometimes lead to dangerous situations. In addition, Austroads (2019) indicated that:

- standards are developed for a range of reasons including for cost or traffic capacity, as well as safety standards often these are only a minimum requirement.
- combining a series of minimum standards is undesirable and can leave no room for error, either on the part of the designer, the builder, or the final road users
- standards usually cover general or common situations, not all situations.
- a standard may not be applicable to the circumstances in the design.
- individual road elements, designed to standard, may be quite safe in isolation but may, when combined with other standard elements, be unsafe and lead road users to make errors.
- a standard may be based on old information.
- a designer may be using an inappropriate standard or an outdated standard.

The compatibility of standards for road transport has been an issue for many years because road vehicles are neither captive to their ground-based infrastructure nor strongly dependent on roadside infrastructure. Several issues have affected the current call for greater standardisation in the realm of road transport (Economic and Social Commission for Asia and the Pacific (ESCAP) 2017).

3.3.4 Road geometry

The geometry of the road influences accident rates as well as the severity of the accident. According to the Highway Safety Manual of the American Association of State Highway and Transport Officials (AASHTO), 33 % of all road accidents result from a combination of roadway factors and human factors. However, these proportions vary depending on the environment. Not only the geometric features of the road but also the existing road safety facilities influence road safety. When encountering unexpected road geometry, the driver may still be able to maintain normal driving, but if the driver keeps receiving additional information, the driver may fail to maintain normal driving and cause a road accident. Negative road engineering factors include those where a road defect directly triggers an accident and where some elements of the road environment mislead users and thereby create human error (Economic and Social Commission for Asia and the Pacific (ESCAP) 2017).

Elements of the road geometry that needs consideration include (Ahmed 2013):

- Cross-section of the roadway
- Roadside condition
- Curvature of the roadway
- Sight Distance
- Access management

3.3.5 Forgiving and predictable (self-explaining) road environments

Roadway elements provide guidance to road users, assisting road users in decision-making processes (Economic and Social Commission for Asia and the Pacific (ESCAP) 2017). Road safety engineering influence road user behaviour through measures such as traffic control and design (rely upon what the road user sees, interpret, respond to, and obey). The road environment should therefore assist the road user in making a series of correct decisions and, if not correct, provide a forgiving road environment to reduce the severity of the accident (Ahmeda 2013).

3.3.5.1 Description of concepts

'Safer roads' incorporates two concepts, namely, inherent safety (forgiving roads) and self-explaining roads (SER). The concept of SER revolves around the notion of providing information to road users in such a manner that the lay-out of the road intuitively guides road users (Sucha, 2015). Therefore, inherent safety refers to limiting the potentially dangerous encounters and traffic interactions, while SER spontaneously invoke safe behaviour from road users (Van der Horst and Kaptein, 2012).

Forgiving roads prevent accidents altogether or, if an accident does occur, limit the seriousness of the consequences (Theeuws 2012). Thus, the safety aspects are planned for, designed, and executed in such a way that road users' mistakes do not kill them, or such that the severity of outcomes (injuries) of traffic accidents are lessened (Pretstor et al., 2014). Van Der Horst et al. (2012) simplified the explanation by stating that the SER concept 'advocates safe driving simply through road design'. A safe road environment should provide no surprises to road users, adequate guidance is needed throughout the route along with controlled release of information – not too much at a given point or over a short length of road, repeat information where necessary to reinforce the message, and forgive road users if these principles fail (Lerner 2005). As such the road should:

- Warn road users of any hazards.
- Inform road users of the type of unexpected conditions that are likely to be encountered.
- Guide road users through sections of a route with sometimes unexpected conditions.
- Control road users through conflict points or areas of conflict.
- Forgive errant vehicles and behaviour of road users involved.

Wegman and Van Aarts states that the sustainable safety principles assist in achieving inherently safe and self-explaining roads (Wegman 2006). These principles are briefly discussed in the sections below.

3.3.5.2 Functional classification

Roads are classified according to a hierarchy according to the function they perform (was build or constructed to do). The road function is determined according to the essential needs which must be met:

- the traffic movement, or mobility, function – providing how people and goods can move from one place to another.
- the access function – providing access to properties and land uses adjacent to the road.

These functions (access and mobility) are fundamental to traffic management. Road classification hierarchy comprises roads with a through function, a distributor and collector function, and an access to property function (Committee of Land Transport Officials (COLTO) 2012). 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. Thus the 'look and feel' of the road should match its function (Mackie, 2010). The functional road classification assists with predictability as every section of the entire road network is split into one of two groups, according to whether it will primarily serve a mobility or an access/activity function.

By providing a suitable balance between mobility roads and access/activity streets, it is possible to provide an elevated level of connectivity, while maintaining a prominent level of road safety and accessibility (COTO, 2012).

3.3.5.3 Homogeneity and separation of traffic

A key issue, especially in developing countries, is the separation of different road users (motorised and vulnerable) at an early stage. The key to a safe traffic system is a design in which diversity would not lead to conflict. When conflict arises, such as in the event of an accident, human tolerance should not be exceeded (the human should not be seriously or fatally injured).

Homogeneity of mass, speed and direction are a key principle to ensure safer roads and refer to limiting the physical vulnerability of humans which can potentially result in injury or death. The foundation of this principle is rooted in the notion that the more homogeneous (similar) the traffic is, the lower the risk of (severe) injury (Wegman 2006).

3.3.5.4 Forgiving roadsides

The concept of infrastructure that is inherently safe for all road users is not new. 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) are 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 so that it forgives the human error (Ogden, 1996).

Existing (endemic) road features can be employed to create self-explaining, predictable roads (Charlton, 2010) The SER design incorporated existing features to visualise differences in terms of the type of roads. In addition, the Swedish Government maintains that there should also be a search for alternatives to building new infrastructure by improving existing infrastructure, improving vehicles, or increasing enforcement (Swedish Traffic Administration, 2012).

3.3.5.5 Managing speed

The safety of road transport involves many factors including driver skills, roadway characteristics, vehicle conditions, and weather. In addition to accident causation, the identification of hazards that may increase severity in the event of an accident is important. Among all contributing elements, speed is a critical factor with statistics showing that speed is a factor in one-third of all motor vehicle fatalities.

Road design elements such as wider roads, which allow for higher speeds, are globally one of the main contributors to the high accident rate (Johannson, 2009). Austroads (2019) reported that:

- Speed in urban areas greater than 5 km/h above average and 10 km/h above average in rural areas doubles the risk of an injury accident.
- Reductions of as little as 1 % to 2 % in average speed result in greater reductions in fatalities and serious injuries. Chances of surviving an accident decrease markedly above certain speeds, depending on the type of accident (illustrated in table 3-1 below).
-

Table 3-1: Type of accident and increase in speed leading to decrease in survival rates	
Scenario	Speed to ensure survival
Pedestrian struck by vehicle	20 to 30 km/h
Motorcyclist struck by vehicle (or falling off)	20 to 30 km/h
Side-impact vehicle striking a pole or tree	30 to 40 km/h
Side-impact vehicle to vehicle accident	50 km/h
Head-on vehicle to vehicle (equal mass) accident	70 km/h

The Safe System approach advocates for better planning and implementation of speed limits. In addition, where road users/vehicles with large mass differences use the same traffic space, the speeds should be low enough that, in the event of a traffic accident, the most vulnerable road users and modes should be able to walk away without any severe injuries.

3.4 Road safety engineering assessments and treatments

3.4.1 Proactive and reactive approaches to road safety

3.4.1.1 Proactive approaches to address road safety

Road Infrastructure Safety Management (RISM) refers to a set of procedures that support a road authority in decision-making related to the improvement of safety on a road network. Some of these procedures can be applied to existing infrastructure, thus enabling a reactive approach; and other procedures are used in initial stages of a project's life cycle allowing a proactive approach (Persia 2016).

The Federal Highway Administration (FHWA) defines a proactive approach to improve road safety as an approach that is associated with the prevention of safety problems before they manifest themselves in the form of a pattern of accident occurrence (Federal Highway Administration, 2018). A pro-active approach to road infrastructure design and renewal is desired, where road safety is considered in all the stages of a road life cycle (Persia 2016).

A proactive approach assists in the prevention of accidents by adoption of corrective measures before accidents occur. Several techniques and processes have been developed in the last two decades for improving road safety infrastructure. RSA is specifically recognised as one of the most efficient engineering tools (A. J. Ross 2016). The AfDB (2014) states that it is important to embed proactive road safety approaches to ensure that road traffic management systems are operational and effective and that there is a continuation in the use of proactive approaches. The steps, proposed by the AfDB (2014) to ensure the establishment of proactive approaches are as follows (African Development Bank (b) 2014):

Step 1 Establish a legal basis for undertaking proactive approaches:

Many countries have a legal requirement for the road authority to investigate and improve safety problems. RSI and RS assessment can support this legal responsibility. RSI and RS assessment responsibility should rest with the relevant authority for safety which must be supported at the highest political level (i.e., President/Prime Minister) and have clearly defined statutory accountability for any actions or failures of the systems.

Step 2 Formalise protocols and procedures:

The road authority needs to write and adopt a formal protocol or procedure for undertaking these proactive approaches (RSIs and RS Assessments) for safety investigations on existing roads. This should include specification of:

- The person or department with specific responsibility for investigation of road safety issues. This would normally be the responsibility of a Road Safety Unit in a Road Authority. This Unit needs to be a dedicated team of professionals whose focus is entirely on safety issues. They need to be trained and provided with high quality advice and technical assistance until they gain experience.
- The level of resources (financial and personnel) necessary to achieve a focussed improvement in road safety. This will depend on the extent and quality of the road network for which the road authority is responsible. At a very minimum, there will need to be a team of two RS Assessors of whom assumes the role of the 'Manager' in the RSU. The RS Inspectors can be engineers that would normally have other routine duties.
- Training and experience requirements for inspectors and assessors.
- The detailed process to be followed as set out in formally approved manuals or guidelines. These documents should specify the approach to be taken in the undertaking of RSI and RS Assessment.
- Requirements for the level of improvement to be achieved and over what period. This may be a numerical target for undertaking safety improvements on, for example, the worst 10% of the strategic or main road network. Longer term casualty reduction targets that can be associated with the improvements can also be developed. Typically, these would be in line with aspects of the African Road Safety Action Plan 2011-2020 supporting the UNDoA for Road Safety.
- Mechanisms for monitoring performance. These need to specify how performance should be monitored and evaluated.

Step 3 Identify personnel:

- Manager to oversee, plan and administrate the RSI and road safety assessments.
- Road safety inspectors to undertake RSI.
- Road Safety Assessors to undertake road safety assessments.

Step 4 Identify a budget for the treatment of existing roads:

There is no point undertaking RSIs and RS Assessments without the financial resources to implement a planned programme of changes. Therefore, an annual budget needs to be established for the treatment of road safety problems identified on the existing road network - irrespective of how these have been identified.

Step 5 Train staff in accordance with the protocols/procedures in Step 1.

For RSIs it is straight forward to train staff to capture information about road characteristics. For RS Assessments personnel must gain relevant experience as well as receiving training. It is considered essential for new RS Assessors to receive mentoring and for them to shadow experienced personnel until they have reached the requirements.

Step 6 Monitor and Review:

Before implementing proposed treatments, it is necessary to assess the potential impact to make a business case for investment. Information on the effectiveness of treatments has Embedding Proactive Approaches undertaken in countries in Europe and in USA and Australia. Little is known about the true effectiveness of the treatments under different circumstances in Africa. An understanding of local effectiveness will only be established if road authorities monitor and evaluate the performance of any measures implemented.

Organisations therefore need to introduce a system for monitoring and reviewing the performance of any implemented RSI or RS Assessment recommendations. This can then be used to identify the most appropriate safety improvements to incorporate in revised design standards. This is particularly important in any country where development of the road network is occurring at a fast pace and where research concerning road characteristics and their impact on road safety outcomes is not available.

3.4.1.2 Reactive approaches to address road safety

The FHWA defines a reactive approach to road safety as measures associated with the identification of locations where safety related problems are experienced (screening), problem definition (diagnosis), and the identification and implementation of countermeasures to improve the safety of the road (Federal Highway Administration, 2018).

The reactive approach, is concerned with safety improvement interventions, taken after many accidents have already occurred on a road or at a specific location. In many countries, adoption of a reactive approach could not gain significant success due to the absence of standard requirements (such as access to quality accident data) needed for such approach.

Figure 3-2 provides an overview of the different safety management approaches, application thereof and whether it is pro- or reactive.

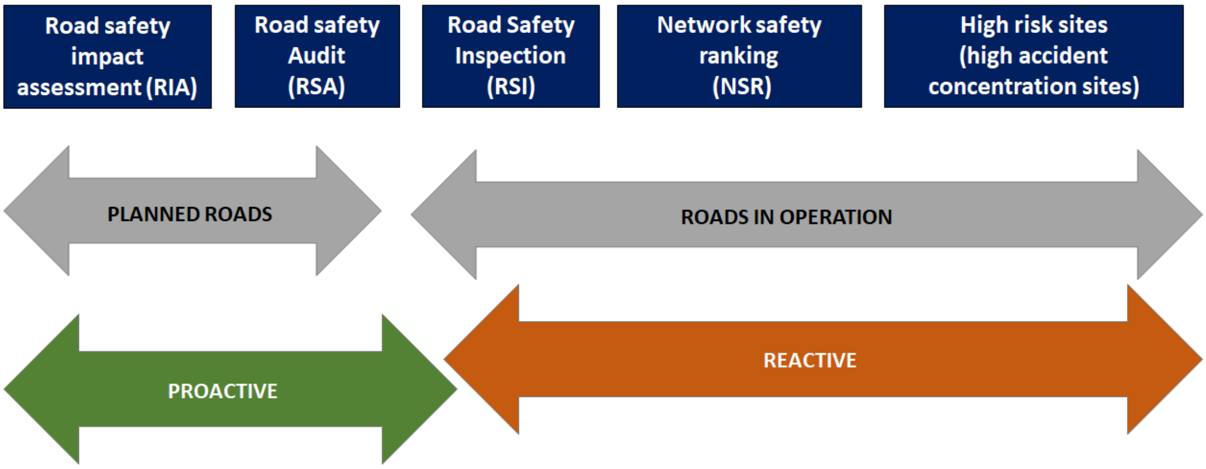

Figure 3-2: The methods of safety management of roads (United Nations Economic Commission for Europe 2018)

3.4.2 Methods to assess road safety.

Road Infrastructure Safety Management (RISM) procedures, such as the treatment of high-risk sites, have been applied in many countries for a long time; other procedures have been proposed and introduced in the last 10 to 20 years (United Nations Economic Commission for Europe 2018). The procedures covered by the directive, which are considered as essential to achieve positive road safety effects include:

- Road Safety Impact Assessment (RSIA) to introduce the factor road safety into the impact assessment procedures for bigger road projects at an early planning stage.
- Road Safety Audits (RSA) for new road at the construction planning stage
- Road Safety Inspection (RSI) for existing roads
- Road Network Safety Management (NSM) and
- Black Spot Management (BSM) to identify and remedy dangerous sections and locations.

The RSA and RSI are part of RSM (on an organisational level) and in terms of the Safer Roads and Mobility pillar, procedures must consider all parts of the Safe System approach (United Nations Economic Commission for Europe 2018).

Figure 3-3 illustrates the road safety procedures in various stages of road development.

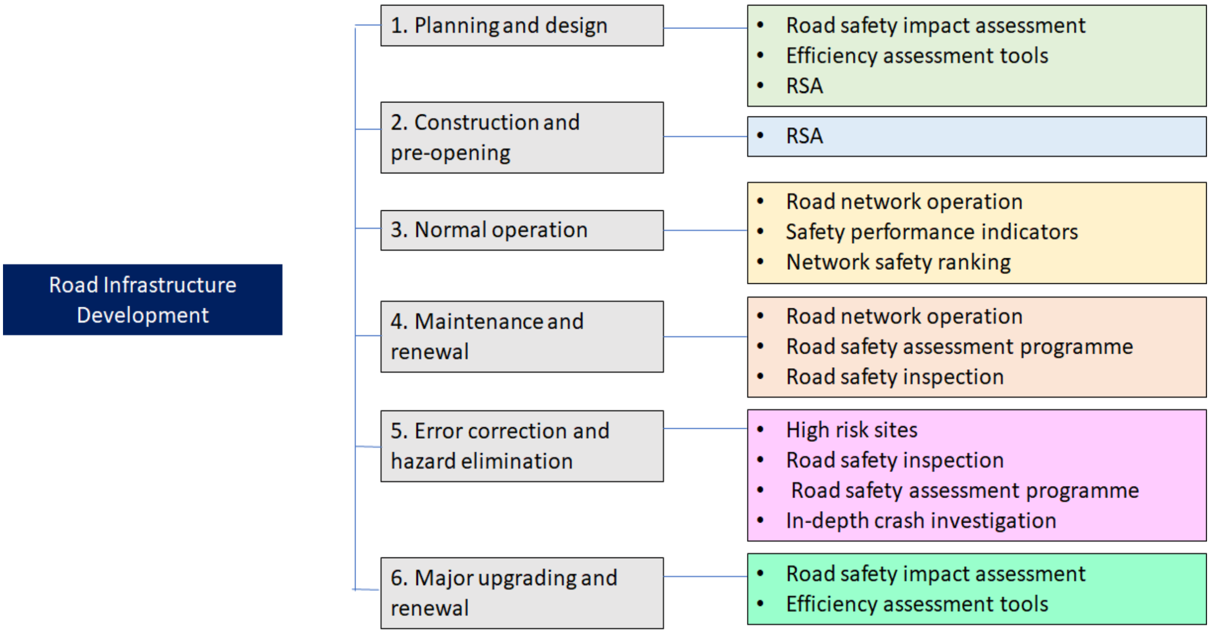

Figure 3-3: The road safety procedures in various stages of road development, adapted from Elvik, 2010 (United Nations Economic Commission for Europe, 2018: 11)

The procedures should be applied in this order to planned roads and existing roads. The procedures could have a proactive approach or a reactive approach to problems. Road safety inspections (RSI), often include both approaches, e.g., in the selection of roads that (primarily) should be inspected or in the case of ad hoc inspections due to accident reasons (United Nations Economic Commission for Europe 2018)

3.4.2.1 Road safety audits

Indications are that thirty-four percent (34%) of all the accidents are caused partially or fully due to roadway factors (Ross, 2016). Whether through a reduction in exposure, removal or reduction of the mechanisms that lead to an accident, or through treatments that reduce the severity of accidents, road safety audits are considered a valuable tool available to road safety professionals (Appleton, 2002; Ross, 2016).

3.4.2.2 Road safety audit reviews (assessments/appraisals)

Road Safety Audit Review (RSARs) is defined as “an evaluation of an existing roadway section by an independent team, focusing solely upon safety issues” (Jones 2013). Road safety assessments play a key role in the theory and practice of transport management systems (G. G. Yannis 2018).

RSARs involve the expert and in-depth review of the safety of existing roads. As well as identifying safety problems, the Assessment team should seek to identify and recommend viable and cost-effective measures which will improve safety (African Development Bank (b) 2014).

Road Safety Audit Reviews (RSARs) are proactive in nature and use accident data when available but are not dependent on it. RSARs focuses more on safety issues associated with the roadway, all road users, operating under all environmental conditions, and to identify the safety issues associated with the existing facility (Wilson and Lipinski 2004; African Development Bank (b) 2014).

The FHWA (Federal Highway Administration 2018) indicate a safety review actively seeks to identify safety concerns before a final design is established and built. This process differs from the RSA in the following aspects:

- Traditional safety review team does not usually include representation from multiple disciplines.
- Traditional safety review team is not necessarily completely independent of the design team.
- Traditional safety review does not necessarily result in formal review and response reports.
- Traditional safety reviews also miss such essential elements of RSAs as consideration of capabilities and limitations of potential road users and the importance of day/night field visits.

Road safety reviews/assessment are compared to post-opening RSAs, typically undertaken one year after a new road scheme has been opened to use (African Development Bank (b) 2014). Although the assessment techniques and methodologies are similar, there are significant differences between road safety assessment and RSAs. Post-opening RSAs are undertaken on new roads, or new road improvements, as part of the design and construction process. Roads which are subjected to RSA should therefore conform to current design practices and standards. In contrast, RS assessments are undertaken on roads which may have been operational for many years and which often do not conform to current design practices and standards (African Development Bank (b) 2014).

3.4.2.3 Traffic Impact Assessments

The focus of these studies is on estimating the volume of traffic associated with a land development project and the impacts that traffic will have on the operation of the adjacent street and road network screening in terms of capacity and levels of service. The difference between RSA and traffic impact assessment is that latter is concerned with land use and the impact it has on the adjacent road infrastructure because of the proposed development. The traffic impact assessment places a significant emphasis on improving the level of service and to a lesser extent on safety-related issues for all road users (FHWA 2006).

3.4.2.4 Road network screening

Road network screening is part of the road network safety management process and defined as a process by which the road network is screened to identify potentially hazardous sites (Ambros Sedoník, Křivánková, 2017). Road network screening employs safety performance functions (SPFs), also known as accident prediction models, and Empirical Bayes (EB) approach (Ambros et al., 2017). The result is a list which enables the road authority to rank the locations based on their potential for safety improvement.

3.4.2.5 Road safety inspections (RSIs)

RSIs are required for the redesign and upgrading of existing roads and it is done in many countries to give the designers insights and direction for safety improvements (Nadler 2014). Road safety inspections (RSIs) is also considered a proactive safety management tool. It comprises a routine, programmed and systematic field survey which is undertaken proactively on existing roads to identify risk factors and to achieve enhanced safety. RSI results in a formal report detailing road hazards and safety issues supported with videos and photographs. An RSI is a standardised survey undertaken to collect prescribed data relating to road characteristics (highway and environmental features) of existing roads. This allows the identification of sections of road that warrant further road safety investigation (African Development Bank (b) 2014).

Road safety inspections follows a similar process to that of RSAs. RSAs are however concerned with assessing potential safety problems before the road is opened while RSI are essential for redesign and upgrading of existing roads, often done to give the road designer insights and direction for safety improvements (Nadler 2014).

RSIs should be conducted on the whole road network at least every 5 years. As a minimum requirement it is recommended that RSIs are conducted on the busiest 10 % of the network (African Development Bank (b) 2014).

An RSI is thus a comprehensive on-site appraisal that makes use of checklists, as well as an analysis of the problems and suggested countermeasures. An RSI can be prompted by locations where accidents often occur (McCarthy 2011). In developing an RSI schedule, consideration should be given to (African Development Bank (b) 2014).:

- Budget and availability of personnel
- The type of roads (i.e., some roads may be particularly susceptible to weathering or other forms of
- deterioration and it may be appropriate to inspect such roads more frequently)
- Level of development (i.e., if there is slow but sustained development in an area then the traffic situation may change sufficiently rapidly for more frequent inspections to be necessary)
- Planned highway improvement schemes and scheduled road works (i.e., if the highway improvement scheme details have already been finalised and cannot be changed then roads due to be replaced/significantly rehabilitated should be avoided/if there is an opportunity to influence the scheme then they can be included).

3.4.2.6 Hazardous location identification (Blackspot identification and management)

Black spot investigations are reactive. Black spot programs aim to reduce accidents at a location. They rely heavily on historical accident records to establish accident patterns at the location. These records provide a view of the accident history and, with an experienced black spot investigator, low-cost accident countermeasures can be developed and applied to reduce future accident frequency and/or severity. While a black spot investigation applies to an existing road that has police accident data, a road safety audit is best undertaken before the road is built and with no accident history to call on (Central Asia Regional Economic Cooperation (CAREC) 2018).

4 ROAD SAFETY AUDITS

4.1 Introduction

As indicated in the previous chapter, RSAs are worldwide recognised as one of the most efficient engineering tools. RSAs have been practiced most countries, following the guidelines of the individual countries (Jones 2013). Experience around the world has demonstrated that it is possible to reduce potential safety problems by implementing systematic safety checks of proposed road projects at various stages in the planning, design, and construction process (Municipality of Abu Dhabi City 2011).

The RSA concept was originally developed and introduced in the United Kingdom (UK) in the mid to late 1980s following the development of Accident Investigation and Prevention (AIP) techniques and the requirements of successive legislation for highway authorities to take steps to reduce the possibility of accidents on their roads (Appleton 2002). The benefits of RSA were soon recognised, and many countries have since established their own similar RSA procedures and systems (Appleton 2002).

An RSA is considered a proactive engineering tool that can be used even in LIMC countries. Proactive safety actions can be employed to avoid future accidents by (World Road Organisation (PIARC) n.d; African Development Bank (b) 2014):

- ensuring the safest road design scheme is selected for construction.
- checking that the proposed road infrastructure or feature is designed and built to minimise the occurrence of road safety problems.
- treating safety issues on existing road network before accidents occur at these locations.

Volpracht (2006) indicated that Germany is using RSAs and the motivation include:

- Prevention is better than cure.
- RSA can be applied to all kinds of road projects.
- RSA is a valuable tool of the Quality Management in Road Design
- RSA is an important argument in rivalry competitive situations.

Jrew et al (2002) refer to RSAs as a data independent program that helps to fulfil safety objectives. Well-documented experience in Europe, Australia, and elsewhere support this notion and highlights that the RSA has the greatest potential for improving safety when it is applied to a road or traffic design before the road is built. It can be conducted on any design proposal that involves changes to the way's road users will interact, either with each other or with their physical environment (FHWA, 2006; Ross et al., 2014; Austroads, Guide to Road Safety Part 6A: Implementing Road Safety Audits 2019).

The departure point is that it is much more cost-effective to identify road safety deficiencies in the process of design, rather than later, after construction is completed (Volpracht et al., 2018). RSAs can produce significant benefits at low cost if carried out in a formal and coordinated manner at all stages in the planning, design, and implementation of a road project. The process requires co-operation, management commitment, skilled auditors, and an on-going training programme (African Development Bank (b) 2014). It results in improved design standards and management practices, ensuring a higher level of safety in the road environment (Ahmeda et al., 2013; Ross et al., 2014; Vollpracht et al., 2018).

RSAs therefore ensures that the road will operate safely in the environment in which it has to operate. However, it was mentioned that road safety auditing alone cannot solve all the safety concerns but can play an important part in preventing the circumstances that can lead to road accidents (Municipality of Abu Dhabi City 2011).

Jovanov (2018) states that despite a worldwide uptake of RSAs, there is still little systematic application or acceptance of RSA in LMICs. RSAs are implemented but mostly only done at the insistence of International Finance Institutions (IFIs) funding the road projects. In addition, Volpracht et al points out that even if RSAs are undertaken, the resulting RSA recommendations are not always implemented by the road authorities. RSAs are usually not undertaken at all on the 95% of the road network funded domestically (Vollpracht 2018). Nonetheless, IFI projects have recently attempted to develop local capacity for RSA implementation in LMICs and have done some pilot projects (Jovanov 2018).

The most important objective of the RSA is to minimise accidents, and to minimise the severity of any accidents that may occur on a new road project (Asian Development Bank 2018). Experience with RSAs in the United States indicates that RSA teams often identify safety concerns that would not otherwise have been discovered by a traditional safety review (FHWA 2006). Yet, although the benefits of RSAs are numerous they are also difficult to quantify. PIARC presenter Fournier (2006), stated this difficulty arises because it is not always possible to conduct a before and after study to compare improvements (Fournier 2006). RSAs are qualitative in nature, drawing on the expertise of the road safety auditor (and specialised team) to identify and interpret potential and existing road safety problems (Appleton 2002; Main Roads Western Australia 2015). RSAs as an accident prevention tool should be supported and progressed (Ahmeda 2013).

Costs that relate to the actual implementation of the RSA, redesigning after the initial early-stage audit (which Fournier indicated is in the region of 1 % of the total project cost) as appose to redesigning much later in the project, which is much more expensive (Fournier 2006). Studies that have attempted to quantify the benefits of audits have yielded impressive results. In the United Kingdom, a local authority has estimated the benefit-cost ratio of an RSA to be 15:1, while TRANSIT New Zealand has estimated the benefit to cost ratio as 20:1 (FHWA, 2006; Fournier 2006). Cost-benefit analysis of safety audited projects in Denmark yielded an expected average first year rate of return of 146 percent (Ahmeda 2013).

The FHWA (2006) indicated that upon implementation of RSAs, New York Department of Transport reported a 20% to 40% reduction in accidents at more than 300 high-accident locations treated with low-cost improvements recommended because of RSAs. The PennDOT trials of RSAs indicated, that the cost of RSAs is “very little for the amount of success.” Conducting RSAs and implementing their recommended safety improvements in design is estimated to typically cost 5% of overall engineering design fees (Federal Highway Administration 2006). These safety improvements resulting from RSAs can be achieved at a low cost and with minimal project delay.

4.2 Directives in support of road safety audits

4.2.1 Institutional directives

4.2.1.1 Addis Ababa Action Agenda (AAAA)

Despite its immense importance, building and maintaining transport infrastructure is costly, and many developing countries need assistance. To help address these needs, among others, the Addis Ababa Action Agenda (AAAA), 37 was adopted in 2015, along with the 2030 Agenda for Sustainable Development (United Nations Economic Commission for Europe 2018).

AAAA consists of a new global framework for financing sustainable development, and is particularly relevant for transport infrastructure, including sustainable and climate-resilient road transport infrastructure. In the AAAA, States reiterated their goal to end poverty and hunger and to achieve sustainable development in its three dimensions through promoting inclusive economic growth, protecting the environment, and promoting social inclusion (United Nations 2017).

4.2.1.2 European Union - Directive of the European Parliament and of the Council no. 2008/96 on Infrastructure safety management

The European Parliament and the European Council issued the Directive, 2008/96/CE on road infrastructure safety management, foreseeing safety checks, training, and certification of road safety auditors (Polidoria et al., 2012). The Directive has led to the establishment of different procedures (Road Safety Impact Assessment, Road Safety Audits, Road Safety Inspections, Network Safety Management) in all Member States (Sitran et al., 2016).

With its European Union (EU) Directive no. 2008/96 on road infrastructure safety management, published in October 2008, the European Union has made a clear decision that the that road infrastructure should be an important part in the road safety chain and that RSA will be mandatory for the Trans-European Road network in forthcoming years (Ross et al., 2014).

Use of road safety management tools such as the RSA, will be mandatory in the forthcoming years and International Finance Institutions (IFIs) are already extending the application of the Directive via their projects. RSAs will have to be performed not only during the design process of new roads but also ahead of major rehabilitations or upgrading of existing roads to detect existing safety deficiencies. Undertaking of RSA is important for road safety because a formal RSA Report should identify the existing and potential road safety deficiencies and, if appropriate, make recommendations aimed at eliminating or reducing these deficiencies. (A. Ross, Jovanov, Brankovic, Volpracht, Trajkovic and Ross, 2016).

Sitran et al (2016) evaluated the performance of EU and the evaluation confirmed that Directive 2008/96/EC encouraged a generalised use of Road Infrastructure Safety Management (RISM) procedures which were based on a minimal set of compulsory rules in the management of the TEN-T roads and implemented within legislative framework.

4.2.1.3 United Nations Economic Commission for Europe

The United Nations Economic Commission for Europe (UNECE) is one of the five United Nations regional commissions administered by the Economic and Social Council (ECOSOC). It was established in 1947 with the mandate to help rebuild post- war Europe, develop economic activity, and strengthen economic relations among European countries, and between Europe and the rest of the world (United Nations Economic Commission for Europe 2018).

In terms of infrastructure and road safety elements or perspectives, these are addressed in UNECE instruments such agreements and projects, including:

- European Agreement on Main International Traffic Arteries, 1975 (AGR)
- Trans-European Motorways (TEM) Project, and
- Trans-European Railway (TER) Project.
- European Agreement Concerning the Work of Crews of Vehicles Engaged in International Road Transport adopted on 1 July 1970.

Accordingly, six core United Nations road safety agreements - including those on Road Traffic 1968; Road Signs and Signals, 1968; Dangerous Goods by Road (ADR), 1957; Vehicle Regulations, 1998; Technical Inspection of Vehicles, 1997; and Global Vehicles Regulations, 199836.

4.2.1.4 PIARC – World Road Association

The World Road Association was established in 1909 as a non-profit organisation. (PIARC Techinal commititee C2 Safer roads and infrastructure 2018). PIARC has participated and supported the development of various country guidelines for road safety (PIARC Techinal commititee C2 Safer roads and infrastructure 2018):

- Road Safety Audit Guideline for Safety Checks of New Road Projects developed by World Road Association (PIARC) in 2011.
- Road Safety Inspection Guideline for Safety Checks of Existing Roads - PIARC in 2012.
- Catalogue of design safety problems and practical countermeasures PIARC, 2009

4.2.1.5 World Bank

The World Bank financing for road infrastructure projects should enhance safety, even though it could increase the project's cost. Safety aspects should be part of the acceptance process at the detailed design and pre-opening stages.

This aim should be emphasised in the Guidelines for Road Safety Management Capacity Reviews and Safe System Projects (Bliss and Breen 2013). The design should account for appropriate due diligence to mitigate for speed and other factors, and the local community should be consulted on the road safety aspects of the project. Road safety should be a safeguard and Bliss and Breen (2012) indicated that a convincing argument should be made for introducing mandatory road safety audits linked to road investment loans or credits (The World Bank 2014).

This requirement was incorporated and Job et al (2020) states that the World Bank's Environmental and Social Framework (ESF) addresses traffic and road safety under Standard 4, Community Health and Safety. This standard requires that all World bank projects incorporate safety, and that consideration is given to measures that avoid or minimise road safety risks and impacts. Any project with potential road safety implications must develop measures and plans to address these risks (Job et al., 2020).

4.2.1.6 Multilateral Development Banks

Seven Multilateral Development Banks (MDBs), which include: the Asian Development Bank, African Development Bank, European Bank for Reconstruction and Development, European Investment Bank, Inter-American Development Bank, Islamic Development Bank, and World Bank, issued a Joint Statement on a Shared Approach to Managing Road Safety in the context of harmonizing policies for road safety operations. The Development Bank of Latin America– joined the Consortium in April 2012 (Gómez Vélez 2014).

This shared approach recognises that a systematic, multisectoral response is required to address the global crisis including interventions that improve the safety of road infrastructure, vehicles, road user behaviour and post-accident responses, and supports the principles of the Safe System Approach aimed at:

- Developing road transport systems prevention, reduction, and accommodation of human errors.
- Considering social costs and impacts of road trauma in the development and selection of investment programs.
- Establishing shared responsibility for road safety among all stakeholders.
- Creating effective and comprehensive management and communications structures for road safety.
- Aligning safety management decision making with broader societal decision making to meet economic, human, and environmental goals, and to create an environment that generates demand for safe road transport products and services.

The Joint Statement acknowledges that a significant and sustained contribution to fatality reduction within the Safe System Approach will come from road infrastructure safety improvements, in which MDBs have a key role (Gómez Vélez 2014). The Joint Statement states the aims to share road safety best practices and knowledge between the MDBs, and to establish common standards and approaches based on best practice and a consistent approach in dealing with road safety issues as now occurs for environment.

The MDB collaboration developed and published guidelines as part of the joint effort of the MDBs to share tools and procedures on road safety to amplify impact in countries1. Each MDB has different approaches and levels of development on road safety. Guidelines are designed in a general manner, for them to be applied according to the policies and strategies of each MDB (Gómez Vélez 2014)

4.2.1.6.1 Asian Development Bank

The Asian Development Bank, in collaboration with UNECO for Europe and the World Bank, sponsored the use of road safety audits and have a published their own toolkit to be used in conducting a road safety audit (ADB 2003).

4.2.1.6.2 African Development Bank

The African Development Bank (AfDB) is engaged in national and multinational road infrastructure projects in African countries. Alongside with the road infrastructure financing, the AfDB has mainstreamed road safety to scale-up and consolidate its efforts to support comprehensive multisectoral road safety investments to reduce the increasing losses caused by road accidents (African Development Bank (b) 2014).

The AfDB developed three road safety manuals for Africa based on the Safe System approach and best practices tailored to African conditions to support road infrastructure safety practices in Africa over the next decade. The developed manuals include:

- New Roads and Schemes: Road Safety Audit.
- Existing Roads: Proactive Approaches; and
- Existing Roads: Reactive Approaches.

These manuals are designed to enable African countries consider and manage road infrastructure safety during design, construction, and operation. The intervention contributes to the achievement of the goal of the African Plan for the UNDoA1. The series of three manuals will be used by road authorities and road designers and planners to conduct road safety audits for new road projects to identify potentially hazardous designs and locations and put remedial measures in place to minimise accidents (African Development Bank (b) 2014).

4.2.2 Regional Directives in support of road safety audits

4.2.2.1 Trans-European North-South Motorway Project (TEM)

The Trans-European North-South Motorway Project (TEM) Project was established in 1977 as a subregional cooperation between Central, Eastern and South-Eastern European countries. Economic Commission for Europe (ECE) is the executing agency. The member States are Armenia, Austria (associate member), Bosnia and Herzegovina, Bulgaria, Croatia, Czechia, Lithuania, Poland, Romania, Slovenia. Road safety audits became mandatory in the European Union (EU) in October 2008 requiring the Trans-European Road Network (TERN) to conduct RSAs in the pre-opening phase of newly constructed roads (Vollpracht et al., 2018).

A Project Master Plan was published in 2006 and revised in 2011. The Master Plan promoted the common planning and integration of European transport infrastructure and supported the implementation of the pan-European transport corridors and intermodal transport operations. In the revised 2011 plan:

- the infrastructure development of 25 participating countries was analysed, and
- a development programme for the road and the rail network until the year 2020 was prepared, including infrastructure development financing.

Road safety and transport security issues found their place for the first time in the revised Master Plan. The overall road safety trends and the social costs of road accidents in TEM member States were presented, with information on ECE activities in road safety. Finally, the revised Master Plan underlined the benefits of a wider deployment of Intelligent Transport Systems (ITS) solutions and stressed the importance of minimizing transport impacts on the environment (United Nations Economic Commission for Europe 2018).

Regions were encouraged to adopt the European Commission's Directive, 2008/96/CE on improving the safety of the European road network to achieve common quality management in infrastructure safety in Europe. The directive only applies to the TEN comprising only the highest-ranking roads, mostly motorways and expressways which already have high road safety levels (Sitra et al., 2016).

4.2.2.2 Transport Corridor Europe Caucasus Asia (TRACEA)

The TRACECA Region contains important transport links (corridors) connecting China and Europe, harmonization of road standards and elimination of potential risks for the road users are of utmost importance. This implies that similar approaches applied to RSA related improvement of road infrastructure should be promoted in all TRACECA Countries (Transport Corridor Europe Caucasus Asia, 2020).

Road safety improvements are based on TRACECA Regional Road Safety Action Plan developed within Project "Land transport safety and security" (2009-2012) and implemented within Project "TRACECA Road Safety II" (2014-2016).

Ross et al (2016) indicted that despite systematic application of RSA at present in TRACECA Region. RSAs that are implemented are mostly pressed by IFIs and implemented by foreign consulting companies and that even if RSAs are undertaken, the RSA recommendations are not always implemented by the road authorities.

EU funded Projects have tried to develop capacity for RSA implementation in each of the countries and in some TRACECA regions steps towards RSA implementation have been taken (each country now has several trained auditors, and a Regional Road Safety Audit manual (based on PIARC – World Road Association) has been produced, and certain Pilot road sections have been audited). In some of the countries RSA has been introduced into the legislation as a mandatory procedure (Ross et al., 2016).

Education and training of the auditors is the weakest point in the entire RSA chain within the TRACECA Region. The reasons for this are brief history of RSA, non-understanding of RSA methodology and procedures and lack of RSA literature in the Russian language (A. J. Ross 2016).

4.2.2.3 Central Asia Regional Economic Cooperation (CAREC)

The Central Asia Regional Economic Cooperation (CAREC) countries committed to road safety at the 14th CAREC Ministerial Conference in Mongolia in September 2015.

The CAREC Road Safety Strategy 2017–2030 was endorsed by ministers from all CAREC countries during the 15th Ministerial Conference in Pakistan in October 2016. The strategy supports and encourages governments and road authorities to plan, design, construct, and maintain roads with road safety as a key and specific objective. As such CAREC members endorsed the road safety audit process as an integral part of the planning, design, and construction of road projects within the CAREC program. Road authorities within the CAREC program are encouraged to implement road safety audit, and to build up expertise in this field (Asian Development Bank 2018).

4.2.2.4 Trans-African Highways Network

In 1971, the United Nations Economic Commission for Africa (UNECA) envisioned the Trans-African Highway (TAH), a network of nine highways that would span a total of 60,000 km across the African continent. Ten routes were planned to include: Tripoli, Libya, to Windhoek, Namibia, (9,610 km), Cairo, Egypt, to Dakar, Senegal, (8,636 km), and Algiers to Lagos (4504 km). Only one of these routes, the 4,500 km (Trans-Sahelian Highway between Dakar and N'Djamena in Chad has been completed (NAMPORT 2018).

Construction has been slow on the TAH, with different construction standards across countries, inadequate funding for maintenance and upgrades, crumbling of already constructed roads due to climate and terrain conditions, and civil conflicts cited as reasons. Further, borrowing limits imposed by the IMF have been an impediment to fast-tracking infrastructure development projects such as highway. (SWECO International and Nordica Consulting 2003).

Setting up and implementing of appropriate management procedures is an essential tool for improving the safety of road infrastructure within the Trans-African Highways Network whether the roads are at the design stage, under construction or in operation. As such Guibo (2013) developed guidelines for TAH road infrastructure management, including:

- Road safety impact assessment for infrastructure projects
- Road safety audits for infrastructure projects
- Safety ranking and management of the road network in operation (best practice method is through iRAP)
- Safety inspections
- Data management
- Appointment and training of auditors
- Exchange of best practices

4.3 Road safety audit: International practice

4.3.1 Definition/s

4.3.1.1 Country and MDB definitions

Road safety audit is the term used internationally to describe an independent review of a future road project to identify anything that may affect future aspects of safety.

For new roads, RSA is a pro-active approach with the primary aim to identify potential safety problems as early as possible in the process of planning and design, so that decisions can be made about eliminating or reducing the problems, preferably before a scheme is implemented or accidents occur. However, it may also be a reactive approach for detecting safety deficiencies along existing roads as a start for rehabilitations (A. J. Ross 2014). Audits that take place on existing roads are referred to as RSARs, appraisals or assessments. RSARs are conducted before or after the opening of the new road, on roads that have been in operation. These reviews also follow a formal process and is conducted by qualified and independent auditors.

An RSA has similar qualities to other types of reviews, but to be considered an RSA, the process should contain several essential elements (Federal Highway Administration 2006):

- Formal Examination: RSAs are a formal examination of the design components and the associated operational effects of a proposed or existing roadway from a safety perspective.
- Team Review: RSAs are performed by a team (at least three auditors) who represent a variety of experience and expertise (design, traffic, maintenance, construction, safety, local officials, enforcement personnel, first-responders, human factors) specifically tailored to the project.
- Independent RSA Team: The audit team members must be independent of the design team charged with the development of the original plans, or, in the case of an RSA of an existing road, the team leader should be independent of the facility owner. Nevertheless, engineering, maintenance, and other representatives of the facility owner may and should participate provided they have not been involved in

prior decisions on the project. This independence insures a fair and balanced review.
- Qualified Team: The auditors must have the appropriate qualifications specific to the RSA.
- Focus on Road Safety Issues: The principal focus of the RSA is to identify potential road safety issues caused by the design, or by some operational aspect of the design. The RSA should not focus on issues such as standards compliance unless non-compliance is a relevant road safety issue.
- Includes All Road Users: The RSA should consider all appropriate vehicle types/modes and all other potential road users (elderly drivers; pedestrians of different age groups, including children and the physically challenged; bicyclists; commercial, recreational, and agricultural traffic, etc.).
- Proactive Nature: The nature of an RSA should be proactive and not reactive. The team should consider not only safety issues demonstrated by a pattern of accident occurrence, but also circumstances under which a cause-and-effect link is not so clear. These include potential safety issues relating to time of day/year, weather, or situational issues that may exist or that may occur because of road user expectations.
- Qualitative Nature: The primary products of an audit are qualitative in nature, rather than quantitative (e.g., numerical). These include lists of identified issues, assessments of relative risk, and suggested corrective measures.
- Field Reviews: RSAs are much more effective when they include day and night field reviews. Even RSAs at the pre-construction stage benefit from field reviews.

Different counties and guidelines have different descriptions and definitions of what constitute an RSA. However, even though definitions differ, it is constant in respect of the fact that RSA is a formal process, undertaken by a qualified and independent team of road safety auditors. In addition, the RSA process is applicable before construction of new roads.

The paragraphs below provide an overview of RSA definitions from various country and institutional guidelines.

i. "A formal examination of proposed or existing roads and road related areas from the perspective of all road users with the intention of identifying road safety deficiencies and areas of risk that could lead to road accidents. It does not consider accident history. It is conducted by an independent, qualified team of professionals. New South Wales Centre for Road Safety research highlights that an RSA does not consider accident statistics (NZ Transport Agency 2013).
ii. A road safety audit is checking fitness for purpose to ensure that proposed measures will be safe (Main Roads Western Australia 2015)
iii. "The evaluation of road schemes (works that involve new road construction or temporary or permanent change to the existing road layout) during design and construction, before the scheme is opened to traffic, to identify potential safety hazards which may affect any type of road user and to suggest measures to eliminate or mitigate those problems (African Development Bank group 2014).
iv. "A systematic and formal examination of a new road or highway improvement project, in which an independent and qualified team of road safety specialists, identifies potential road safety problems from the point of view of all road users (African Development Bank group 2014).
v. "A formal, systematic, and detailed examination of a road project by an independent and qualified team of auditors that leads to a report with a list of potential safety concerns in the project" (Asian Development Bank 2018).
vi. A road safety audit is (Asian Development Bank 2018):
    - a formal process (not just an informal, quick check).
    - conducted by persons who are independent of the design; and

- conducted by persons with appropriate training and experience.

vii. "A formal examination of a road project because it follows a clearly defined process that concludes with a written report" (Asian Development Bank 2018).

viii. RSA is a dynamic and structured process that requires a detailed examination of design drawings, an inspection of the location for the new road, a written report about the safety concerns identified by the audit team, and a subsequent response by the project manager stating why recommended actions have (or have not) been accepted, and what changes will be implemented (Asian Development Bank 2018).

ix. "An assessment of road engineering projects and as such the Safe System sphere of influence is limited to two of the four cornerstones of the Safe System approach, namely, Safe Roads and Roadsides, and Safe Speeds (Main Roads Western Australia 2015).

x. "A formal safety performance examination of an existing or future road or intersection by an independent audit team (Federal Highway Administration 2006).

4.3.1.2 Elements of RSA definitions across guidelines

Most RSA guidelines, irrespective of country or continent tend to have a similar definition for what a road safety audit constitute. As such, most entities (as highlighted above) include the following key elements as part of the definition of an RSA:

- Formal examination:
- Inspection
- Independent review by an audit team
- performance, detailed, systematic, structured process.
- evaluation
- assessment

Key elements of the audit team include:

- The team is formally qualified.
- The team is independent (ADB refers to road safety specialists)

The RSA considers:

- Future road (traffic project; intersection; highway project) or;
- Existing roads
- road engineering projects (Austroads - works that involve new road construction or temporary or permanent change to the existing road layout)
- limited to two of the four cornerstones of the Safe System approach, namely, Safe Roads and Roadsides, and Safe Speeds (Main Roads Western Australia)

The RSA identifies:

- Potential road safety problems (AfDB-from viewpoint of all road users)
- Project's accident potential and safety performance
- identify potential safety hazards which may affect any type of road user (ADB)

The RSA results in a written report that:

- identify road safety issues (AfDB; ADB)
- list of safety concerns (FHWA; Austroads)
- and to suggest measures to eliminate or mitigate those problems (ADB)

and;

- makes recommendations to remove or reduce the impact of these issues (ADB)
- highlight opportunities for safety improvement (FHWA)

4.3.1.3 Elements of what an RSA is not.

RSAs are not procedures for checking for compliance.

Austroads (2002) provides guidance about what an RSA is not. Specifically, a road safety audit is not the following (Austroads, 2002):

- A way of assessing or rating a project, is not a means of ranking projects.
- A way of rating one option against another.
- A check of compliance with standards.
- An accident investigation.
- A redesign of project.
- Something to be applied only to high-cost projects or only projects involving safety problems; and
- The name to use for informal checks, inspections or consultations.

4.3.2 RSA purpose

Pro-active good road designs and well-developed traffic management measures produce roads which are safer, and which are less likely to develop problems. RSA procedures can be used to attempt to ensure that both new and existing roads have potential safety problems removed before they lead to accidents (Ogden, 1994). RSAs are therefore part of the multi-disciplinary safety management system and not meant to replace studies such as traffic impact assessment, road safety inventory, traffic safety modelling, safety review standards among other studies.

RSAs attempt to identify features of the highway–operating environment that could be potentially dangerous to road users and others affected by a road project and to ensure that measures to eliminate or reduce the problems are fully considered. The RSA process focuses on evaluating safety in the context of all users, including pedestrians and cyclists, under the full range of environmental circumstances such as inclement weather and night-time conditions (Ogden 1996).

An RSA should include two integrated procedures: reducing accidents and preventing accidents. Moreover, it should establish remedial actions for locations where frequent incidents occur, but also reshape existing routes or design newer and safer routes to prevent accidents. (Ogden, 1996). An RSA addresses the safe operation of a roadway and ensure adequate safety for all users. Any changes applied to the road and adjacent road environment must not include features, or combination of features, that may contribute to future accidents (Municipality of Abu Dhabi City 2011). With the audit process, it is possible to reduce the number and severity of traffic accidents by improving the road safety performance (Ross et al., 2016).

4.3.3 RSA aim

The aim of road safety audit is to reduce the hazard and the road severity accidents, reduce the necessity for corrective effort after structure, and to reduce the total cost of the project (Ogden, 1996). Furthermore, this exercise can eventually prompt consciousness of safe design exercises by everybody participated in the design, planning, roads maintenance and construction. (Austroads, 2002).

RSAs assist in developing safer roads by promoting elimination or mitigation of safety hazards (such as inappropriate intersection layouts) and by encouraging incorporation of suitable accident-reducing features (such as guard fencing, traffic control devices and delineation). RSAs promote the removal or alleviating of safety hazards such as wrong cross-sectional layouts and by supporting the integration of appropriate features to reduce accidents such as traffic control devices, guard fencing and delineation (Al-Adhoobi 2017).

4.4 Safe System Auditing and Safe System Assessments

4.4.1.1 Introduction

The road authority has the responsibility to ensure that the road project is aligned with Safe System principles (Beer 2015). Safe System principles can be applied throughout the road network lifespan - using tools such as the Safe System Audit/Assessment (SSA). Auditors should fully understand the Safe System and be able to integrate this approach, as appropriate, into the audit process (Main Roads Western Australia 2015).

An RSA is a vital proactive road safety mechanism for assessing the road safety risk of permanent changes to the road network which incorporates Safe System principles embedded within the process. The RSA provides project managers with a powerful mechanism to identify potential accident risk in the delivery of infrastructure projects and aims to reduce the risk of trauma and accidents on the road network(Main Roads Western Australia 2015).This is achieved by applying the principles to the existing RSA processes and by making sure that the focus of the audit is to consider key accident types that may lead to fatal or serious injuries and kinetic energy generation and their management. This is to be achieved by focusing the audit process on considering safe speeds and by providing forgiving roads and roadsides. This is to be delivered through the RSA process that accepts people will always make mistakes and by considering the known limits to accident forces the human body can tolerate with the aim to reduce the risk of fatal and severe injury accidents (Main Roads Western Australia 2015).

To embrace the Safe System approach, there are three main options available:

- Modify the RSA objectives and processes in some way to incorporate the Safe System principles.
- Replace RSAs with techniques (such as SSA) more consistent with the Safe System approach.
- Optimise the uptake of RSAs and Safe System principles and tools (such as SSA).
- Austroads (2019) published a guideline to implement and management RSA, which included a review of traditional as well as modern safety orientated approaches to ensure that a network is safe (Figure 4-1).

Figure 4-1 illustrates the following processes (Austroads, Guide to Road Safety Part 6A: Implementing Road Safety Audits 2019):

- The top row components set out a typical approach to road infrastructure development – with road network level decisions (e.g., the planning of a road network and corridors within it) preceding and influencing project-level processes (i.e., from design to construction and to opening) and then on-going operational and maintenance demands.
- The top components are aligned vertically with the following road-safety-related activities: – the application of a safety vision (green boxes) – and the Safe System approach, which applies throughout the process.
- proactive (blue boxes) – road network safety reviews, road safety audits and road safety checks
- predictive (orange boxes) – risk assessment models/tools, including the Australian National Risk Assessment Model (ANRAM) and Safe System Assessment Framework (SSAF)
- reactive (red boxes) – including post-implementation reviews and treatment of accident locations (blackspot engineering).

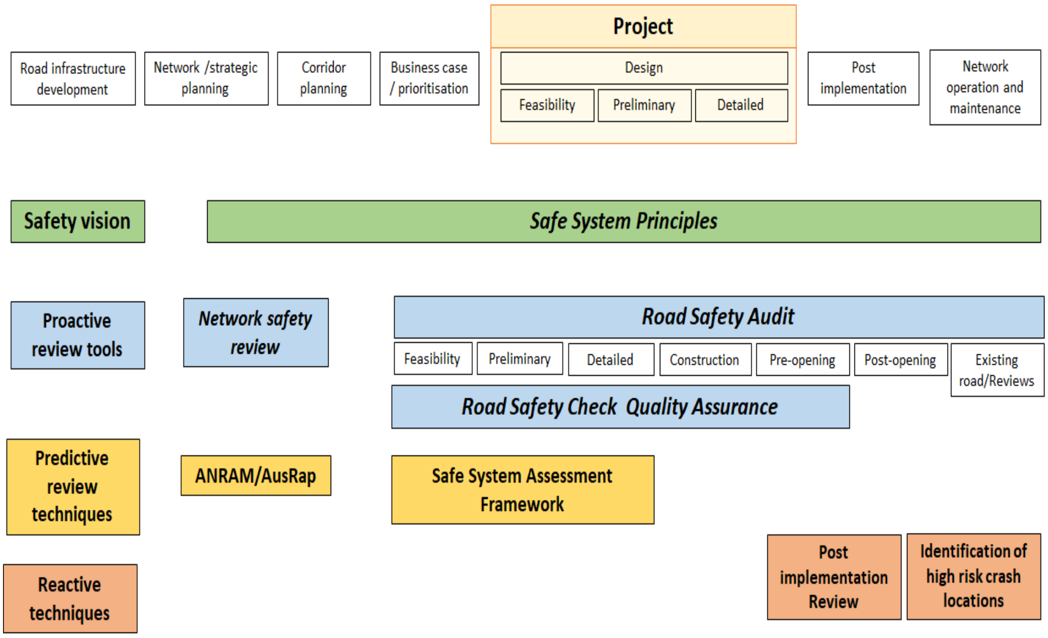

Figure 4-1:Approaches to road network and project-level road safety management (Austroads, Guide to Road Safety Part 6: Managing Road Safety Audits 2019)

4.4.1.2 RSA and SSA Application

Safe System Assessments examine a road related program, project, or initiative's alignment with Safe System principles. The Safe System Assessment (SSA) comprehensively assess and contribute to the safety of (K. Beer 2019):

- an existing road, intersection or length
- a road investment project, whether at feasibility, design or pre-opening stage
- an infrastructure program or funding application • a developer funded proposal/project.
- a road transport policy or strategy

An SSA needs to be used on all road infrastructure projects at all levels of government and within the private sector. RSAs identify specific design deficiencies, however a SSA is still required to ensure that a harm elimination agenda is being pursued. Ideally, an assessment would be conducted at the planning stage of a project and again towards the end of the project to counter the possibility of de-specification and diminishing safety effectiveness against delivery pressures.

Safe System Assessment Framework

The RSA team considers the safety of all road users, qualitatively estimates and reports on road safety issues and opportunities for safety improvement (Federal Highway Administration 2006). A RSA is intended to help deliver a safe road system and is not a review of compliance with standards (NZ Transport Agency 2013).

As part of aligning the RSA with Safe System principles, the following key questions should be raised for each of the safety risks or hazards identified. An affirmative response reflects a high severity risk, and as such is the focus of the subsequent risk assessment (Beer 2015):

- Is it possible to have a head-on accident at a speed greater than 70 km/h?
- Is it possible to have an intersection (right-angle) accident at a speed greater than 50 km/h?
- Is it possible to have a run-off-road (side impact with a rigid object) accident at a speed greater than 40 km/h?

- Is it possible to have a vulnerable road user (e.g., pedestrian, cyclist and motorcyclist) accident at a speed greater than 30 km/h?

The Safe System Assessment Framework (Figure 4-2) developed by Austroads addresses a wide variety of project types and can be utilised at any stage across the lifespan of a project and include an assessment of all pillars of the Safe System (Turner et al., 2016).

Figure 4-2: Austroads Safe System Assessment Framework (Turner et al., 2016)

The assessment framework is a valuable to assist road authorities to consider Safe System objectives scientifically and objectively in road infrastructure projects (Figure 4-2).

Table 4-1 provides an overview of the matrix according to which the facilities are scored. The higher the score, the higher the likelihood of a crash, which for safety reasons warrant that treatments are considered to reduce exposure and likelihood of a crash.

Table 4-1: Safe System matrix for safe roads and roadsides and safe speeds (Turner et al., 2016)

Road user group	Pedestrians	Cyclists	Other
Exposure	/4	/4	/4
Likelihood	/4	/4	/4
Severity	/4	/4	/4
Product	/64	/64	/64

Questions for consideration when using the scoring matrix are illustrated in Table 4-2 below.

Table 4-2: Questions for consideration when using the scoring matrix (Turner et al., 2016)	
Pillar	Questions
Road users	• Are road users likely to be alert and compliant? • Are there factors that might influence this? • What are the expected compliance and enforcement levels (alcohol/drugs, speed, road rules, and driving hours)? What is the likelihood of driver fatigue? • Can enforcement of these issues be conducted safety? • Are there special road uses (e.g., entertainment precincts, elderly, children, on-road activities, motorcyclist route), distraction by environmental factors (e.g., commerce, tourism), or risk-taking behaviours?
Vehicles	• What level of alignment is there with the ideal of safer vehicles? • Are there factors which might attract large numbers of unsafe vehicles? • Is the percentage of heavy vehicles too high for the proposed/existing road design? • Is this route used by recreational motorcyclists? • Are there enforcement resources in the area to detect non-roadworthy, overloaded or unregistered vehicles and thus remove them from the road network? • Can enforcement of these issues be conducted safety? • Has vehicle breakdown been catered for?
Post-crash care	• Are there issues that might influence safe and efficient post-crash care in the event of a severe injury (e.g., congestion, access stopping space)? • Do emergency and medical services operate as efficiently and rapidly as possible? • Are other road users and emergency response teams protected during a crash event? • Are drivers provided the correct information to address travelling speeds on the approach and adjacent to the incident? • Is there reliable information available via radio, VMS etc. • Is there provision for e-safety (i.e., safety systems based on modern information and communication technologies, C-ITS)?

Table 4-3: Safe System assessment – scoring sheet criteria

Score	Road user exposure	Crash likelihood	Crash severity
0	0 = there is no exposure to a certain crash type. This might mean there is no side flow or intersecting roads, no cyclists, no pedestrians, or motorcyclists).	There is only minimal chance that a given crash type can occur for an individual road user given the infrastructure in place. Only extreme behaviour or substantial vehicle failure could lead to a crash. This may mean, for example, that two traffic streams do not cross at grade, or that pedestrians do not cross the road.	Minimal chance that it will result in a fatality or significant injury to the relevant road user involved. *This might mean that kinetic energies transferred during the crash are low enough not to cause a fatal or serious injury (FSI), or that excessive kinetic energies are effectively redirected/dissipated before being transferred to the road user.
1	Volumes of vehicles that may be involved in a particular crash type are particularly low, and therefore exposure is low. For cyclist, pedestrian and motorcycle crash types, volumes are < 10 units per day	It is highly unlikely that a given crash type will occur	Should a crash occur, it is highly unlikely that it will result in a fatality or serious injury to any road user involved.

			*Kinetic energies must be low during a crash, or the majority is effectively dissipated before reaching the road user
2	Volumes of vehicles that may be involved in a particular crash type are moderate, and therefore exposure is moderate. For cyclist, pedestrian and motorcycle crash types, volumes are 10–50 units per day.	Crash is unlikely to occur	Should a crash occur, it is unlikely that it will result in a fatality or serious injury to any road user involved. *Kinetic energies are moderate, and most of the time they are effectively dissipated before reaching the road user
3	Volumes of vehicles that may be involved in a particular crash type are high, and therefore exposure is high. For cyclist, pedestrian and motorcycle crash types, volumes are 50–100 units per day .	Crash is likely that a given crash type will occur.	Should a crash occur, it is likely that it will result in a fatality or serious injury to any road user involved. *Kinetic energies are moderate, but are not effectively dissipated and therefore may or

			may not result in an FSI
4	Volumes of vehicles that may be involved in a particular crash type are very high, or the road is very long, and therefore exposure is very high. For cyclist, pedestrian and motorcycle crash types, volumes are > 100 units per day	The likelihood of individual road user errors leading to a crash is high.	Should a crash occur, it is highly likely that it will result in a fatality or serious injury to any road user involved. *Kinetic energies are high enough to cause an FSI crash, and it is unlikely that the forces will be dissipated before reaching the road user
* Refer to Safe System-critical impact speeds for different crash types, while considering impact angles, and types of roadside hazards/barriers present.			

The scoring system (Table 4-3) consists of the following (Turner et al., 2016):

If recommended treatment options are provided in an audit report, the treatments should be categorised into the four Safe System categories illustrated the following treatment hierarchy (Figure 4-3).

Figure 4-3: Treatment hierarchy (NZ Transport Agency, 2013; (Austroads, Guide to Road Safety Part 6A: Implementing Road Safety Audits 2019)

4.5 RSA process and lifecycle

4.5.1 Overview of RSA process

The RSA should be conducted at every stage in the lifecycle of a transport facility i.e., pre-construction phase, construction, post-construction, and development project.

Different guidelines have variations on the process. However, in its simplest form the process is illustrated in Figure 4-4 which is broken down into 8 steps. Austroads (2019) highlight that regardless of the organisational structure and size of the project, the sequence of RSA steps will still apply, although some of the steps may be brief. (Austroads, Guide to Road Safety Part 6A: Implementing Road Safety Audits 2019).

Ross et al (2016) states that opportunities to influence the design decreases with the phase of the lifecycle (A. J. Ross 2016).

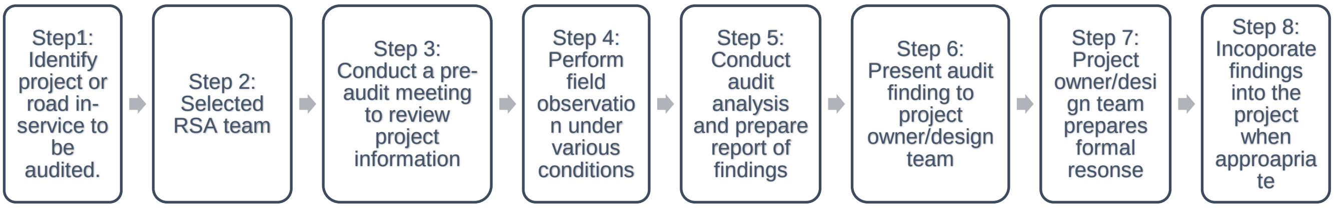

Figure 4-4: Road Safety Audit Process (Ross et al., 2016)

4.5.2 Role players and responsibilities in an RSA

There are three main groups involved in the road safety audit process (Central Asia Regional Economic Cooperation (CAREC) 2018).

- The client: The organisation responsible for the project and which is deemed to be the owner of the road. While the client is usually a road authority, owning the road on behalf of the government, it can also be a private investor for toll roads. The client will decide what is to be done (and not done) in the road project. The project manager is the day-to-day representative of the client on technical matters.

- The designer: An individual or team commissioned by the project manager on behalf of the client to design the road project. The designer may be a part of the client organisation, a design institute, or may come from a separate consulting company. The designer provides a service to the client by designing the new road within the client's stated constraints.
- The audit team: Usually comprises at least two people who are qualified as road safety auditors, and who are independent of the design and the proposal. The audit team is engaged by the project manager for the client. While the audit team may come from the client organisation (provided team members are clearly independent of the project), they are most commonly from specialist organisations and consultancy companies. The audit team provides a service to the client by examining the drawings for safety issues.

In Australia, the following roles and responsibilities are highlighted:

- Project sponsor: Employed or appointed by the roads authority responsible for overseeing and delivering the infrastructure related works.
- Lead auditor is a practicing professional with experience and capabilities in road design, traffic engineering, traffic / transport management, road construction techniques, road safety engineering, road user behaviours or another closely related road safety discipline, who is qualified to undertake road safety audits and has recent and regular demonstrated experience in conducting road safety audits (NSW Centre for Road Safety 2011).
- Audit Team means a team that shall comprise of at least two people, independent of the design team, comprising of members appropriately experienced and trained in road safety engineering or crash investigation with knowledge of current practice in road design or traffic engineering principles who undertake road safety audits.
- Audit team member has the qualification, skills, and experience to take part in the audit.
- Active observer is a person with an interest in undertaking the audit as directed by the lead auditor (e.g., gaining experience).
- Specialist advisor is a practicing professional with a specific subject knowledge and skills to provide independent input into the road safety audit (to the sponsor or to the audit team). This person approved by the Project Manager to provide independent specialist advice to the audit team, such as, road maintenance advisors, traffic signal specialists, police advisors and individuals with specialist local knowledge (Hatzivalsamis, S. 2019).
- Road safety advisor is a practicing professional with a specific subject knowledge and skill set in relation to road safety matter, In Australia this person does not need to be independent from the audit project.
- Project stakeholder is a person or organisation with an interest in the infrastructure – a designer, construction or asset manager or owner.
- Approval manager is the manager appointed by the road's authority and accountable for all aspects of delivering the road infrastructure.
- Service provider refers to the person, organisation contracted to deliver the services.

Figure 4-5 shows the phases in the project lifecycle that the RSAs need to be considered (Federal Highway Administration 2018).

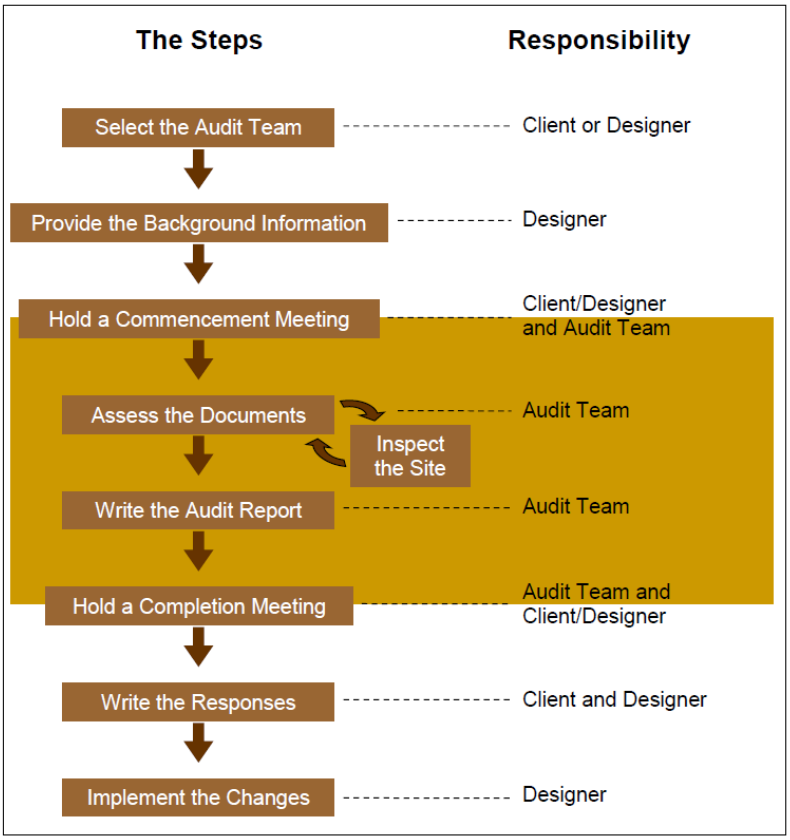

Figure 4-5: The steps and role-players in a road safety audit (Austroads, Guide to Road Safety Part 6A: Implementing Road Safety Audits 2019)

4.5.3 Selection of project and area of application

The RSA may be undertaken on any size of the project throughout the lifecycle, the earlier the better (Appleton 2002; Ross 2016). RSAs can be undertaken on a wide range of projects varying in size, location, type, and classification. The types of projects that can be audited are include (A. J. Ross 2016):

- RSAs are recommended to be undertaken for all new road designs and their major rehabilitation and could be conducted as follows.
- on new roads, motorways, highways, and other road surroundings/equipment,
- before and during reconstruction and rehabilitation
- inside and outside built-up areas.

4.5.3.1 Existing roads

The audit process when applied to existing roads is given a different name to emphasise the difference between design stage audits such as a review or assessment (e.g., road safety review or road safety assessment). The issue is that an independent assessment is made against objective criteria (A. J. Ross 2016). An audit / review of existing roads must be undertaken in the context of the road safety audit model, with a particular emphasis for (Appleton 2002):

- The accreditation of those undertaking the audit / review.
- The independence of those undertaking the audit / review.
- The audit / review should be a formal process and documented accordingly.

Differences between an audit of an existing road and a maintenance review (Appleton 2002) are also important. However, functions such as regular maintenance works (although not necessarily altering the road environment) needs consideration to be executed safely and there needs to be consideration in terms of protecting not only the workers but road users in general (Municipality of Abu Dhabi City 2011).

4.5.3.2 Work zones

RSAs for road works are not mentioned explicitly in all RSA guidelines. In many countries temporary traffic management (work zone) safety projects do not typically require road safety audits. The quantity and range of regular maintenance works makes it impractical for a full safety audit to be carried out in every work zone activity. The Municipality of Abu Dhabi City (2011) indicated that where a temporary traffic management project is to remain in operation for a period of six months or more, a safety audit should be undertaken. Consideration should also be given to auditing temporary traffic management projects that are to remain in operation for a period of less than six months if a significant impact on the road is anticipated (Municipality of Abu Dhabi City 2011).

However, the CAREC region states that in addition to the rest of the stages, road works need special mention as these areas are inherently risky (Central Asia Regional Economic Cooperation (CAREC) 2018). Road works take place during the construction phase of a project and entails a review of traffic management plans for each phase of construction of the road project (i.e., before the work begins). In addition, an RSA at road works inspects for road safety at the road work site during the construction period (Central Asia Regional Economic Cooperation (CAREC) 2018).

Applying RSAs to work zones can result in a unique set of safety and operational benefits. Temporary traffic control (TTC) devices and construction or work zone staging often represent 05-10 percent of project costs. By identifying improvements to work zone elements and staging early, agencies may realise substantial savings (Atkinson et al. 2013). Recommendations from a Work zone RSA (WZRSA) can affect roadway users immediately and broadly when applied to active work zones. In addition to identifying opportunities to improve safety for roadway users and workers, WZRSAs can lead to other benefits. In addition to the work zone projects being reviewed, observations from the WZRSA team may provide recommendations that benefit future work zones and design (Atkinson and A. 2013).

Typical considerations include the provision of an advance warning zone, adequate lengths for transition zones, effective numbers of reflective signs, safe delineation devices, credible speed limits, temporary accident barriers, lighting, and diversions (Central Asia Regional Economic Cooperation (CAREC) 2018). Key concepts include (American Traffic Safety and Services Association 2013):

- Work Zone Inspection: A work zone inspection is a review of temporary traffic control devices (TTCD) and safety/mobility strategies deployed per an approved plan, standards, and specifications in an active work zone. Member(s) of the agency responsible for the road work typically perform the specific project inspections. Compliance and deficiencies are documented formally, using a work zone inspection sheet, or informally, using visual judgment. Work zone inspection sheets can vary in complexity and categories, but typically identify criteria deemed most critical to the work zone (e.g., signing quality/location, whether the work zone set-up matches design plans, presence of flaggers, safety/mobility concerns, etc.).
- Work Zone Process Review: A work zone process review is a periodic evaluation of work zone policies, processes, procedures, and work zone impacts that aids in the process of addressing and managing the safety and mobility impacts of work zones. The process review helps assess the effectiveness of a program or a set of processes and procedures.
- A Work Zone Road Safety Audit is a formal safety performance evaluation performed at any stage of a planned or existing work zone (project planning and design, or in active work zones) by an independent, multidisciplinary team, and considers methods

of improving safety in a work zone. A WZRSA assesses the temporary elements of a project that will eventually be removed once the active work zone phase is completed. Due to the temporary nature of work zones, WZRSA recommendations must be provided to the road owner in a timely fashion.

4.5.4 Preparation of the audit brief

The RSA brief means refers to the preparation of instructions prepared that defines the scope of the audit and provides sufficient information to enable the audit team to conduct the audit (NSW Centre for Road Safety 2011). The Employer prepares a RSA brief describing the audit required and the works that it will cover. The list below describes the necessary information that should be provided for each RSA, where relevant:

- design brief or design report that describes the scheme and objectives.
- departures from standard.
- scheme drawings
- other scheme details, e.g., signs schedules, traffic signal staging
- accident data for existing roads affected by the scheme.
- traffic surveys, including pedestrian and cycle movements, for existing roads affected by the scheme.
- previous road safety audit reports and designer responses /feedback form
- previous exception reports.
- date audit report is required and any other relevant information.

CAREC (2018) refer to the brief as a Terms of Reference (ToR) for the audit, or engaging an audit team to undertake an audit, it is necessary:

- to be clear about the interaction of these three key groups.
- to facilitate a shared cooperation through a clear understanding that all three groups are working to achieve one goal.

Preparing an effective RSA brief, including a clear statement of the audit scope and the desired outputs, is considered critical in the process of procuring and managing the RSA (Karndacharuk and Hiller, 2018). The RSA brief needs to set out:

- general information – stage (timing) of the audit (e.g., preliminary design, pre-opening)
- project location and descriptions
- contact details of the client and audit teams.
- project background:
  - list of relevant documents (e.g., plans, drawings, and visualisation)
  - list of previous audits, SSAs and corrective action reports
  - key road and traffic characteristics (e.g., volumes, speed environment and accident data)
- project requirements:
  - a clear requirement that the audit should be carried out with a focus on Safe System principles
  - an instruction to carry out the audit in accordance with a recognised guidance document and/or local policy.
  - on-site inspections to cover relevant road conditions and/or specific road user groups (e.g., thematic audits)
  - timeframe and milestones (including provision for commencement and completion meetings)

Specific considerations include (Karndacharuk and Hiller, 2018):

- out-of-scope items (e.g., issues related to interface with adjacent land use and rail corridor, structural integrity, personal security and operation considerations)

- audit team composition and particular expertise (e.g., additional expertise required in human factors or a vulnerable road user group)
- use of control data, namely evidence-based sources, including best practice guidelines and research publications, to support the audit findings.
- whether recommendations for treatment options to address issues are required; if so, the recommendations are to be presented in accordance with their alignment with Safe System.

4.5.5 Team selection and requirements

Since an RSA is a formal process using a defined procedure and for it to most effective, it must be conducted by people who are independent and who have appropriate experience and training.

The project owner is responsible for selecting the RSA team that is independent and qualified auditors (Asian Development Bank 2018).

The road safety audit team is the champion of the cause of road safety. Audit team members need to be clear and firm in focusing on safety and should recognise that the client has the responsibility to weigh all competing factors, and to decide the way that will lead to success. The audit team puts forward its case for safety, but then leaves the client, project manager, and the design team to decide what will be done (Federal Highway Administration 2018)

The audit team uses the same technical skills and knowledge as the black spot investigator, but applies these in a proactive, rather than a reactive, fashion. The skills and knowledge involved in each may be the same, but the processes are quite different (Federal Highway Administration 2018)

Each auditor must be independent of the project design, and each must be qualified in road safety engineering practices. Working as a team of auditors (rather than as a single auditor working alone) means the mix of educational backgrounds and experiences of the team leader and each member of the team increases the likelihood all potential safety concerns will be identified and recorded in the final report (Asian Development Bank 2018). The audit team is to be an independent, qualified, and multidisciplinary team of experts. Among the recommended team of specialists, include road safety specialist, traffic operations engineer, road design engineer, local contact person, other areas of speciality (Federal Highway Administration 2018).

Road Safety Auditors should base their comments on sound safety experience, and where possible, to have the means to back up the recommendations from documented sources. Road safety auditors should have broad experience in road, traffic and safety engineering to ensure that has the knowledge and ability to refer back to the basic principles in road safety (NSW Centre for Road Safety 2011)

The Road Safety (Lead) Auditor’s role is to use safety engineering experience to ask the question: “How will all road users cope at all times and in all conditions with this road environment?” to identify safety problems, and to suggest measures that will minimise future accident occurrence and severity (NSW Centre for Road Safety 2011).

In Australia, the Audit Team must comprise a minimum of two members of which one is an Accredited Senior Road Safety Auditor. Specialist Advisors audit team by providing independent specialist advice to the audit team on aspects of a project. There is no requirement for a specialist advisor to be an Accredited Road Safety Auditor. Specialist advisors shall be listed as an “Advisor” in the audit report and shall not be listed as a team member (NZ Transport Agency 2013)

Team Leaders/Members shall excuse themselves from participation in the audit if they have had any involvement in planning, design, construction, or maintenance activities for road infrastructure for the project; or perceive any possibility of duress or coercion by their employer or employer's staff in relation to the audit. Persons not accredited as a Road Safety Auditor or do not have relevant specialist skills may still participate as an observer if invited to do so by the Team Leader (NSW Centre for Road Safety 2011)..

4.5.6 Conduct a pre-audit meeting to review project information.

This step aims to set the context of the RSA and to establish the alignment between the project owner, design team and audit team. The critical issues this step is meant to facilitate includes hand over of the relevant information, establish the scope and objectives, delegation of responsibilities, establishing the line of communication (Federal Highway Administration 2018).

A formal meeting has been found to be the most efficient way for the client team to instigate communication with the audit team. The objectives of the commencement meeting are as follows:

- to confirm the purpose and scope of the audit
- to discuss the process, including the roles and responsibilities and timeframe
- to formally provide the audit team with a hard and/or electronic copy of the brief and associated documents, and an opportunity for discussion and clarification
- to confirm any further requirements, including time periods for inspection (at night, during school holiday or off-peak hours) and consideration of weather conditions.

With input from the project sponsor and the design team, the project manager is responsible for organising such a meeting and ensuring that any key issues and constraints are properly discussed, and agreement/actions recorded. It is also possible to hold the meeting at the site/location, which allows the participants the chance to drive and/or walk through the site and gain a better understanding of the immediate areas of interest and any adjacent areas (Austroads, 2019; NZ Transport Agency 2013)

4.5.7 Review of Project Data and Field

Project data is reviewed to among other things to inform the site visit and to identify the preliminary areas of safety concern.

4.5.8 Conduct Audit Analysis

RSA is undertaken at various stages of road design and construction including at feasibility, preliminary design, and detailed design stages, and then prior to, and after, road opening. The RSA team provides suggestions on measures to mitigate the problems identified (African Development Bank (b) 2014).

4.5.9 Prepare Report of Findings

The outcome of an RSA is a report that identifies road safety issues and makes recommendations to remove or reduce the impact of these issues. Responsibility to implement these recommendations remains with the executing agency" (Asian Development Bank 2018)

Documentation of the responses to audit findings should be made a high priority by all asset owners. Development of tools that facilitate the traceability of audit findings, assessment of audit findings and corrective actions undertaken should be further investigated (Appleton 2002).

The RSA process results in a report describing potential safety concerns that should be considered prior to advancing to the next stage of the design process or works (African Development Bank (b) 2014). The report identifies safety issues as well as suggested measures to reduce the degree of risk. Following is the suggested structure outline of the RSA:

- Introduction
- Scope and purpose of RSA.
- Identification of project stage or existing road or, items reviewed and not reviewed.
- Project limits.
- Background
- Audit team, affiliation and qualifications.
- Commentary on data received from the project owner and design team.
- General observations regarding site visit.
- Findings and suggestions
- Safety Issue 1 - Description of issue, evaluation of safety risk, suggestions.
- Safety Issue 2 - etc.
- Formal statement - concluding statement signed by RSA team members indicating that they have participated in the RSA and agreed or reached consensus on its findings.

4.5.10 Present findings to Project Owner/Design Team

The audit team presents the audit findings to the project owner and design team (African Development Bank (b) 2014)

4.5.11 Preparation of formal response in relation to audit findings.

The project owner and the design team responds to the audit report. When considering the results of an audit, it is critical for the project manager to consider each finding, the importance assigned to it and its alignment with the Safe System principles. For each finding, the project manager must document the rationale and decision-making process in all the decisions reached. In doing so, the project manager may seek input from the design team and specialist advisors. Any contentious or outstanding issues should be identified for discussion during an interactive completion meeting (NZ Transport Agency 2013).

4.5.12 Completion of the RSA process

From a contractual perspective, the completion meeting is typically one of the last deliverables of the audit team. It is, therefore, important for the project manager to have a good understanding of the findings and recommendations, and the factors and principles behind them e.g., the link between the identified risk and its FSI accident potential and Safe System compliance of the countermeasures.

A collective response from the client team on the findings can be provided to the audit team by the project manager. This includes both agreed items and outstanding issues, which are open for discussion and clarification with the audit team.

An interactive, open meeting is preferred and on no account should the audit team members be unreasonably requested or put under any pressure to withdraw or modify any findings.

This is an identified area of high importance and where practice may potentially be poor. There are three general options for a client in responding to an audit finding and the associated recommendation/s:

- Accept the finding and recommendation in its entirety – the next step is straightforward and involves documenting the proposed action(s) in a corrective action report and implementing the agreed changes accordingly.
- Accept the finding and recommendation in part only – the project manager reaches this decision by undertaking a local context and risk assessment, considering a. outcomes from the audit team.
- the project sponsor and designer’s assessment of the risk
- severity of the harm and effectiveness of the suggested treatments (including improving on the recommendation)

- Consider cost and effectiveness of potential alternative treatments.
- Reject the finding and take no action – a project manager may decide to reject the finding and take no action but should do so cautiously. In these circumstances, it is the project manager's responsibility to justify and document the decision with supporting rationale and evidence.

4.5.13 Record Keeping and Reviewing Treatment Performance

Guidance on the keeping of risk registers to formally log unaddressed risks and issues identified during audits is likely to receive further consideration in the future consolidation of the RSA guidance. Formally recording unaddressed risks is a much more positive outcome than having several audit reports that are not being closed out and ignored.

It is an important responsibility of the project manager and/or asset owner to keep records of:

- the status of audit projects (e.g., initiated, in progress and completed)
- findings and the responses from the client team
- action items, including timing and responsible parties.
- how the treatments perform in addressing the safety risks identified.
- A minimum retention period for the records should be decided by the organisation to ensure that documentary evidence can be produced should there be any issues involving duty of care and future litigation.

As with any strategy, policy and plan, a formal mechanism for the evaluation of and continual improvement in audit practice should be encouraged.

4.5.14 Addressing road safety issues highlighted by the RSA.

The RSA process is designed to pro-actively improve road safety through formal independent review of designs and inspections of new and existing roads and traffic operation plans (Appleton, 2002). In recent years, road authorities in Australia and New Zealand have recognised the potential of RSA as a means of preventing accidents or reducing their severity and have embraced the process as an effective road safety tool.

Responsibility to implement these recommendations remains with the executing agency and requires response by the project manager stating why recommended actions have (or have not) been accepted, and what changes will be implemented (Asian Development Bank 2018). It is argued that the effectiveness of the countermeasures should be implemented shortly after conducting RSA, this is important to allow for the before-and-after study to be conducted. RSA informs the designing roads that reduce the risk of accidents and minimise the harm caused during accidents.

RSAs are used as tools that minimise future accident occurrence. Among the elements that are considered in the RSA in terms of physical infrastructure (Vardaki, Papadimitriou and Kopelias 2014);

- Signage
- Roadside hazards
- Cross-sections
- Stopping sight distance
- Decision sight distance
- Driver behaviour
- Special consideration for vulnerable road users

PIARC deficiencies into 8 broad groups or categories:

- Road function
- Cross section

- Alignment • Intersections
- Public and private services; service and rest areas, public transport
- Vulnerable road user needs
- Traffic signing, marking and lighting.
- Roadside features and passive safety installations
- Typical Road Safety Engineering Deficiencies:
- Temporary signing and marking at Work Zones.
- Accident type sketches
- Potential accident reduction via various countermeasures.

4.6 RSA stages

The RSA process as it relates to the design stages of a proposed project should be encouraged and implemented for all projects. Regardless of the planned project cost, the audit process has the potential to identify deficiencies and associated treatments with a significantly high return on investment. This is equally possible for minor and major projects (Appleton 2002).

The RSA process is required for various stages of a project in different countries (Ahmeda 2013). This includes every stage in the lifecycle of a transport facility including pre-construction, construction, and post-construction and it seeks to identify potential safety hazards that may affect any type of road user (Municipality of Abu Dhabi City 2011).

Road authorities, according to the City of Abu Dhabi (2011) should consider conducting an RSA at the earliest stage possible (planning or preliminary design) when all roadway design options and alternatives are being explored. This evaluation is carried out during the design stages (stages 1 & 2), as closely as possible after the measures become operational (stage 3) and at 12 and 36 months after the measures become operational (stages 4A & 4B).

4.6.1 Design stages

In 1998, during the Austroads International Road Safety Forum, four stages were defined in the, then new edition of the Austroad Guide and the fifth stage is considered at another grade of the process and been named as a road safety review when the road is operating. (Appleton 2002). More recently five stages are presented for an RSA, which are: possibility, incipient proposal, comprehensive proposal, before opening and on existing roads (Al-Adhoobi 2017).

4.6.1.1 Feasibility audit reviews

During the feasibility stage, the following are identified: the nature and scope of the sketch and identify the starting point of the actual design, such as design options, route options, or/and treatment options. This allows for an assessment of the safety performance of each option and identifies specific safety needs of different road users. Within this stage changes or improvements to consolidate and enhance safety are very cost effective and comparatively inexpensive (Al-Adhoobi 2017).

4.6.1.2 Initial design stage

The initial design stage addresses the selected design criteria’s and issues such as the layout of the intersection. Upon completion of this stage, the design should be well sufficiently to make decisions on land tenure, where appropriate (Al-Adhoobi 2017).

4.6.1.3 Comprehensive design stage

The comprehensive design stage looks at specific design issues. Signing schemes, geometric design, line marking plans and roadside equipment including lighting ensuring that it appeared to be in relation to the operation of the safety and the safety of all road users, these are some examples of the specific design issues (Al-Adhoobi 2017).

4.6.1.4 Pre-opening stage

Before opening, or the pre-opening stage entails an inspection of the site. It is conducted to ensure that past concerns are addressed and to distinguish any hazardous conditions that may not be clear from the plans. The inspection is advisable to be done under different conditions such as severe weather and darkness as well as from the point of view of all road users, including cyclists and pedestrians (Al-Adhoobi 2017).

4.6.1.5 Road Safety Audit Reviews

Existing roads safety audit referred as road safety review differs from the project or strategic plans safety audit and is handled separately. (Appleton, 2001). By given the name of the road safety assessment or road safety review on the existing road network, the RSA process gets applied.

The RSA process applied to the existing road network is given the name of road safety review or road safety assessment. Road safety reviews are completed to identify hazards and deficiencies, affecting safety, which may lead to future accidents, so that remedial treatment may be implemented. Although the published guidelines included procedures to audit existing roads, road safety reviews have always been a minor element in RSA programs.

This apparent lack of action may be because the investigation of high accident points, called blackspots, could appear a more effective treatment to improve safety. The difference is that blackspots work is reactive, rather than not proactive (Ogden et al., 1995).

In general, treating known accident sites is more cost-effective than treating sites where accidents are yet to occur. However, the most effective procedure is indeed complementing both approaches in the study.

The revised Austroads guidelines indicate that the aim of a review is to identify any existing safety deficiencies of design, layout, and road furniture and to check consistency of standards such as the road user's perception of local conditions assist safe behaviour. Austroads states the value of conducting safety reviews, specifying that they complement a program of accident blackspot treatment (Austroads, 2002).

Some corrective actions can be implemented to identify risks and deficiencies that affect safety and may lead to future accidents upon the completion of the road safety reviews. With the fact that even the released guidelines incorporated with the procedures for reviewing the existing roads, road safety reviews have always been considered as a small component of the RSA programs. This can be directed to the high accident points investigation or which is known as the black spots, which could show a more effective treatment for improving safety (Al-Adhoobi 2017).

In Australia Northern Territory the following stages apply (NZ Transport Agency 2013)

- Feasibility Design
- Preliminary Design
- Detailed design
- Work Zone Traffic Management of Construction Works
- Pre-Opening (when the project is complete and prior to opening to the public)
- Post Completion of Projects
- Land Use Developments
- Existing Roads

Table 4-5 provides an overview of the stages when they are initiated and what information is needed to conduct the audits.

Table 4-4: Stages, initiation, and accompanying information (NZ Transport Agency 2013)

Audit Stage	Description	When to initiate RSA process	Information required
Feasibility Design (Stage 1)	An audit of the feasibility project design	Prior to land acquisition	RSA brief. Drawings including horizontal and vertical alignment and basic form of intersections proposed in hard copy and electronic format.
Preliminary Design (Stage 2)	An audit of the preliminary project design	On completion of preliminary design prior to commencement of detailed design	RSA brief. Drawings including horizontal and vertical alignment, typical cross section and form of intersections proposed in hard copy and electronic format. Copy of previous stage audits undertaken and completed Corrective Action Report.
(Stage 3) Detailed project design	An audit of the detailed project design	Prior to tendering the contract for the project	RSA brief. Drawings including horizontal and vertical alignment, cross sections, road markings, signage, kerbing, safety barriers, drainage, lighting, traffic signal details and landscaping in hard copy and electronic format. Copy of previous stage audits undertaken and completed Corrective Action Report.
Pre-Opening (Stage 4)	An audit of the constructed project	Once substantially complete prior to opening to road users	RSA brief. As-built drawings in hard copy and electronic format, if available. Copy of previous stage audits undertaken and completed Corrective Action Report.
Work Zone Traffic Management	Audit of the construction work site	To be undertaken where construction activity extends to active traffic areas	Project drawings and Specification, and Work Zone Traffic Management Documents

Table 4-6 illustrate the different RSA stages according to the FHWA framework (Federal Highway Administration 2018) (Federal Highway Administration 2018).

Table 4-5: RSAs at the phases of the project lifecycle (FHWA 2006)	
Project lifecycle phase	Stages in the distinct phases
Pre-construction Phase RSAs	At this stage of the project, lifecycle change may be incorporated into the designs without much delay to the project. In this phase of the project lifecycle the RSAs may be conducted at the various stages as follows. Planning (feasibility), Preliminary design (functional designs) (iii) detailed designs
Construction Phase RSAs	The RSAs are required in the various stages of Construction i.e. preparation of the construction, during construction and the opening period. Whilst the focus might be on the safety performance of the final product as designed, it is also important that the temporary roadway and transitions areas are also compliant in terms of safety.
Post-construction Phase RSAs	RSAs for existing roads or intersection. The procedure used for the assessment for existing infrastructure is different from those that are pre-construction phase or in the construction phase. For instance, to inform the assessment datasets such as as-built plans as well as accident data should also be used among other datasets.

Table 4-7 below provides an overview of the different RSA stages, comparing different countries.

Table 4-6: RSA stages – comparison between regions							
Australia[1]	New Zealand [2]	United States of America [3]	United Kingdom [4]	European Union [5]	Africa [6]	United Emirates [7]	Central Asia Regional Economic Cooperation (CAREC) [8]
		Pre-construction Stage					
Feasibility stage	Feasibility stage	Planning	Stage F: Feasibility/ Initial Design Stage	Planning stage	Stage 1: Feasibility Study		Stage 1: During Feasibility Study During Construction Stage
Preliminary design stage	Preliminary design stage	Preliminary Design	Stage 1: Preliminary Design/ Draft Plans		Stage 2: Preliminary Design	Stage 1 – undertaken following completion of the preliminary design. The project design should be sufficiently progressed such that all noteworthy features are clearly shown.	Stage 2: During Preliminary Design

Detailed design stage	Detailed design stage	Detailed Design	Stage 2: Detailed Design	Design stage	Stage 3: Detailed Design	Stage 2 - Upon completion of detailed design and before the preparation of any works orders or tender documents.	Stage 3: Completion of Detailed Design
		Construction Stage RSA		Construction stage			Stage 4: During Construction Stage
		Work Zone Stage					Road works stage
		Construction Stage					
Pre-opening stage	Pre-opening stage	Pre-opening Stage	Stage 3: Pre-opening	Pre-opening stage	Stage 4: Pre-Opening		Stage 5: Pre-opening
Or soon after the	Or soon after the	Post-construction			Stage 5: Post-Opening	Stage 3 – After completion of works and after	

project is complete).	project is complete).	Stage RSA of Existing Roads				opening to traffic.	
		Development Project RSA – For Land Use Developments					
						Stage 4 –RSA is widened to encompass accident investigation and will be an integral part of routine accident monitoring system. i) Stage 4A prepared using 12 months of accident data from the time the project became operational and 36 months of accident data from prior to the commencement to the commencement of works	

						Stage 4B - The Client Officer should decide if a Stage 4B RSA needs to be prepared. The Client Officer’s decision should be led by the results of the Stage 4 report, the scale of changes instigated by the original project and any issues highlighted following completion of a Safety Unit site investigation sheet.	

1 Austroads. 2019. Guide to Road Safety Part 6A: Implementing RSAs

2 New Zealand Transport Agency. 2013. Interim road safety audit guidelines

3 (Asian Development Bank 2018)

4 Federal Highway Administration. 2018. Road Safety Audit Guidelines

5 United Nations Economic Commission for Europe. 2018. Road safety audit and inspection guidelines on the TEM network.

6 African Development Bank Group. 2014. Road safety manuals for Africa: New roads and schemes – Road Safety Audit Guidelines

7 Department of Municipal Affairs and Transport. 2018. Abu Dhabi Road Safety Audit Manual

8 Central Asia Regional Economic Cooperation. 2018. Road Safety Engineering Manual 1: Road Safety Audit

4.6.2 Specialised skills to be included for various stages.

4.6.2.1.1 Feasibility stage

In the feasibility stage, the issues to be examined are quite different (broader and often more subtle) from later stages and these audits should be undertaken only by very experienced auditors. Include an experienced road design professional(s) who is familiar with road design standards and can visualise the layout in three dimensions (Institute of Highways and Transport 1996); Austroads, 2019).

Road safety audit inputs at the feasibility stage of a road scheme can influence fundamental issues such as the design standards, the route choice, continuity (Central Asia Regional Economic Cooperation (CAREC) 2018).

4.6.2.1.2 Preliminary design stage

Similar skills are required as described for feasibility stage audits, but not all team members need be as experienced. Include team members with local knowledge of road user activities. For some audits it might be useful to include team members with relevant specialist experience (e.g., of different road user groups, human factors experience etc.) (Institute of Highways and Transport 1996): (Austroads, Guide to Road Safety Part 6A: Implementing Road Safety Audits 2019).

An audit on completion of the preliminary (draft) design examines features such as horizontal and vertical alignments, and cross-sections and intersection layouts. Careful auditing at this early design stage can help to reduce the costs and lost time associated with changes that may otherwise be brought about during later audits (Central Asia Regional Economic Cooperation (CAREC) 2018).

4.6.2.1.3 Detailed design stage

In addition to the skills described for preliminary design stage audits, there is a need to include team members familiar with the types of details the project includes, for example, those with expertise in traffic signal control, traffic signs, street lighting, bicycle facilities, accident barriers or any other local road user issue (Institute of Highways and Transport 1996; Austroads, Guide to Road Safety Part 6A: Implementing Road Safety Audits 2019).

This audit stage occurs on completion of the detailed road design (final), but before the preparation of contract documents. Typical considerations include geometric layout, signs and line markings, signals, lighting, intersection details, safe roadsides, and provision for vulnerable road users. Attention to detail at this design stage can do much to reduce the costs and disturbance associated with last-minute changes that may otherwise be brought about with a preopening audit (Central Asia Regional Economic Cooperation (CAREC) 2018).

4.6.2.1.4 Road works stage / Temporary traffic works (during construction):

In the road works stage, there is a need to include someone with experience in managing road works sites and an engineer familiar with the details of the traffic control and safety devices typically used at work sites (Institute of Highways and Transport 1996; Austroads, Guide to Road Safety Part 6A: Implementing Road Safety Audits 2019).

4.6.2.1.5 Pre-opening stage

The pre-opening stage needs to include someone who has experience in traffic and safety, such as a traffic officers, a maintenance engineer, someone familiar with traffic control devices, experts with experience with relevant road user groups (e.g., buses, cyclists etc.) and someone involved with the behavioural side of road safety.as this audit involves a detailed inspection of the new road project immediately prior to its opening. Although most road projects are constructed “under traffic,” there is a time near practical completion, just before the contractor hands over the project, when a preopening stage audit is undertaken. The audit team should drive, ride, and/or walk over (as appropriate) the new road to ensure the safety needs of all road users are provided for. A night-time inspection is particularly important at this stage to check signage, delineation, lighting, and any other night-time- and/or low light-related issues.

4.6.2.1.6 Existing road (road safety inspections)

Some road authorities undertake RSAs (often called road safety inspections) of existing roads and highway is as a way of identifying high-risk locations for remedial action. Road safety inspections have value in countries where accident data is lacking or inaccurate, as they are one way to point authorities to high-risk locations.

Road authorities in some countries aim to “catch up” with safety problems on the existing road network by auditing their main roads and highways as a matter of priority. This shows a commitment to RSA, but also shows that many road authorities perceive the audit of an existing road as the “easiest” stage of audit. Unfortunately, a focus on existing road audits can undermine the awareness of RSAs among some professionals. Some audits of existing roads find so many safety concerns that the cost to eliminate them is extremely high. It can leave a legacy of many audit reports recommending safety improvements that cannot be treated because of limited funding. There can also be a mistaken perception that RSAs and accident remedial work are identical. Such misunderstanding can destroy the credibility of the entire RSA process. If there is too much misunderstanding of audits, it may lead an organisation to disregard the process altogether.

4.7 Virtual Road Safety Audits

Driving simulators have grown in popularity and as these research tools become widespread and more available in the world, an opportunity is presented to introduce the technology into the road design process as opposed to only using the technology for pure research purposes (UNIVERSITY of WISCONSIN–MADISON 2020).

Introduction into the design process does not mean using driving simulators for visualisation purposes; instead, is the use of driving simulator to perform what is described as a virtual road safety audit (Figure 4-6).

A virtual road safety audit (VRSU) involves the evaluation of a design by exposing real users to the design using a driving simulator and obtaining performance measures that reflect how different elements of the design support the driving tasks. The methodology has been used by the research team not only for the evaluation of proposed interchanges designs but also for the evaluation of safety treatments on highways (UNIVERSITY of WISCONSIN–MADISON 2020).

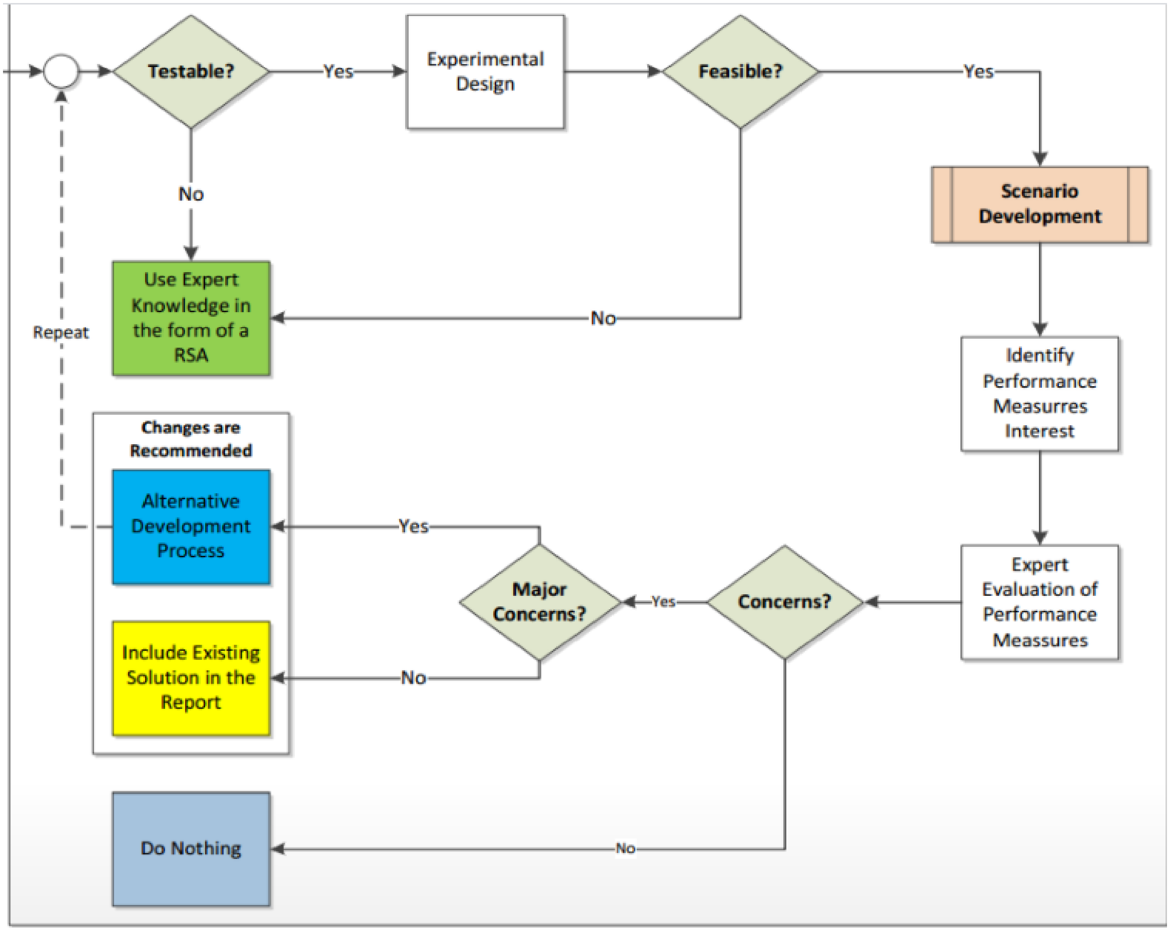

Figure 4-6: Virtual RSA methodology (UNIVERSITY of WISCONSIN–MADISON 2020)

As part of an RSA, the existing or expected characteristics and traffic conditions of a location are evaluated using multiple points of view to identify what could be the factors causing the safety issues identified. The potentially proactive nature of the RSA approach is the ability to conduct an RSA regardless of sufficient accident history at a location (Noyce 2018).

The goal of the RSA process is to obtain better insights into the behaviours that drivers exhibit (or could exhibit) at a location. Unfortunately, there is a limited amount of information that can be obtained through field visits or assumed by analysing the design documents of a proposed project (Noyce 2018).

If the geometry and operational characteristics of an existing or proposed design are converted into a virtual scenario, an experiment can be conducted to obtain detailed driver behaviour measurements that can be used to characterise potential safety problems and identify the corresponding solutions (Noyce 2018).

A VRSA allows engineers to focus on understanding specific driver behaviours in a controlled laboratory environment. VRSAs can be conducted with various levels of fidelity, ranging from a full-scale driving simulator experiment to a dynamic survey that simulates driving scenarios. This report summarises steps followed in the selection of a signalised intersection for a VRSA and steps involved in the creation of a virtual scenario required for a VRSA. An alternative approach to the identification of candidate intersections, based on objective measurements, is introduced to address the limitations of relying on feedback from users to identify potentially unsafe locations within the transport road network (Noyce 2018).

4.8 Thematic Road Safety Audits

The Australian Roads and Traffic Authority (RTA) have recently introduced a new element of road safety audits and named it as the Thematic Audits (Al-Adhoobi 2017). This new element intended to focus on a facility, a particular aspect, or a user in a road environment. The major aim is not just to address areas of concern in the network, but with the time the knowledge gained from those areas extend boosted practices, training, and guidelines, because of that enhancing continuous improvement. (Brisbane and Yee, 2002) [12].

Thematic audits are an element of road safety audits that have been introduced by in Australia. A thematic audit aims to focus on a specific aspect, facility, or user in the road environment. The ultimate purpose is not only address concerning areas of in the network, but over time knowledge gained from them provide improved guidelines, training, and practices, thereby promoting continuous improvement (Brisbane-Yee, 2002). Thematic audits can be applied to various situations in the road environment. They can focus on different themes such as clear zones or roadside fixed objects. Thematic audits can also adopt the perspective of a given road user group such as pedestrians, cyclists, or heavy vehicles. The purpose of this research is to focus the safety audit review on speed issues.

Thematic audits can be used in different placements in the road environment, focusing on various subjects such as clear areas or fixed objects on the side of the road. The thematic audits can also be based on the views of a particular group of road users, such as heavy vehicles, pedestrians, or cyclists. The aim of this paper is to focalise on reviewing the safety audit reviews on issues related to speed.

4.9 Global review of RSA guidelines with emphasis on low- and middle-income countries

4.9.1 Background

The PIARC technical Working Group C2 for Safer Roads and Infrastructure (PIARC, 2019) did a comprehensive review of current Road Safety Audit Manuals and Guidelines from different countries to establish current practices and to consider previous international reviews to determine key areas where additional guidance is required, or exemplar practice is well established.

Several reviews, consisting of international experience in RSAs undertaken over recent years were considered before examining a wide range of manuals and guidelines from across most continents. PIARC (2019) highlights that “these documents draw upon similar principles and content, having been developed by international road safety experts. For example, the International RSA manuals and those from countries such as Uganda, Ghana, Tanzania, and Ethiopia are all similar in layout and content. It is often only the degree of detail that varies. Similarly, whilst there are differences in approach between US and other manuals, their layout and process are similar.”

Therefore, for the reporting of the review, best examples and those that offer some difference in approach were selected. This means that the manuals selected for detailed review provide the best representation of different approaches available that will together be most useful in the context of LMICs. These were then used to highlight areas in the current PIARC manual that could be improved to assist LMICs in developing their own comprehensive approach to RSA and RSI.

4.9.2 Summary of issues found in LMIC RSAs

Core issues facing many LIMC countries regarding implementing a comprehensive audit system include:

- Variability of situations across LMICs: Due to the significant differences in variables (geography; climate; culture; socio-economic development etc.) and organisation road safety culture (amount of institutional leadership) influence the way in which RSAs are implemented in LMICs.
- Traffic mix: LMICs have a more diverse mix of traffic (two and three wheelers, cyclists, and pedestrian as well as motorised traffic) greater walking distances, speed differences and less integration with other modes.
- Main accident types: In Africa, the largest proportion of road deaths are VRUs.
- Vehicle condition: Vehicle standards and maintenance procedures are poor. Vehicle standards are based on international (first world country) standard. Because the vehicle fleet tends to be old, safety features such as anti-break locking systems (ABS) and electronic stability control (ESC) are absent, influencing risk and a person's ability to survive an accident.
- Driver competency, compliance and use of infrastructure: Driver training, law enforcement and levels of compliance in a country influence the way road users interact with the road environment and infrastructure. These differences will need to be considered to ensure that the right treatment measures are proposed.
- Increasing motorisation and modal changes: Provision of infrastructure needs to consider rising levels in motorisation as well as modal shift from for example walking as a main mode of transport motorcycles and public transport.
- Rapid infrastructure expansion: investment in infrastructure coupled with rises in motorised traffic as well as the type of motorised transport will change the scale in terms of infrastructure provision. As such there is a need to understand and have knowledge about road user behaviour in the context of these changing environments.
- Small number of experienced road safety auditors/inspectors: RSA knowledge and good practice is lacking in LMICs. Dependence on international experts is not sustainable and as such LMICs need to develop local capabilities.
- Capacity of road safety engineers and designers to deal with recommendations arising from RSAs: Road safety auditors and road designers need to have mutual respect for the work that each of these entities. Road safety auditors need to acknowledge that road designers often must deal with many, often competing objectives while road designers need to acknowledge that the function of an auditor is to provide constructive feedback to improve the safety of a road.
- Economic pressures and the need for cost benefit analyses: LMIC countries emphasised the lack of funding for RSAs.
- Variation in design standards: Design standards vary from country to country. This creates inconsistencies in the way that problems are reported and addressed (even if making use of international best practices).
- The importance of early intervention and land use planning: An RSA, early on can eliminate problems related to land use practices that leads to unsafe conditions. The report provides an example of a road dividing a community.
- Road user behaviour: Road user behaviour differ between countries. Road user behaviour impacts the way infrastructure is used and determine the proposed ameliorative measures.
- Legal environment and enforcement: Enforcement practices influence the level of compliance - the way infrastructure is used. Deterrence and effective law enforcement influences road user's behaviour.

4.10 Preparation of RSA Guidelines

4.10.1 Conventional approach to the writing of RSA/RSI guidelines

RSA Guidelines are prepared based on the approach used in Road Safety Audit Manuals and apply a conventional approach to RSA/RSI based on PIARC (World Road Association) guidance. This ensures a similar approach are applied to RSA/RSI related improvement of road infrastructure (RSA/RSI Reports) in various parts of the World. The approach of these guidelines is to give an overview of typical deficiencies in design and in the existing roads. It also provides an understanding of unsafe design and its consequences. Most typical accident types are dedicated to the related deficiency. Volpracht et al (2018) states that the authors of these manuals attempt to make the RSA Guidelines user-friendly.

4.10.2 Preparing best practice guidelines for use in RSAs

Country guidelines for road safety auditors have through the years been compiled using international best practice and the direct experience of the authors and initially have drawn guidance and concepts from the following sources (PIARC Techinal commititee C2 Safer roads and infrastructure 2018):

- Towards safer roads in developing countries a guide for planners and engineers, developed by TRL, Ross Silcock partnership and ODA in 1991.
- Road Safety Audit Guideline for Safety Checks of New Road Projects developed by World Road Association (PIARC) in 2011.
- Road Safety Inspection Guideline for Safety Checks of Existing Roads - PIARC in 2012.
- Catalogue of design safety problems and practical countermeasures PIARC, 2009
- “The handbook of road safety measures” written by Rune Elvik and Truls Vaa, in 2004.

The above sources provide detailed guidance on all critical aspects of safety engineering, and the authors recommend that road engineers should use these in planning and operation of roads to ensure safer road (PIARC Techinal commititee C2 Safer roads and infrastructure 2018).

4.10.3 Steps in development of an RSA methodology

Fournier (2006) proposes the following steps for planning/ developing a methodology for road safety audit guidelines:

- Examine best practices and international guidelines.
- Decide on how to train and accredited the road safety auditors in your country.
- Develop institutional support for the RSA process, for it to be sustainable.
- Convene a working party including national and international experts and stakeholders.
- Develop draft procedures based on relevant local practice.
- Consult the draft procedure at national and local level.
- Adopt the procedure within national design standards.
- Determine training need and appropriate training programmes.
- Prepare seminars for awareness raising and long-term training programmes for national and local auditors.
- Install a national road safety audit centre.

4.11 RSA tools

4.11.1 Design review and prompt lists

These are tools used by the design team to evaluate items related to: standards, details, exceptions, right-of-way issues, or cost and material estimates. The review is not conducted by an independent, multi-disciplinary team. Furthermore, these design reviews are not primarily looking for safety issues nor is there always an adequate focus on all types of road users (FHWA 2006).

4.11.2 Standards and Compliance Reviews

This review to determines if all applicable standards (have been met or exceeded. Compliance reviews do not always consider the safety aspects of the design for different road users. Standards compliance reviews do not exercise one of the major road safety principles inherent to RSA “adherence to the design standards does not guarantee that the road is optimally safe" (FHWA 2006).

4.11.3 Value Engineering Studies

Value Engineering refers to a systematic application of recognised techniques by a multi-disciplined team to identify the function of a product or service, establish a worth for that function, generate alternatives using creative thinking, and provide the needed functions to accomplish the original purpose of the project, reliably, and at the lowest life-cycle cost without sacrificing safety, necessary quality, and environmental attributes of the project. Experience does indicate that RSAs can be integrated with the value engineering method and the results of RSAs can be used in value engineering studies (FHWA 2006).

4.11.4 Quality Assurance Processes

This is a management process that is used to ensure that the quality of goods or services meets the agreed standards. Quality assurance, even when the safety aspects of a project are reviewed, is checking compliance with standards, and is not done by a multidisciplinary team possessing qualifications necessary to examine safety performance of a road for all road users. RSAs and quality assurance do not negate one another, but they may be complimentary. Specifically, quality assurance procedures may be modified to include specific requirements of RSAs, e.g., required skills and experience of the auditors, the size of the team, the RSA process to be followed, and others.

4.11.5 Software

Interactive Highway Safety Design Model (IHSDM) is a set of computer software analysis tools used to evaluate the safety and operational effects of geometric design decisions. IHSDM evaluates a design and furnishes quantitative information on its predicted safety and operational performance (FHWA 2006). It differs from RSAs in that it provides quantitative output on safety performance based on the application of the software. It lacks the qualitative aspect of RSA and is focused on optimal design solutions rather than being focused exclusively on safety. IHSDM, therefore, is a complementary tool that can provide quantitative input to RSAs during the design phase of projects (FHWA 2006).

4.11.6 Safe System Assessment tool and Safe System Assessment Framework

The Safe System Assessment (SSA) tool considers and quantifies the degree of alignment of a design or concept with Safe System principles with the objective of minimising fatal and severe injury (Austroads, Guide to Road Safety Part 6: Managing Road Safety Audits 2019). The SSA is founded on the Safe System Assessment Framework (SSAF) that has a Safe System Matrix as its ‘engine room’. This ensures consistent consideration of major accident types and prompts an assessment of the three components of risk management as they apply to each accident type, namely accident severity, road user exposure and accident likelihood.

When SSAs are undertaken at the early planning and design stages, the need for a feasibility stage RSAs (and to a lesser degree preliminary design stage) is lessened. It is possible that an SSA can replace a feasibility or preliminary design RSA. If that is the case, the SSA should follow the key principles of undertaking RSAs including, utilising an independent and qualified team, providing a detailed brief, undertaking commencement and completion meetings, responding to the report findings and recommendations, and closing the loop. It is also important for the subsequent RSAs undertaken at the later stages in the project development and road network management cycle to refer to the earlier SSA findings. This is to ensure that the project has not been adjusted or contemporary design features have not been included to lessen alignment with Safe System principles.

4.12 Additional considerations for RSAs

4.12.1 Legal Liability Aspects in RSA

Many countries have a legal requirement for the road authority to ensure that new roads and schemes are subjected to safety reviews (African Development Bank (b) 2014).

Written and formal protocol or procedure to be produced by the road organisation for establishment of RSA within the design and construction process. This protocol/procedure can be based on this manual, though it should be adapted for local conditions wherever possible (African Development Bank (b) 2014).

The focus of asset owners should be on identifying the audit recommendations that are most likely to return high value and investing funds in the appropriate treatments. Budgetary constraints may not allow all recommendations to be treated, however this study has highlighted that with a targeted approach to addressing audit findings the reduction in road trauma can be maximised (Appleton 2002):

Responsibilities

- Endorsement
    - All audit reports shall be endorsed by the road safety audit team leader, prior to submission.
- Distribution and audit registration
    - Project manager and team leaders shall arrange for the road safety audit corrective action report to be recorded on the relevant project file, electronically forwarded with a workflow action assigned to the project manager, regional manager or the delegated representative, and registered on the road safety audit tracking system.
    - Consultant or other agency project team leader consultants or other design team leaders shall arrange for the audit report (including the corrective action report) to be electronically forwarded to the project manager. The project manager shall arrange for the full audit report (including the corrective action report) to be recorded on the relevant file.
- Close out process.

The project manager, in consultation with the design manager or external project team leader shall complete the corrective action report and incorporate any changes into the project documentation.

Redress of project impacting actions shall be undertaken in time frames extending from immediate rectification completion to rectification within one calendar month, commensurate with the severity of the identified issue as defined by the priority risk rating listed in the corrective action report.

The project manager, regional manager or the delegated representative shall be responsible for the proposed actions and comments resulting from the corrective action.

- Court Appearances

The Audit Team Leader is responsible for the findings and recommendations of the Audit Report. There may be instances where the Project Manager is requested to appear in court via:

- Subpoena
- Summons; or
- Contact

to be a witness by:

- Police Officer (prosecuting or Coroner's Court);
- Counsel Assisting (Coroner's Court);
- Departmental Legal team; or
- Lawyer acting for party to or interest in an action.

4.12.2 Policy development

The development of Road Safety Audit policies should link with other Road Safety Strategies / Action Plans that may exist (Appleton 2002).

Responsibility should rest with the relevant authority for safety which must be supported at the highest political level (African Development Bank (b) 2014). The success of road safety audit depends on a strong commitment to the process from leaders and decision-makers in road authorities. It must be part of corporate policy, integrated within quality management systems and include set procedures for dealing with audit findings (Appleton 2002).

Karndacharuk and Hiller (2018) state that with the 'Vision Zero' objectives that focus on the long-term elimination of deaths and serious injuries, the audit of road transport projects are conducted to ensure the safe planning, design, operation and use of the road network is a product of an institute (or authority) with a Safe System result focus.

To align with the RSM system, the key objectives of an effective intervention (World Road Association 2015) for the RSA practice and policy development can be outlined as follows (Karndacharuk and Hiller, 2018):

• Shifting of focus from crash prevention to death and serious injury prevention.

• Placing an emphasis on the implementation of evidence-based approaches to:

  - Reduce exposure to the FSI risk.
  - Prevent FSI; Mitigate the severity of injury when a crash occurs.
  - Reduce the consequence of injury.

The policy framework for RSA with effective institutional management contributes to the ultimate goal of a Safe System where road users are no longer exposed to death or serious injury on the road network (Karndacharuk and Hiller, 2018).

4.12.3 Training and experience

4.12.3.1 Training

Education and training of the auditors is the weakest point in the entire RSA chain and this reason include the brief history of RSA, non-understanding of RSA methodology and procedures and lack of RSA literature in the Russian language. Therefore, the team of safety engineering specialists (Ross et al., 2016).

Road safety engineering practitioners must be trained in the road safety audit process, and a register of qualified auditors established. Qualifications must include relevant technical expertise, training, experience, and currency in road safety audit practice (Appleton 2002).

Road Safety Auditors should be registered, and the registers should identify senior auditors, based on the requirements previously established. The Summit did not support the development of competency-based standards currently (Appleton 2002).

Road safety audit registers identify individuals that have been accredited, and not organisations that they represent Road Safety Auditors should be registered and that the actual arrangements for each register can be managed within each authority. The register should reflect the auditor's accreditation as an auditor, based on the core requirements established at the 1997 Summit, and jurisdictions were encouraged to implement systems to maintain an accurate register of auditors, Similarly, the registers should identify senior auditors, based on the requirements previously established (Appleton 2002).

Minimum core components of training were still appropriate, and that each authority is complying with the requirements. The purpose of the training courses are awareness of the road safety audit process, and that the courses are only part of the overall accreditation process (Appleton 2002).

4.12.3.2 Auditor Accreditation

To ensure only qualified audit teams assess road projects, Austroads developed a set of criteria to become a registered auditor (Deng 2012). To become and remain accredited, auditors are required to:

- Have a minimum of five years of relevant experience in road design, traffic engineering, road safety engineering, or other closely related road safety discipline.
- Successfully complete a road safety audit training course approved and recognised by a road authority.
- Participate in at least five road safety audits under the guidance and leadership of a senior auditor, of which at least three must be design stage audits and one a pre-opening or existing road audit: and
- Participate in at least one audit per year to maintain practice and experience.

To become registered, a road safety auditor must satisfy the first two criteria. After participating in five audits (the third criterion), an auditor can become a senior road safety auditor. The final criterion is a requirement for all registered auditors to maintain accreditation (Deng 2012).
International road safety engineering practitioners will assist with dissemination of information on the safety audit process and findings, and to promote the value of this in road safety management (Appleton 2002).

5 NETWORK LEVEL ASSESSMENTS AND ROAD SAFETY INVESTIGATIONS

5.1 Introduction

Road safety and traffic engineering initiatives aim to improve roadway safety performance by minimising the number fatal accidents and serious injuries that occur on a road network by designing and maintaining road environments that considers all road users (Federal Highway Administration 2019).

Chapter 3 of this review highlights that the safety of the roadway is measured in terms of the number and severity of accidents that occur on the road. This indicator provides an idea of the safety performance of the road. To measure this safety performance there is a need for quality road traffic and accident data.

Chapter 3 further emphasises that safety considerations are needed during the planning, design as well as during the construction, maintenance, and operation of roads. Roadway safety performance can therefore, depending on the phase/stage, be measured throughout the lifecycle of the road. Summary table 5-1 provides an overview of the road safety review related to the various stages of a road project or to road safety management efforts on road network elements previously discussed in this review.

Table 5-1: Summary of road safety reviews in relation to the operational phase of the road as discussed in this literature review

Assessment	Description
Road Safety Audit Review (Appraisal or Assessment)	A road safety audit review (RSAR) refers to the road safety audit process, as applied to an existing road (Jrew, 2002). RSAR is defined as "an evaluation of an existing roadway section by an independent team, focusing solely upon safety issues" (Jones 2013).
Network road safety/screening	Road network screening is part of the road network safety management process and defined as a process by which the road network is screened to identify potentially hazardous sites (Ambros et al., 2017).
RS Investigations	Road safety inspections (RSIs) comprises a routine, programmed and systematic field survey which is undertaken proactively on existing roads to identify risk factors and to achieve enhanced safety (African Development Bank (b) 2014). The RSI is compared to the RSA pre-opening phase of newly constructed roads (Volpracht et al., 2018).
RS inspections	RS inspections routinely considers the safety performance of roads already in operation.
Traffic Impact Assessment (TIA)	TIA may be regarded as a proactive approach to prevent the potential for new safety problems to develop and to consider measures as part of land development to improve road safety performance of the infrastructure on which the development impacts.

Indications are that previously, the road was considered safe if it adhered to design guidelines and standards (Hauer 1998). The FHWA (2019) state that many of the design standards, have in fact not been tested against safety performance of roadways and that a road can be designed and constructed to the best safety standards, with accidents still occurring on the road. It is therefore important to realise that traffic/ road safety engineering is but one of many strategies and interventions that is used to address road trauma. Road and traffic engineering is used within the context of the transport, traffic, and road safety management system.

The transport and traffic system consists of three elements namely the human, the vehicle, and the road (Ogden, 1994). These components are in constant interactions, if any one of these components (user/vehicle/road) fail in its interaction with each other (Reason et al., 2006), the system collapses resulting in traffic accidents leading to deaths and road traffic injuries (RTIs).

This chapter provides and overview of network screening and the subsequent investigations that follow to identify hazardous locations or high-risk sites that can be addressed by the implementation of remedial measures. Where RSAs are concerned with evaluating the safety performance of planned or existing roads, network screening, road safety inspections, road safety investigations and hazardous location identification entails a road safety review of existing roads that have been in operation for some time beyond the initial handover after construction. The RSA process is described as mostly qualitative in nature while network screening and investigation approaches make use of statistical models and risk indices to rank and prioritise roads in terms of safety. In addition, network screening and road safety inspections and investigations consider contributory factors to provide human centre designs that address road user behaviour and safety within the context of the road environment.

The Safe System frameworks recommend moving away from traditional black spot management, which focuses on the most critical but isolated parts of road network to ensure a proactive and systemic approach to safety management, with longer road segments including intersections (Ambros et al., 2018).

5.2 Overview of key concepts

5.2.1 Nominal and substantive safety

The FHWA (2011) states that nominal safety refers to whether a design (or design element) meets minimum design criteria based on national or state standards and guidance documents. If a roadway meets minimum design criteria, it can be characterised as nominally safe. Nominal safety does not characterise the actual or expected safety of a roadway (Austroads, 2019).

Substantive safety refers to the actual or expected safety on a roadway. Substantive safety is quantified in terms of:

- Crash frequency (number of crashes for a given road segment or intersection over a specified time).
- Crash rate (normalised to account for exposure);
- Crash type; and/or
- Crash severity (i.e., fatality, injury, or property damage only).

A roadway is characterised by its safety performance which is relative to an expected value for the facility type; this could include regional, state, or national averages, or some other measurement. Safety performance needs to be compared between roads that are similar in terms of design because the expected safety performance of the road is strongly related to its context (e.g., traffic volume, location, design type, terrain, etc.). If the roadway in question has a significantly higher incidence or severity of crashes than other roads of its kind, it may have a substantive safety problem. In addition, unusual crash patterns, such as more angle or night-time crashes than on other facilities with similar characteristics, may indicate a problem, such as insufficient signage or lighting (Federal Highway Administration 2019).

5.2.2 Contributory causes to accidents

The road and traffic system have three interactive components namely the human, vehicle, and the road environment.

To understand the causation of accidents, William Haddon proposed a matrix of the sequence of events and factors contributing to an accident before, during and after in relation to the human, environment, and the vehicle (Figure 5-1).

	HUMAN	VEHICLE	ENVIRONMENT
PRE-EVENT	AGE EXPERIENCE ALCOHOL DRUGS SPEED	DEFECTS BRAKES TIRES AVOIDANCE SYSTEMS	VISIBILITY PAVEMENT SIGNALS CONSTRUCTION
EVENT	BELTUSE HELMETUSE TOLERANCE	AIR BAG AUTOMATIC BELTS CRASH-WORTHINESS	GUARDRAILS MEDIANS BREAKAWAY POSTS
POST-EVENT	AGE PHYSICAL CONDITION	POST-CRASH FIRE FUEL LEAKS	EMS SYSTEM FIRST RESPONDER BYSTANDER CARE

Figure 5-1: Haddon Matrix

Human factors are considered the greatest contributor to accident causation (Ogden,1994; Haddon 1999).

5.2.3 Quality road and traffic data

Road and traffic data is used for several purposes. In terms of roadway safety, it is used to reduce risk. The data should be reliable and be good enough to extract intelligence from it and the data should inform at a strategic and tactical level (Kathmann 2016).

Quality road and traffic data assist in the setting of performance targets, identification of performance measures, the selecting of activities/remedial measures as well as in monitoring and evaluation efforts. Kathmann (2016) states that quality data is detailed (e.g., contributory factors) and spatially connected (precise locations) to be of strategic value. The data also needs to be referenceable and defendable which has implications for the processes that dictate the lifecycle management of the data. The data should be usable to develop and report on safety indicators, develop policy and inform strategy.

There should be an aspect of quality management in terms of how data is collected and analysed ensuring that the outputs facilitate the “on time” delivery of information and quality data is consistent and error free.

The FHWA (2019) provides the following criteria that for the collection of quality road and traffic data:

- Timeliness: Timeliness is a measure of how quickly an event is available within a data system. Available technologies allow automated crash data collection and processing of police crash reports; however, many agencies rely on traditional methods of data collection (i.e., paper reports) and data entry (i.e., manual entry).
- Accuracy: Accuracy is a measure of how reliable the data are, and if the data correctly represent an occurrence. Crash data are reported by various agencies and inconsistencies arise due to multiple data collectors, some error in judgment is likely to occur. In addition, the description of the accident and contributing factors are based on the reporting officer’s judgment.
- Completeness: Completeness is a measure of missing information, including missing variables on the individual crash forms, as well as underreporting of crashes.
- Uniformity: Uniformity is a measure of how consistent information is coded in the data system, and/or how well it meets accepted data standards.
- Integration: Data integration is a measure of how well various systems are connected or linked.
- Accessibility: Accessibility is a measure of how easy it is to retrieve and manipulate data in a system, by those entities that are not the data system owner. Successful integration of safety throughout the transportation project development process (planning, design, construction, operations, and maintenance) and meaningful implementation of safety improvements demands complete, accurate, and timely data be made available.
- Liability: Liability associated with data collection and data analysis is an issue of concern as there could be legal implications related to the collection, analyses or reporting of the data.

5.3 Requirements for improving road network safety.

5.3.1 Evidence based planning.

Science-based road safety management is data-driven or evidence-based (Wegman, Bergblain, Cameron, Thompson, Siegrist, Weijermarse, 2015). This approach to road safety emphasises the effect that data analysis thereof has on safety, rather than adherence to standards based on personal experience, beliefs, and intuition. The safety metrics (e.g., fatalities and serious injuries) of a roadway are compared to roadways with similar characteristics to evaluate its safety performance. The goal of the evidence-based approach is to understand and quantify the expected consequences and outcomes of our actions (e.g., changes in the expected number of crashes/injuries/fatalities); the resulting calculations become the experience or evidence on which future decisions are made (Wegman et al., 2015).

5.3.2 Towards result focus

The RTSMS described earlier in this review, reiterates that the goal of a safe system is the elimination of fatal accidents as well as serious injuries. The focus is thus on this result and since the goal is to reduce the number and severity of accidents, there is a need to set goals to which to work towards, the implementation of interventions or remedial measures to address the objectives as well as the need for safety performance measures against which progress can be monitored and evaluated.

5.3.3 Data requirements and safety performance measures

To quantify the safety performance of the road, authorities make use of statistical models and indexes (Gotts 2004). Quality data is a prerequisite for preparation of these statistical models and risk indexes. Due to several reasons' quality road traffic and accident data are unfortunately not always available.

5.3.4 Performance measures

Performance measures communicate the priorities, results, and value of road safety programs and activities. Performance measures are used to connect goals to actions, allocate resources, and to monitor and evaluate progress (Bliss and Breen, 2009). Performance measures also determine the effectiveness of safety policies and countermeasures and how changes in the system may affect performance (Federal Highway Administration 2019).

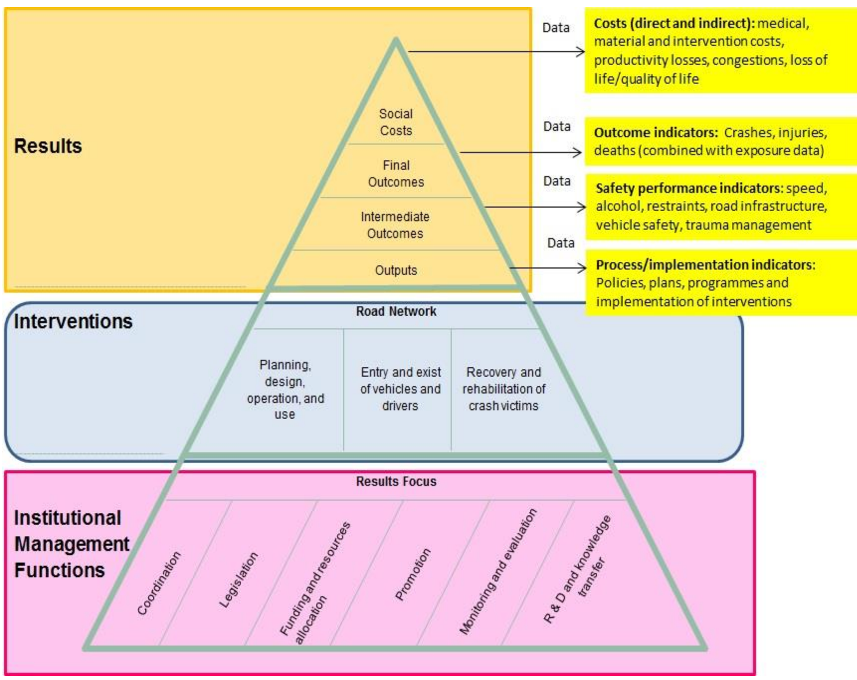

Figure 5-2: RTSMS – ISO 39001

Within the Safe System, and the RTSMS (Figure 5-2) output performance measures identify the progress in utilising resources, such as the total number of projects, total funding, and related output measures (e.g., the number of traffic signals installed, the number of intersections with improved pavement markings, etc.). Outcome performance measures are focused on the intended results of the program. General statistics (e.g., the number of crashes and crash rates), trend analysis, and benefit/cost analysis are used to measure performance outcomes (Bliss and Breen, 2012).

5.4 Safety performance measures to assess roadway safety.

5.4.1 Overview

The concept of Safety Performance Indicators (SPIs) was developed by the European Transport Safety Council (ETSC). The reason for the SPIs development was the assumption that accidents and injuries are only the beginning because they occur as the 'worst case' result of unsafe operational conditions in the road traffic system (Shah 2018).

Previously, road safety outcome (discussed in section 5.2.2) was related with and calculated using the different exposure variables, but handling the multiple variables remained a problem. It is necessary to evaluate the risk and its relationship with the road safety performance indicators (Shah 2018). A variety of performance measures can be used to evaluate the potential to reduce the frequency and severity of accidents at a site. Factors that contribute to accident occurrence include driver behaviour, traffic and geometric characteristics, weather conditions and interrelationships between these varied factors (Ahmed, Huang, Abdel-Atya, and Guevara, 2011).

The type of safety study that can be conducted vary according to the quantity and quality of the data used. Safety analysis can however be conducted with little data (Ambros et al., 2018). Quantitative data used for safety analysis include accident data, traffic volumes, and roadway characteristics while qualitative or anecdotal information from stakeholders also is used in safety analysis (Ambros et al., 2018). Researchers have calculated exposure according to the availability of data; some have used passenger kilometres travelled, population, number of registered vehicles, etc (Shah et al., 2018; Yannis et al., 2018)

SPIs are defined as measures that are causally related to accidents or injuries and are used in addition to the figures about accidents or injuries, to indicate safety performance or understand the processes that lead to accidents. Road network screening employs safety performance functions (SPFs), also known as accident prediction models, and Empirical Bayesian (EB) approach. These SPFs assist in the d of a list which enables the road authority to rank the locations based on their potential for safety improvement (Archer, 2005; Ambros et al., 2017). The ranking of sites is important to enable officials to pay more attention to those sites with high accident risk and can be ranked by the probability that a site is the worst or by posterior distribution of ranks (Tanaru, 2002).

5.4.2 Safety Performance Functions

A Safety Performance Function (SPF) is an equation used to predict the average number of accidents per year at a location as a function of exposure and can include roadway or intersection characteristics (e.g., number of lanes, traffic control, median type, etc.).

It has become a standard to develop SPFs for separate entities, typically intersections and road segments (Ambros J. Sedoník 2018). SPFs are considered a critical component of the Empirical Bayes method, which combines the accident history for a given site or road segment with the predicted accidents from an SPF. In addition, the SPF helps to account for changes in traffic volume over time (Federal Highway Administration 2016).

5.4.3 Application

Safety Performance functions are used in the following:

- **Network screening** (Federal Highway Administration 2016): SPFs can be used in the network screening process to determine whether the observed safety performance at a given location is higher or lower than the average safety performance of other sites with similar roadway characteristics and exposure. This is useful in the safety management process to identify sites with potential for safety improvement.

- **Countermeasure Comparison** (Federal Highway Administration 2016): SPFs can be used to predict the baseline accident frequency for given site conditions when comparing potential countermeasures.
- **Project Evaluation** (Federal Highway Administration 2016): Safety effectiveness of roadway improvements are evaluated to provide input to future planning, policy, and programming decisions. The current practice is to employ the Empirical Bayes method in an observational before-after study to develop Crash Modification Factors (CMFs).

5.4.4 Description of safety performance measures

Depending on the source, safety performance measures are also referred to safety indicators and safety functions. The FHWA (2019) highlights that safety performance measures should be:

- Important, valid, and ensure the quantity measured impacts traffic safety.
- Sensitive to actual trends (a change in the measure will provide useful and meaningful traffic safety information).
- Measurable for many years.
- Accurate, reliable, and repeatable over time.
- Understandable and easily communicated to decision-makers and the public.
- Timely; and
- Cost reasonable for the value of information obtained.

When incorporating safety into system performance measures issues should be sensitive enough to assess changes in safety performance after strategies are implemented and it should be possible to collect and assess timely and accurate data relevant to the performance measures. Finally, the safety performance measures should be linked to evaluation criteria for assessing the relative benefits of one project or strategy over another.

Existing safety performance measures used globally include:

- **Exposure data:** AADT are normally available for all roads (from periodical traffic censuses) to develop SPFs. Use is also made of ADT (average daily traffic) as precise data may not be available to determine AADT. If AADT data are unavailable, ADT can be used to estimate AADT (AASHTO 2009). Data for analysing accidents at intersections specifically include total entering vehicles (TEV), and vehicle-miles travelled (VMT) on a roadway segment, which is a measure of segment length and traffic volume. Additional volume data, such as pedestrian crossing counts or turning movement volumes, may be necessary (AASHTO 2009)
- **Accident data:** Accident contributing factors are described in the Highway Safety Manual (2009) as "the result of a convergence of a series of events that are influenced by a number of contributing factors (time of day, driver attentiveness, speed, vehicle condition, road design etc). These contributing factors influence the sequence of events before, during and after an accident (Kathmann 2016). In terms of police reports, this information is not always available, or the quality of the information is questionable (Archer, 2005).

The predominant accident types that result in deaths and serious injuries (Austroads, Guide to Road Safety Part 6: Managing Road Safety Audits 2019) are:

- head-on (accidents that occur when one vehicle crosses onto the opposing side and impacts another vehicle, including head-on accidents at intersections)

- intersection (accidents at intersections including side-impacts involving vehicles from adjacent directions and turning vehicles)
- run-off-road (accidents that occur when a vehicle leaves the carriageway without impacting another vehicle, including run-off-road accidents at intersections)
- vulnerable road user (accidents involving pedestrians, cyclists, motorcyclists, the elderly, children, and people with special needs).
- Rear-end accidents are also a cause of severe injury.

Roadway characteristic data (AASHTO 2009; Federal Highway Administration 2018):

- **Roadway segment characteristics.** Characteristics of roadway segments include such items as roadway functional classification, number of lanes, length of medians or guardrail, and width and type of shoulder.
- **Intersection characteristics.** Typical intersection characteristics include traffic control and signal phasing (if appropriate), number and type of lanes at each approach, sight distance, skew angle, and number of approaches.
- **Roadway conditions include geometric and other elements:** These elements influence the capacity of a road and can affect a performance measure such as speed, but not the capacity or maximum flow rate of the facility.

The USA uses additional datasets namely Model Minimum Uniform Accident Criteria (MMUCC) and the Model Minimum Inventory of Roadway Elements (MMIRE) as input for accident analysis. Both MMUCC and MMIRE aims to provide transferability by standardising database information (AASHTO 2009):

- MMUCC (http://mmucc.ua) is a set of voluntary guidelines to assist states in collecting consistent accident data. The goal of the MMUCC is that with standardised integrated databases, there can be consistent accident data analysis and transferability (AASHTO 2009).
- MMIRE (http://www.mmire.org) provides guidance on what roadway inventory and traffic elements can be included in accident analysis and proposes standardised coding for those elements. As with MMUCC, the goal of MMIRE is to provide transferability by standardising database information (AASHTO 2009).

Roadway factors include the following:

- Number of lanes
- The type of facility and its development environment
- Lane widths
- Shoulder widths and lateral clearances
- Design speed
- Horizontal and vertical alignments, and
- Availability of exclusive turn lanes at intersections.

5.4.5 Example of safety performance use

The FHWA (2019) provide the following examples of performance measures used for various safety improvements:

- The number of fatal or serious injuries resulting from a particular crash type.
- The number of fatal or serious injury crashes occurring on a particular facility type.
- The number of intersections with improved pavement markings.
- The number of intersections with enhanced signal head visibility.
- The number of rural intersections upgraded with sight distance improvements.

- The number of rural intersections upgraded with access improvements.
- The number of medians installed or upgraded.
- Miles (kilometres) of median cable barriers installed.
- Miles (kilometres) of rumble strips or stripes installed.
- Miles (kilometres) with new or upgraded installation of raised pavement markers (RPM) to improve night-time visibility.
- The (kilometres) number of rural intersections with post mounted delineation signage upgrades; and
- The (kilometres) number of intersections with upgraded sign replacement.

The FHWA (2019) provide the following example to demonstrate how goals, objectives, and performance measures are used:

"A state selects a goal to reduce the number of motor vehicle fatalities by 20 percent by 2015. To reach this goal, one objective the state will aggressively pursue is to reduce fatal rural intersection crashes by 15 percent by 2012. As a result, the state designs a five-year program to increase visibility of roadway signs, signals, and markings. To assess progress and evaluate success of the rural intersection program the performance measures will include:

- The number of fatal rural intersection crashes each year.
- The number of fatal night-time rural intersection crashes each year.
- The number of angle-accident fatalities at rural intersections each year.
- The number of barrier reflectors upgraded in the entire district system over five years.
- The number of signpost/drive post delineators installed to 100 percent of all applicable signposts within one year;
- The number of dual stop and "stop ahead" signs installed in the entire district system within two years; and
- The number of flashing LED stop signs installed in the entire district system within two years".

5.5 Network screening

Improving road safety on the road network requires two steps of network screening and site diagnosis, which both require safety to be objectively quantified. In the screening phase, sites are identified and prioritised to maximise the efficiency of implemented countermeasures (Stipancic 2017).

5.5.1 Definition

A road network is made up of all the transportation facilities (freeways, highways, intersections, ramps, etc.) in a road's authority. A "network" refers to the collection of roads under the authority of a road agency (Federal Highway Administration 2013). The road authority has the task to examine the road network for sites (individual road segments, intersections, etc.) that demonstrate a need for improved safety (Gotts 2004).

A "Safety Network Screening" according to the FHWA (2013) is a process that is followed to review a transport network, to identify sites, based on the potential for reducing average accident frequency.

The Highway Safety Manual (2009) refers to the process of studying safety conditions on all the road network or a subset of the network (e.g., all collector roads or all stop-controlled intersections). The safety analysis is conducted using the same method at each location so that the results can be compared and prioritised (Federal Highway Administration 2013).

5.5.2 Network screening purpose

Network screening objectively considers crash history, roadway factors, and traffic characteristics that may contribute to future crashes and helps agencies identify and prioritise locations for potential safety investment. Network screening provides solid documentation and justification for prioritising
safety needs data.

The result of network screening is a ranked list of sites, with those sites at the top of the list representing the most ‘unsafe’ sites. Some or all of these sites are then flagged" for a more detailed investigation, sometimes called a detailed engineering study (DES). The aim of a DES is to suggest feasible accident-reduction countermeasures for the flagged sites (Gotts 2004). The overall effectiveness of the roadway safety management process relies on a robust method for identifying and ranking sites with major potential for safety improvements (Jamille 2017).

5.5.3 Network screening as part of the road safety management process

The roadway safety management process as outlined in the Highway Safety Manual (AASHTO, 2010) include the following steps (Figure 5-3):

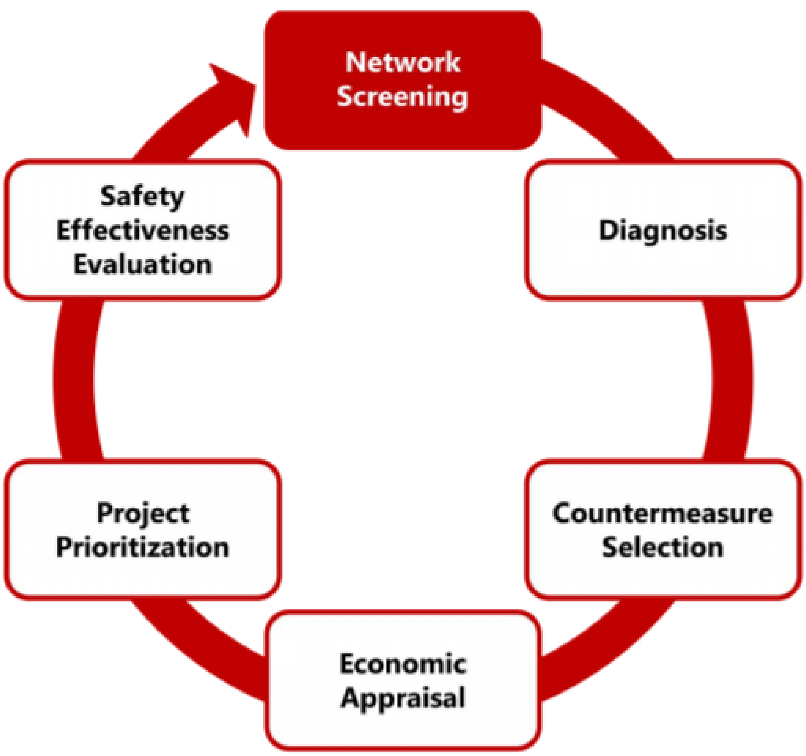

Figure 5-3: Schematic of Roadway Safety Management process

The FHWA recognised the need for state-of-the-art highway safety practices that makes use of a set of software tools designed to improve the safety management programs of highway agencies. Purpose of network screening

Networking screening is the first step in managing a safe road network. The information for the road network screening can be provided by authorities and stakeholders through a competent road safety specialist that works in cooperation with the lead road safety agency if it exists. It is recommended to carry out the screening in an independent and transparent manner to produce objective results (Tanaru, 2002).

Road network screening as part of the road network safety management process and is conducted to identify potentially hazardous sites or sections of road (Ambros Sedoník, Křivánková, 2017). The process of network screening is considered a low-cost statistical analysis of roadway safety data, which yields a ranked list of sites to be investigated in detail. The FHWA (2013) states that effective road network screening is enabled by the selection of appropriate performance measures as more reliable performance measures account for regression-to-the-mean differences in traffic volume, and accident severity.

5.5.4 Network screening process

The literature provides several methods of network screening and these methods are usually based on safety performance measures ranging from observed accident frequency to the most elaborated ones obtained from statistical modelling or composite indexes. To conduct road network screening, safety performance functions are required (Ambros J. Sedoník 2018). These methods differ in respect to the data requirements and modelling skills needed for their application and the limitations in considering the rare random nature of accidents (Xavier 2017).

Srinivasan, et al. (2016) state that one of the assessment approaches commonly used, is to identify road segments or intersections of interest and then divide these roadway components into groups with similar characteristics for a more detailed analysis. The results can then be collectively evaluated for corridor safety evaluations.

5.5.4.1 Determine focus and motivation for the screening.

The first step is used to define the problem and determine the reason for applying a network screening effort (Srinivasan, et al. 2016).

Sites that qualify for screening can be selected based on accident frequency and severity or sites with potential to benefit from a safety improvement involves a comprehensive review of a selected roadway network to identify locations with a potential safety problem.

5.5.4.2 Site selection

Secondly, the types of sites or facilities to needs to be screened are selected. The screening a network allows for the screening of many locations at once. Site selection can include road segments, corridors, and even entire networks. Analysts look beyond a particular location and concentrate on surrounding road segments for more efficient and effective countermeasure implementation. By establishing a reference population, the performance at a particular site is compared to the expected safety of the reference population, yielding a relative measure of comparison for determining sites with potential for improvement. Reference populations can be established based on several characteristics.

Intersections potentially may be grouped into reference populations based on:

- Traffic control (signalised, two-way or all-way stop control, yield control, roundabout);
- Number of approaches (three-leg, four-leg intersection);
- Cross-section (number of through and turning lanes);
- Functional classification (arterial, collector, local);
- Area type (urban, suburban, rural);

- Traffic volumes (million entering vehicles (MEV), peak hour volumes, or average daily traffic; including pedestrian, bicycle, trucks, bus volumes);
- Terrain (flat, rolling, or mountainous); and
- Turning movements.

Similarly, roadway segments may be grouped into reference populations based on:

- Area type (urban, suburban, rural);
- Number of lanes per direction;
- Functional classification (arterial, collector, local);
- Area type (urban, suburban, rural);
- Access density (driveway or intersection spacing);
- Traffic volumes (peak hour traffic, average annual daily traffic (AADT); including pedestrian, bicycle, trucks, bus volumes);
- Median type and/or width of median;
- Operating or posted speed; and
- Terrain (flat, rolling, or mountainous).

5.5.4.3 Select safety performance measures.

To perform the screening, there is a need to select the safety performance measures. Safety performance measures could include more traditional methods such as crash frequency and severity or more advanced methods, which involve more detailed analysis and produce more reliable outputs compared to the traditional methods.

5.5.4.4 Choose a screening method.

Three screening methods exist: sliding window, peak searching, and simple ranking methods. Each requires a differing range of analysis, from most to least complex, respectively. After calculating the performance measures for the reference populations, the agency looks for the most suitable method to compare the numerical results.

Simple Ranking: Simple ranking is the simplest of the three screening methods and may be applicable for roadway segments, nodes (intersections, at-grade rail crossings), or facilities. The sites are ranked based on the highest potential for safety improvement or the greatest value of the selected problem identification methodology. Sites with the highest calculated value are identified for further study.

Sliding Window: With the sliding window method, the value of the problem identification methodology selected is calculated for a specified segment length (e.g., 0.3 miles), and the segment is moved by a specified incremental distance (e.g., 0.1 miles) and calculated for the next segment across the entire segment. The window that demonstrates the most potential for safety improvement out of the entire roadway segment is identified based on the maximum value. When the window approaches a roadway segment boundary in the sliding window method, the segment length remains the same and the incremental distance is adjusted. If the study roadway segment is less than the specified segment length, the window length equals the entire segment length.

Peak Searching: Like the sliding window method, the peak-searching method subdivides the individual roadway segments into windows of similar length; however, the peak-searching method is slightly more meticulous.

Only simple ranking is applicable for screening discrete nodes, such as intersections. The method chosen is dependent on the reference population and the selected problem identification methodology. Table 5-2 provides a summary of when each method is applicable. The sliding window and peak-searching methods are only applicable for segment-based screening. Segment-based screening identifies locations within a roadway segment that show the most potential for safety improvement on a study road segment, not including intersections.

Table 5-2: Methods for screening

Problem Identification Method	Segments			Nodes	Facilities
	Simple Ranking	Sliding Window	Peak Searching	Simple Ranking	Simple Ranking
Average Crash Frequency	Yes	Yes	No	Yes	Yes
Crash Rate	Yes	Yes	No	Yes	Yes
Equivalent Property Damage Only (EPDO) Average Crash Frequency	Yes	Yes	No	Yes	Yes
Relative Severity Index (RSI)	Yes	Yes	No	Yes	No
Critical Crash Rate	Yes	Yes	No	Yes	Yes
Excess Predicted Average Crash Frequency Using Method of Moments	Yes	Yes	No	Yes	No
Level of Service of Safety	Yes	Yes	No	Yes	No
Excess Predicted Average Crash Frequency Using SPFs	Yes	Yes	No	Yes	No
Probability of Specific Crash Types Exceeding Threshold Proportion	Yes	Yes	No	Yes	No
Excess Proportion of Specific Crash Types	Yes	Yes	No	Yes	No
Expected Average Crash Frequency with EB Adjustment	Yes	Yes	Yes	Yes	No
EPDO Average Crash Frequency with EB Adjustment	Yes	Yes	Yes	Yes	No
Excess Expected Average Crash Frequency with EB Adjustment	Yes	Yes	Yes	Yes	No

5.5.4.5 Screen and evaluate results.

For screening and evaluation of results, use is made of the completed evaluation for all sites to compare, rank, and prioritise sites for potential improvements. To screen the network, the authority/agency ranks the intersections based on the probability of the target crash types (e.g., severe angle crashes) exceeding the threshold. Projects are prioritised based on:

- a decision process for countermeasure selection.
- develop safety projects; and
- prioritise project implementation.

5.5.5 Network screening methodologies

5.5.5.1 Highway safety manual

The Highway Safety Manual (HSM) provides a detailed method for estimating the mean accident frequency (considering total accidents, or specific types/severity) for a given period and according to traffic volumes, geometric and traffic control features (Xavier 2017). The estimates for each site namely a homogeneous road segment (urban/rural, divided/undivided, two-lane/multilane) or intersection (signalised/un-signalised), are based on a predictive method composed by:

- Safety Performance Functions (SPFs): regression models, able to estimate the mean accident frequency of a given road infrastructure type for a set of base conditions, based on data related to comparable sites.
- Accident Modification Factors (CMFs): representing the impact on safety of different road features (greater than 1 if the road attribute increases accident occurrence, and vice versa). The base accident frequency predicted by SPFs is multiplied by CMFs for accounting differences between base and site-specific conditions.
- Calibration Factor (Cx): This is a factor multiplied to the mean accident frequency predicted by the SPFs for considering both the differences between jurisdictions and the periods of SPF development and application.

5.5.5.2 World Bank Road Safety Screening and Appraisal Tool

The Road Safety Screening and Appraisal Tool (RSSAT) has recently been prepared by the World Bank's Transport Global Practice and the GRSF is a tool, project teams can use to evaluate road safety performance based on existing conditions and screen for safety improvement opportunities in road and roadside infrastructure (JOB 2020). It allows for estimations of fatality rates under scenarios with and without the project, as well as the associated economic costs.

RSSAT will be available to governments, development agencies and researchers in general through an interactive web platform. Use of the RSSAT is now required for all World Bank transport projects, and it is also recommended for other operations that can have road safety impacts, such as urban and agriculture projects. All new World Bank transport projects must:

Estimate the economic cost of road accidents on project roads using RSSAT and include these road accident costs in the economic analysis.

Achieve a RSSAT Project Safety Impact index of 1 or below for all its road segments before approval.

5.5.5.3 IRAP Star Rating System

The iRAP Star Rating and Investment Plan Implementation Support Guide provides help and guidance to road authority engineers, design consultants and others using the iRAP Star Rating and Investment Plan results to assess road user risk and improve the safety of road infrastructure for all users.

The Star Rating Scores (Figure 5-4) identify elevated risk locations and analyse and prioritise road safety countermeasure treatments for inclusion in routine maintenance, local safety schemes, planned road upgrades and rehabilitation projects. The implementation phase is shown on the right of the process diagram below. (iRAP 2017).

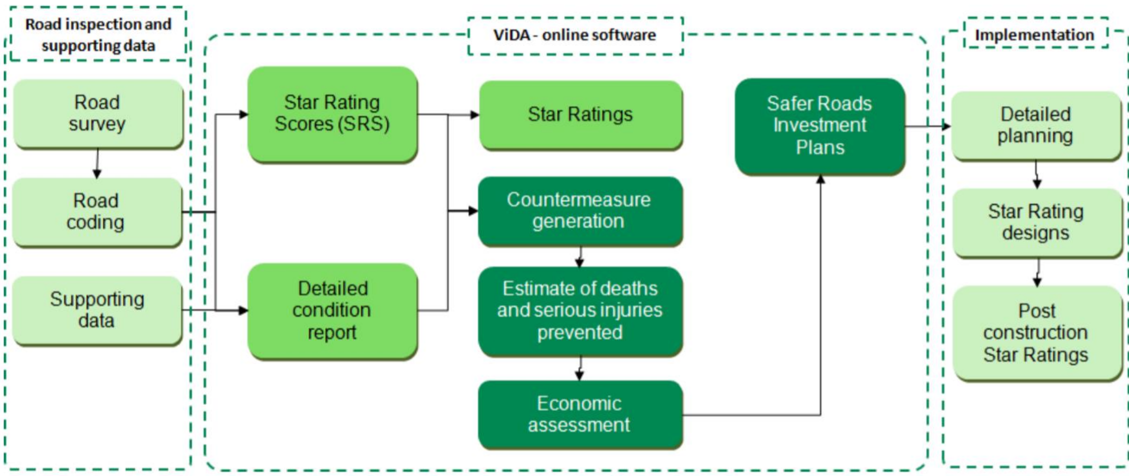

Figure 5-4: The iRAP Start Rating and Safer Roads Investment Plan process diagram (iRAP 2017)

The ideal, in a perfect world, would be for all roads to receive a 5-Star rating (i.e., the safest roads) for all groups of road users. Although there is an overwhelming financial case for investing in safer roads a 5-Star world for all people on all roads will remain as an aspiration for the future (iRAP 2017).High-volume roads can cost-effectively be raised to a 5-star level, 3-Star or better roads for all road users presents a realistic target for national and regional governments and road authorities to adopt. As part of an overall Safe System approach, iRAP believes that a 3-star or better world will help to meet the UN Strategic Development Goal 3.6 of halving road deaths and serious injuries by 2020 (iRAP 2017).

Infrastructure upgrades and speed management are the most effective ways to achieve 3-star or better roads for all road users. When investment is not readily available, or is restricted, dramatic improvements can be achieved by a mix of low-cost infrastructure options such as line markings and reductions in speed on the most hazardous sections of the road (Figure 5-5).

Star Rating	[Pedestrians]	[Cyclists]	[Motorcyclists]	[Car occupants]
★	No sidewalk, No safe crossing, 60 km/h traffic	No cyclepath, No safe crossings, poor road surface, 70 km/h traffic	No motorcycle lane, undivided road, trees close to road, winding alignment, 90 km/h traffic	Undivided road with narrow centerline, trees close to road, winding alignment, 100 km/h traffic
★★★	Sidewalk present, pedestrian refuge, street lighting, 50 km/h traffic	On-road cycle lane, good road surface, street lighting, 60 km/h traffic	On-road motorcycle lane, undivided road, good road surface, >5m to any roadside hazards, 90 km/h traffic	Wide centerline separating oncoming vehicles, >5m to any roadside hazards, 100 km/h traffic
★★★★★	Sidewalk present, signalized crossing with refuge, street lighting, 40 km/h	Off-road dedicated cycle facility, raised platform crossing of major roads, street lighting	Dedicated separated motorcycle lane, central hatching, no roadside hazards, straight alignment, 80 km/h traffic	Safety barrier separating oncoming vehicles and protecting roadside hazards, straight alignment, 100 km/h traffic

Figure 5-5: Star rating of roads - What makes a road safe?

5.5.5.4 iRAP Accident Risk Mapping

In regions where detailed accident data is available, iRAP partners produce color-coded Accident Risk Maps that represent the actual number of deaths and injuries on a road network screening.

Accident risk maps capture the combined risk arising from the interaction of road users, vehicles, and the road environment. The maps provide an at-a-glance objective view of where people are dying and where their accident risk is greatest.

Accident Risk maps are a powerful tool for road safety policy makers, professionals and advocates. Accident Risk Maps can help inform priorities across all pillars of road safety action (management, infrastructure, vehicles, road users and post-accident care). They include standard ways of expressing and benchmarking:

- accidents per kilometre or mile
- accidents per kilometre or mile travelled.
- accidents per road user group, accident type or other metrics
- accident costs per length or distance travelled.

5.5.5.5 USA network screening approaches

The US FHWA (2013) states that methods for the screening road networks include:

- Network screening with maintenance staff.
- Network screening with accident data – frequency, accident mapping, and equivalent property damage only
- Network screening with accident data and traffic volume data – accident rate
- Network screening utilising software; and
- Network screening with systemic analysis.

5.5.5.5.1 Network screening with maintenance personnel

The FHWA (2013) states that road maintenance staff can be taught to identify safety issues. This training, combined with their knowledge of the roadway network, qualifies maintenance staff as excellent sources of information on locating safety concerns.

Educating and relying on maintenance staff to identify safety issues is sometimes referred to as one component of developing a safety culture (another way to describe "developing a safety culture" is "to challenge employees to incorporate safety into their everyday activities regardless of their formal job function"). In fact, some agencies adopt formal policies on the frequency, type, and content of safety inspections (Federal Highway Administration 2013).

Local agency/authority implementation of road inspections can be informal and can include training staff on how to recognise safety issues, or as formal as an officially sanctioned process specifying inspection frequencies and methods to be followed as in the Aberdeen example. The training material needs to suffice as a good primer for a basic understanding of safety issues and would be valuable for informal inspection processes. Whether informal or formal, training staff on how to recognise safety issues is a low-cost method of empowering staff to improve traffic safety and can lead to early detection and correction of safety issues (Federal Highway Administration 2013).

5.5.5.5.2 Network Screening with Accident Data

5.5.5.5.2.1 Accident frequency

If accident data are available, accident frequency and accident mapping are methods that can be used for network screening. The accident frequency method is a basic network screening method. This method counts the number of accidents that have occurred at a given location (along a roadway section or at an intersection) over a specified time, typically three to five years. The results are ranked from highest to lowest accident frequency. Locations with higher accident frequency are selected as sites for detailed investigation. Some agencies further segregate accident frequency data by accident type or accident severity to identify locations with high accident severity or focus on a specific accident type – for example roadway departure accidents.

Accident frequency is an attractive quantitative screening technique because the only data required are accidents and their physical locations. In addition, data like traffic volume and roadway features are not necessary for using this technique, making it a quick assessment (Federal Highway Administration 2013).

The accident frequency method does not take traffic volumes into account. Because higher volume locations are likely to have more accidents than lower volume locations, this method has an intrinsic bias toward higher volume locations. Another drawback to this method is that it does not account for the natural variation in accident frequency that occurs at any given site. On an annual basis, the number of accidents at a site will fluctuate up and down. Over time, if nothing changed at the site (e.g., traffic volume, surrounding land use, weather, driver demographics), the frequency of accidents at the site would converge on an average accident frequency (Federal Highway Administration 2013).

This is called regression to the mean. Regression to the mean refers to the tendency for a site to experience a period with a comparatively high accident frequency followed by a period with comparatively low accident frequency. If regression to the mean is not accounted for, a site might be selected for study because the annual number of accidents that occurred was higher than "usual" due to a random fluctuation in the data. Conversely, a site that should be selected for study might be overlooked because an unusually small number of annual accidents occurred there. To reduce the influence of regression to the mean the agency should calculate the average of the most recent three to five years of accident data to determine the average accident frequencies. This minimises year-to-year fluctuations in data and is appropriate if site conditions (e.g., traffic volume, land use, driveway access, roadway configuration) have not changed. However, if site conditions have changed significantly during the analysis period, it may be more appropriate to monitor the site and evaluate safety after conditions have stabilised (Federal Highway Administration 2013).

5.5.5.5.2.2 Accident maps

This involves mapping the locations of accidents over a given time (usually three to five years). Each accident is represented by an icon or marker on a map detailing the type of accident that occurred. Locations with high accident densities are termed "dark spots" and can be visually identified on the map.

This method can be applied without the use of computer technology by simply using a paper map and push pins. It also can be done using the electronic mapping functions within geographic information systems (GIS) or mapping software. The resources listed at the end of this section describe each of these methods in more detail (Federal Highway Administration 2013).

The accident mapping method does not take traffic volumes into account so, like the accident frequency method, it tends to be biased toward higher volume locations.

5.5.5.5.2.3 Network Screening with Accident Data – Equivalent Property Damage Only (EPDO)

The equivalent property damage only (EPDO) method is documented in the Highway Safety Manual. In this method, weighting factors related to the societal costs of fatal, injury, and property damage-only accidents are assigned to accidents by severity (typically, at a given location over three to five years) to develop an equivalent property damage-only score that considers frequency and severity of accidents. The sites are ranked from high to low EPDO score. Those sites at the upper end of the list may be selected for investigation. To apply the EPDO method for ranking sites, it is necessary to know the number of accidents per year, and the severity of accidents per year. In this method, all injury accidents (incapacitating, non-incapacitating, minor injury) are grouped together (Federal Highway Administration 2013).

5.5.5.5.2.4 Network Screening with Accident Data and Traffic Volume Data

Accident rates describe the number of accidents in each period as compared to the traffic volume (or exposure) to accidents. Accident rates are calculated by dividing the total number of accidents at a given roadway section or intersection over a specified time (typically three to five years) by a measure of exposure. While traffic volume is the most typically used measure of exposure, others such as population, lane or roadway miles, and licensed drivers within a community also can be used. The locations are then ranked from high to low by accident rate (Federal Highway Administration 2013).

Accident rate screening can identify low volume, high accident risk locations that do not necessarily experience a high total number of accidents (Federal Highway Administration 2013). An accident rate is the number of accidents that occur at a given location during a specified time (usually three to five years) divided by a measure of exposure for the same period. Typical measures of exposure for intersections and roadway segments are identified below.

The following extract from the FHWA (2013) toolkit for improving road safety in tribal areas stipulates that exposure can be measured for:

Intersections – the measure of exposure is the total number of vehicles entering the intersection during the specified time – usually one year. The total number of vehicles entering the intersection is called Total Entering Vehicles (TEV). If intersection traffic counts are not available to calculate the TEV, average annual daily traffic (AADT) volumes on each approach roadway can be used instead. Because the number of vehicles entering an intersection throughout the year can be quite large, the TEV is usually expressed as Million Entering Vehicles (MEV). MEV is used as a scaling factor and is calculated by dividing the total number of vehicles per day per year by 1,000,000.

The equation for MEV is:

$$\text{MEV} = \frac{\textit{TEV per day} \times 365 \times \textit{number of years}}{1{,}000{,}000}$$

Segments – the measure of exposure is the total number of vehicles traveling on the road segment during the specified period. This is called vehicle miles of travel (VMT). VMT is usually expressed as Million Vehicle Miles (MVM).

The equation for MVM is:

$$\text{MVM} = \frac{\textit{AADT} \times \textit{segment length} \times 365 \times \textit{number of years}}{1{,}000{,}000}$$

Note: 1) AADT stands for Annual Average Daily Traffic.

Accident rates are then calculated by dividing the number of accidents by the measure of exposure. The equations are:

- Intersections (Accident Rates for *n* years):

$$\text{Intersection Crash Rate} = \frac{\text{Number of Crashes in the } n \text{ Year Period}}{\text{MEV for the } n \text{ Year Period}}$$

- Segments (Accident Rates for *n* years):

$$\text{Segment Crash Rate} = \frac{\text{Number of Crashes in the } n \text{ Year Period}}{\text{MVM for the } n \text{ Year Period}}$$

*Note: To calculate accident rate for multiple number of years, the number of accidents and the measure of exposure should be over the same number of years.

To compensate for short-term random fluctuations in annual accident numbers, it is recommended that three or five years of accident and exposure data be used to calculate accident rates.

If traffic volume data are not available, estimates can be made based on known traffic volumes on roads of similar functional class or use (Federal Highway Administration 2016).

5.5.5.5.3 usRAP

The U.S. Road Assessment Program (usRAP), sponsored by the AAA Foundation for Traffic Safety, systematically assesses risk to identify locations where fatal and severe injury accidents can be reduced. To do this, usRAP utilises a risk-mapping protocol to create maps that show variations in the level of accident risk across a road network. These maps can guide the prioritisation of highway infrastructure improvements and targeted enforcement strategies. usRAP also provides ***usRAP Tools*** which is software that can develop a recommended program of location-specific accident countermeasures for any road network based on benefit/cost analysis (see Step 5 for a description of benefit/cost analysis).

One strength of the ***usRAP Tools*** software is that it uses roadway and traffic control feature data to assess risk and does not require site-specific accident data. Roadway characteristics data do need to be collected and input into the software however, usually through a combination of video data collection and manual data input.

5.5.5.6 Australian network screening approaches

5.5.5.6.1 AusRAP and ANRAM

The HSM approach was targeted as a robust benchmark for detecting accident risk on the Australian network. Hence, local SPFs for fatal/severe injury accidents were developed. In addition, local and international CMFs can be considered, if relevant. At the same time, the existing AusRAP risk algorithms were assessed as valuable methods for identifying accident risk and then applicable as well. These algorithms put together several previously developed CMFs for different road attributes, by allowing their application to any road location.

The AusRAP approach is based on the combination of local CMFs related to three vehicle accident types (run-off-road; head-on; intersection-related). AusRAP refers to these CMFs for each accident type as Star Rating Scores (SRSs), related to road infrastructure, speeds and traffic levels. Summing up the partial accident type SRSs scores, the total SRS, a numerical value representing the relative severe accident likelihood for each 100 m road segment, is obtained.

A similar procedure is proposed in iRAP (http://www.irap.org/en/about-irap-3/methodology). The average SRSs values refer to the whole road section and then are divided by the Australian network-wide SRS averages for each accident and road type, to obtain a specific accident-type weighting factor. This factor is equivalent to a HSM CMF for an individual road section given its features, speeds, and potential conflicts.

Therefore, even if the predictive method used in the ANRAM is based on SPFs and the use of CMFs in the ANRAM approach differs from the HSM method.

The ANRAM model, as the HSM procedure, is used to model future benefits of road safety programs, by estimating accident reductions, and Benefit Cost Ratios (BCRs) at various levels (Xavier 2017).

5.5.5.6.2 Australia National Risk Assessment Model (ANRAM)

The Australian National Risk Assessment Model (ANRAM) provides a system to implement a nationally consistent risk-based road assessment program, to identify road sections with the highest risk of severe accidents (Figure 5-6: ANRAM Structure).

ANRAM is a nationally agreed approach that has built on existing Australian and international risk-based road safety programs such as AusRAP, NetRisk, iRAP and KiwiRAP, to create a system directly relevant and applicable for Australian state and local road agencies. ANRAM v1 was developed by ARRB, funded by Austroads and guided by Australian road agencies.

ANRAM supports a Safe System approach by focusing on the risk of fatal and severe injury (FSI) accidents. It uses a systematic and consistent methodology based on local and international research to identify, compare and priorities for severe accident risk (https://www.arrb.com.au/anram).

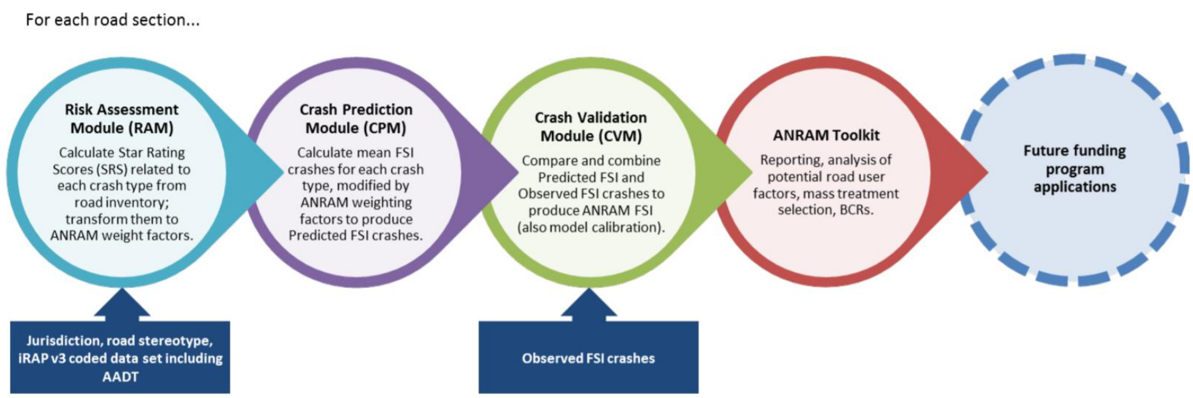

Figure 5-6: ANRAM Structure (Jurewicz, Steinmetz and Turner 2014)

The Risk Assessment Module is the first step in the estimation of severe accident risk. It accounts for the relative risk of diverse types of severe accidents because of road features, speed, and levels of potentially conflicting traffic. ANRAM adapted the iRAP v3 Beta 3 risk assessment algorithms, road attributes and risk factors relevant to vehicle and pedestrian severe accidents (Star Rating Score, or SRS). The iRAP algorithm structure (see Figure 5-7) has been modified for the purposes of ANRAM, but it is the same as for iRAP v3 (Beta 3) and can report matching results if required. (Jurewicz, Steinmetz and Turner 2014)

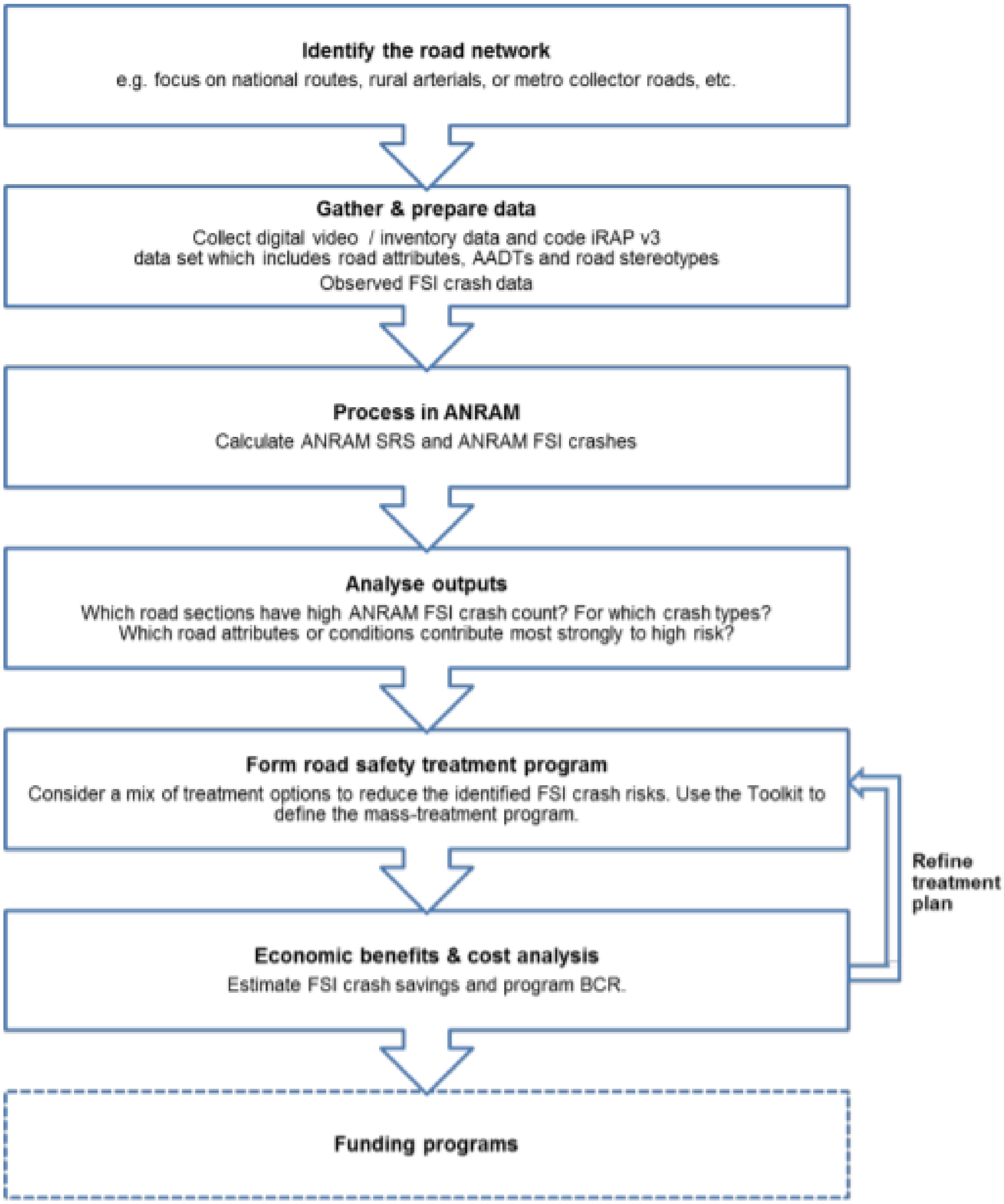

Figure 5-7: Application of ANRAM (Jurewicz, Steinmetz and Turner 2014)

5.5.5.6.3 Australia Road Safety Risk Manager

The Road Safety Risk Manager (RSRM) provides authorities with a tool to manage, prioritise and track the status of road safety issues on their road network screening. Figure 5-8 shows the initial screen of the RSRM. (Austroads, Guide to Road Safety Part 6A: Implementing Road Safety Audits 2019)

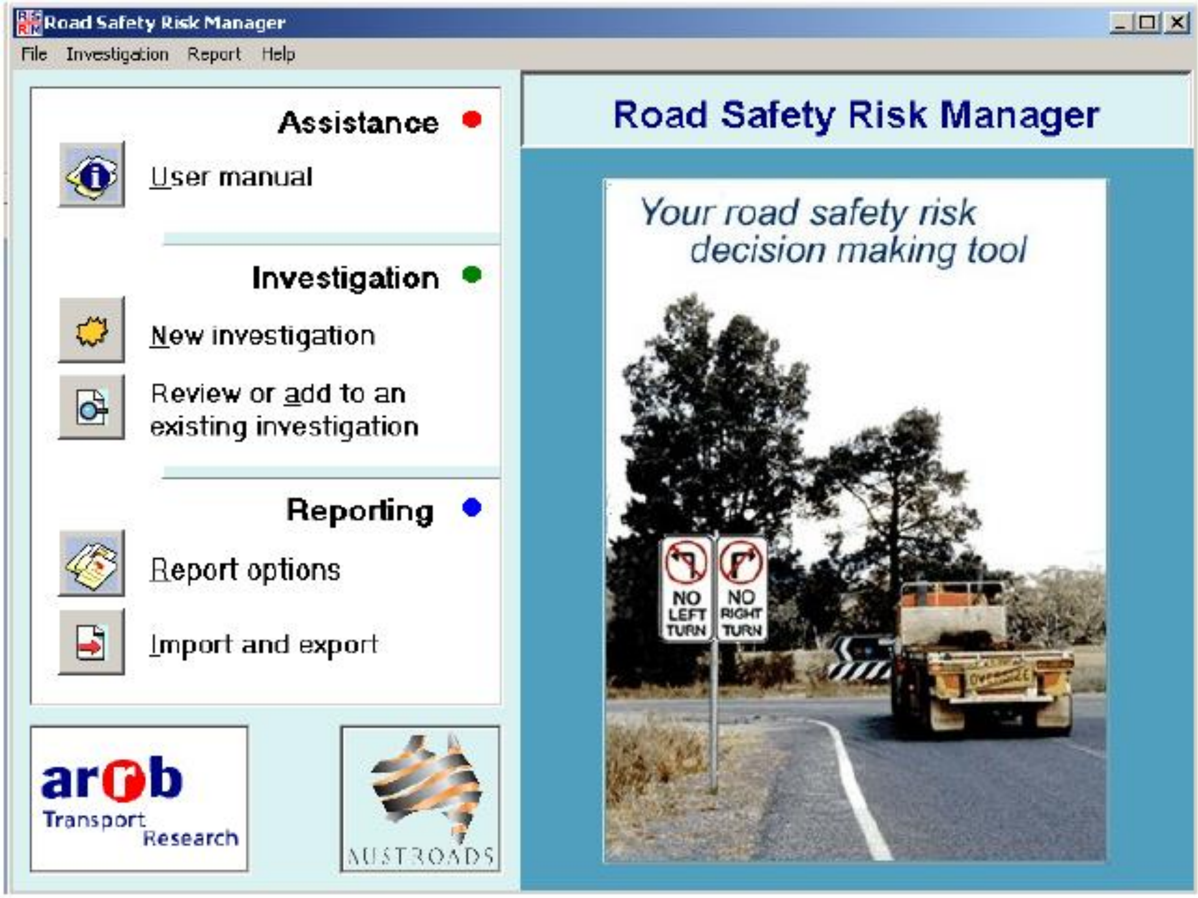

Figure 5-8: Road Safety Risk Manager software

The process allows an assessment of hazards for locations without a history of accidents or waiting for accidents to occur. The preferred treatments can be prioritised to develop a works program focussed on maximising the reduction in road trauma. (Austroads, Guide to Road Safety Part 6A: Implementing Road Safety Audits 2019)

The software allows the assessment and comparison of some 70 different road safety treatments including issues such as the duplication of a highway, intersection upgrades, guardrail and other roadside treatments, signage, and delineation. The flexibility of the tool also allows for the assessment of design options in addition to hazards in the existing road environment. (Austroads, Guide to Road Safety Part 6A: Implementing Road Safety Audits 2019)

RSRM is most relevant to the road safety audit process in the prioritisation of road safety audit issues requiring treatment. The tool allows the optimisation of accident risk reduction from these treatments based on limited available budgets. (Austroads, Guide to Road Safety Part 6A: Implementing Road Safety Audits 2019)

Further details can be found on the ARRB website (www.arrb.com.au), or in Part 7 of the Guide to Road Safety (Austroads 2006).

5.5.5.6.4 Australia Road Safety Engineering Toolkit

To assist road safety practitioners, identify solution options to road safety problems Austroads has developed a Road Safety Engineering Toolkit (Figure 5-9). It may be used by road safety auditors to identify safety deficiencies, and to also make recommendations when requested, as part of their audit report. The toolkit can be used to obtain information related to deficiencies commonly identified through the audit process. (Austroads, Guide to Road Safety Part 6A: Implementing Road Safety Audits 2019).

Treatments options can be selected by identifying either an accident problem (such as head-on or run-off-road accidents) or by selecting a specific road safety deficiency (such as pavement issues or deficiencies at signalised intersections). Information is provided for a few treatments on the situations where a treatment should or should not be used; the benefits of the treatment (including an indication of accident reduction); approximate costs and treatment life; alternative treatments to consider; and references for further information. (Austroads, Guide to Road Safety Part 6A: Implementing Road Safety Audits 2019).

The toolkit can be accessed at www.engtoolkit.com.au

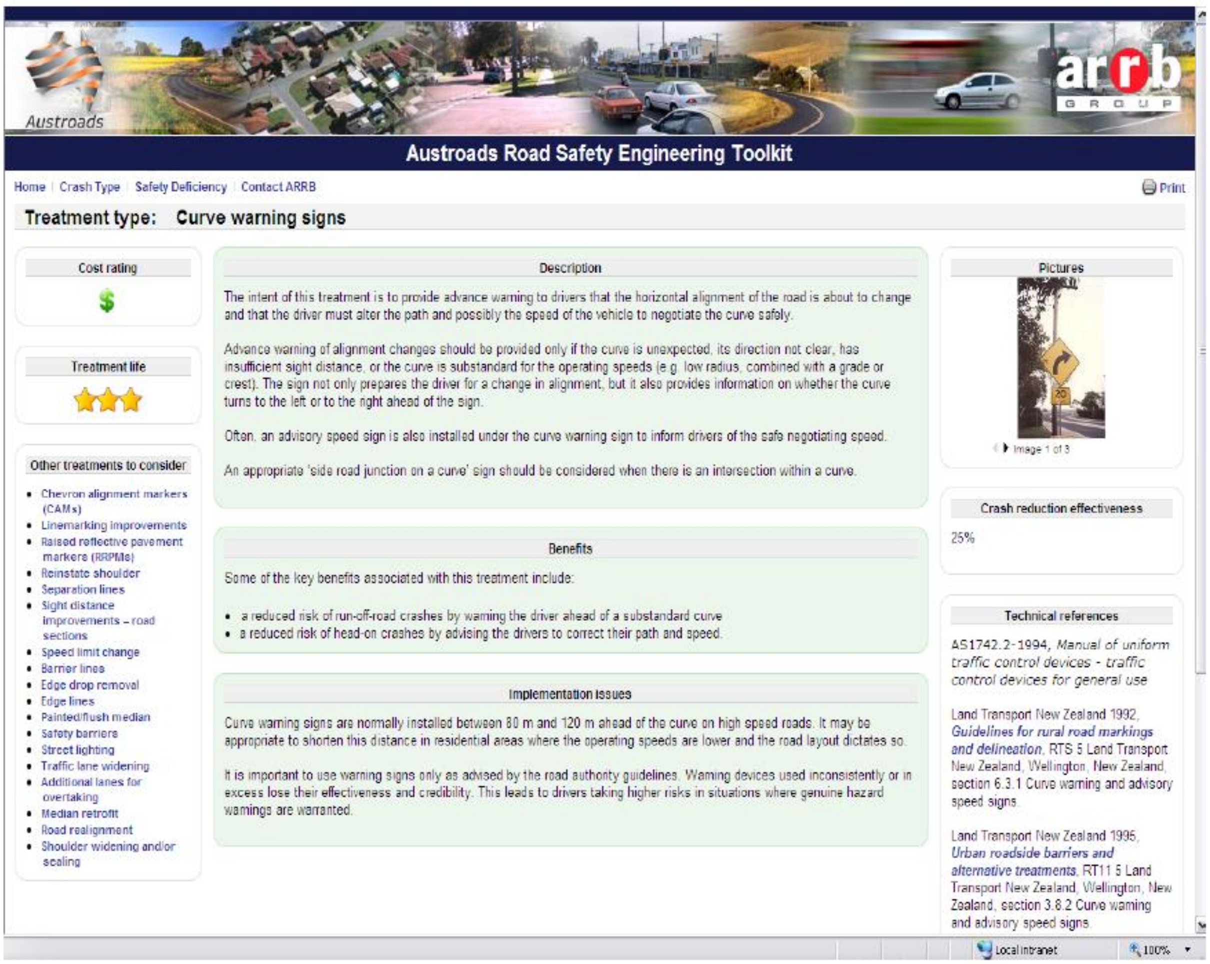

Figure 5-9: Road Safety Engineering Toolkit

5.5.5.7 Network Screening utilising software.

Several software tools are available for screening road networks. These typically require extensive road network data and considerable time to set up. However, these tools have advantages over "manual" or hand calculated methods, including:

- Once the software is set up, analyses can be completed and repeated easily.

- Inputs and outputs can be modified and the analysis re-run with little effort; and
- Complex data analysis can be completed in a short amount of time.

These software are data intensive and, in most cases not likely be to implement due to the start-up time and costs. However, if an agency does choose to invest the time and resources required to utilise these programs, the safety analysis benefits can be good (Federal Highway Administration 2013).

SafetyAnalyst provides highway safety practitioners with several tools, each representing a different “stage” of a safety management program (Gotts, 2002). The tools include (Fderal Highway Administration 2009):

- Network Screening Tool to identify sites that may have safety deficiencies: With reference to network screening, SafetyAnalyst assist users to identify potential sites for safety improvements. Algorithms will identify: This tool assist users in understanding the nature of problems at specific sites. It generates accident diagrams to identify the predominant accident patterns and assess whether these patterns represent higher-than-expected frequencies of accident types. The tool guide users through investigations to identify safety concerns at the specified location.
- Diagnosis Tool for site-specific diagnoses of safety problems. This tool will help users understand the nature of problems at specific sites. The tool generates accident diagrams to identify the predominant accident patterns and assess whether these patterns represent higher-than-expected frequencies of accident types and guide users through office and field investigations to identify safety concerns at the specified location. The diagnosis tool will help users consider both traditional engineering criteria and human factors needs. The result will be the identification of existing accident patterns and a list of safety concerns that could potentially be mitigated by countermeasures. The diagnosis tool also will include a basic accident diagramming capability and will be able to interface with select commercially available accident diagramming software packages, including accident diagramming software with interactive capabilities.

Additional software tools include:

- Countermeasures Selection Tool for identifying specific remedial projects for a given site.
- Economic Appraisal Tool for identifying cost-effective countermeasures at a given site.
- Priority Ranking Tool, which ranks those sites that have been selected for the application of specific countermeasures based on the cost/benefit analysis performed using the Economic Appraisal Tool.
- Evaluation Tool to evaluate the effectiveness of highway safety projects by employing before-after studies.

5.5.5.8 Proximal indicators (Surrogate data based on traffic conflicts)

Accidents are rare events therefore due to the limitations of accident data, using non-accident traffic events for road safety inferences can be beneficial (Anarkooli 2019). The concept of surrogate safety metrics is increasingly used to diagnose traffic safety problems and act before a serious accident happens. Surrogate safety metrics are based on identifying the occurrence and severity of traffic conflicts involving evasive actions such as braking or swerving, but not necessarily accidents (International Road Traffic and Data group, 2019)

The premise of using a non-accident event approach is that a relation exists between the frequency and severity of accidents and different events in traffic. The term safety surrogate measures (SSM) is used to refer to such non-accident traffic events to describe the relationship between two road users in a traffic event for the purpose of representing the accident frequency or severity in some meaningful ways (Anarkooli 2019).

Proximal indicators have the advantage of being more frequent than accidents, and therefore require shorter period of study to establish statistically stable values. Proximal indicators are adaptive to the specific characteristics and conditions of traffic locations or facilities, making them useful in before-and-after study designs, and other safety assessment strategies (Archer, 2005).

The most widely used SSMs considered in highway safety analysis are traffic conflicts. Since the process of development of traffic conflicts is like that for real accidents, they can be efficiently used to understand how accidents happen. Hydén suggests that traffic conflicts and accidents belong to the same process, but their severity is different (Figure 5-10).

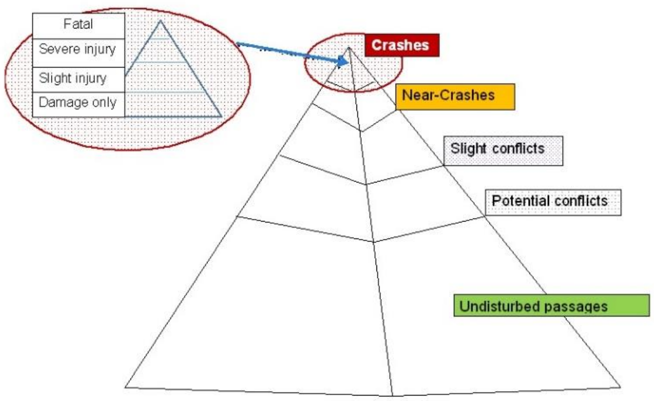

Figure 5-10: Hyden's triangle – Traffic accidents vs. Traffic conflicts.

Traffic conflicts can also vary in severity, which is not recognised in much of the previous SSM research, which has typically specified the severity of a conflict by a variety of indicators of its proximity to a potential accident in terms of time or space. These indicators are categorised into a Time-to-Collision (TTC) family, a Post-Encroachment Time (PET) family, a Deceleration family, and other (the few indicators that do not fall within those families).

The most prevalent indicators are the TTC and PET families. TTC is originally defined as" …the time that remains until an accident between two vehicles would have occurred if the accident course and speed difference are maintained". Other indicators in the TTC family that have been derived based on TTC, including Time Exposed TTC, Time-to-Zebra, Time-to-Line crossing (Anarkooli 2019).

A further variation of the TTC concept is PET, which measures situations in which two road-users are not on an accident course. PET is the time between the moment that the first road user passes a certain point, and the moment that the second road user reaches that point. At intersections, TTC family measures work best when applied to rear-end conflicts, while PET has been suggested as the best measure for investigating angle conflicts, including those resulting from left turn opposed and cross-path movements (Archer 2005).

Using artificial intelligence, substantial amounts of video footage and data points from road-side cameras and sensors can be analysed to identify close calls in which an accident was narrowly avoided. Street imagery can be used to support the assessment of the safety characteristics of roads. This already happens for the attribution of star ratings under road assessment programmes. The next generation of star-rating programmes will benefit from more frequent and broader collection of image data as well as automated image analysis from computer vision solutions. Drones and satellites can capture additional data and will play an increasing role for road safety. These innovations will facilitate the planning of road safety investments as well as the monitoring of result (International Road Traffic Information and Data group 2019).

A major drawback associated with proximal safety indicators concerns their validity, i.e., how well they represent '*safety*' as a theoretical concept. Archer (2005) states that this is measured by the strength of the relationship between safety indicators and traffic accidents and accident outcome severity, and how accurately an expected number of accidents (as an accepted measure of safety) can be predicted (Anarkooli 2019).

Validity is concerned about whether the events measured are representative of the same underlying processes that precede accident occurrence. Other questions concern the reliability of the various measurement techniques, their advantages and disadvantages and their usefulness from a practical perspective (Anarkooli 2019).

5.6 Road safety inspection

5.6.1 Definition and purpose

Road safety inspections (RSIs) comprises a routine, programmed and systematic field survey which is undertaken proactively on existing roads to identify risk factors and to achieve enhanced safety (African Development Bank (b) 2014). The RSI is compared to the RSA pre-opening phase of newly constructed roads (Volpracht et al., 2018).

Network screening (and/or road safety inspection) is just a starting point for further investigation. The next step is for the road authority to review locations identified as hazardous locations or as sites with safety performance improvement potential and identify/select appropriate countermeasures. For some locations on this list, a cost-effective solution may not exist.

5.6.2 Road safety inspection methodologies

The FHWA (2013) states that site selection is a qualitative process and rely on considerations like relative severity and frequency of accidents at the site, traffic volumes, stakeholder concerns, potential solutions. While not an exhaustive list at all, some reasons to select a site for more detailed analysis could be:

- The site is ranked high on a screening list when using quantitative screening criteria – e.g., accidents, accident rates.
- Funding program targeted at issues comparable to those expected at the site.
- There is an upcoming maintenance or construction project in the vicinity of the site where the safety improvement could be integrated into the project.
- Improving the site would be consistent with other agency plans, policies, or programs; or
- In sites where accidents have occurred, a sizeable proportion have resulted in fatalities or serious injuries.

The FHWA (2013) however acknowledge that due to time and resource constraints, it may not be possible to study all sites in depth.

Site selection should be documented by noting which sites were and were not selected with the motivations that informed the decisions (Federal Highway Administration 2013). Community members or stakeholders familiar with the safety issues can be provide additional input into the site selection process. If there is sufficient interest, a standing community traffic safety committee could be organised to provide input and advocate for traffic safety (Federal Highway Administration 2013).

The outcome of a network screening activity is either a list of high accident locations or an accident map. In an ideal situation, every identified site would be analysed in more detail (Federal Highway Administration 2013).

5.6.2.1 Site diagnosis - accident conditions

Once the site(s) have been selected for evaluation; accident data, traffic volume data, and roadway characteristics at the selected sites should be studied to identify the factors contributing to the accidents (Federal Highway Administration 2013).

Stakeholders also should be consulted to better understand their impressions of conditions and issues at the sites. This is referred to as site diagnosis. The availability of data influences the methods available for diagnosis. This step presents information about diagnosing site accident conditions both without and with accident data and identifying countermeasures for a site (Federal Highway Administration 2013).

5.6.2.1.1 Site diagnosis – without accident data

Accident data, accident patterns, past studies, and physical characteristics of the site(s) are studied to understand accident contributing factors and identify potential countermeasures to address them (Federal Highway Administration 2013). Accident contributing factors include driver behaviour, roadway or infrastructure characteristics that contribute to the occurrence of the accident. Examples provided by the FHWA include texting while driving, low roadway friction around a curve, sight distance constraints, or inadequate lighting. Countermeasures/treatments refer to strategies implemented to reduce a specify accident type or accident severity (Federal Highway Administration 2013). Options for conducting site diagnosis without accident data are:

- Utilise existing expertise.
- Conduct a road safety audit; and
- Apply the predictive method from the AASHTO Highway Safety Manual.

The FHWA (2013) further state that these methods can provide reasonable estimates of safety conditions; improved understanding of issues contributing to the safety conditions; and potential countermeasures to address them (Federal Highway Administration 2013).

5.6.2.1.2 Site diagnosis with accident data

Several tools/techniques are available to diagnose safety concerns when accident data are available.

The first suggests a review of accident report forms that provide detailed information about individual accidents at a site. The Haddon Matrix can help relate the series of events leading up to and following an accident (i.e., pre-accident, accident, and post-accident) to typical categories of contributing factors (i.e., human, roadway, and vehicle). This can be used to identify safety issues at a site and countermeasures:

- **Accident Report Forms.** Accident reports for a particular site can be studied and compared to determine if there are any common factors among the accidents. Sometimes the prevalence of a single accident type or common contributing factor or other recognisable patterns may become apparent. These patterns provide clues to identifying the underlying factors contributing to accidents at the location.

- **Haddon Matrix.** The Haddon Matrix is a tabular summary of site accident conditions designed to help practitioners understand accident contributing factors. A unique feature of the Haddon Matrix is the specific categories of summary information. The rows correspond to stages of the accident event (pre-accident, during the accident event and post-accident), and the columns correspond to categories of contributing factors (human error, vehicle/equipment, physical environment, and socioeconomic) involved in most accidents.
- **Contributing Factors or Causal Factors.** Most accidents cannot be related to a singular causal event. Instead, accidents are the result of a convergence of a series of events that are influenced by several contributing factors, including time of day, driver attentiveness, speed, vehicle condition, and road design. Contributing factors fall into three major categories: human, vehicle, and roadway.
- **Accident Diagrams and Conditions Diagrams.** Accident diagrams graphically illustrate accident data associated with a given site. Each accident is plotted on a schematic of the site at the approximate location where the accident occurred. Icons are used to represent accident types so that patterns are identifiable. Accident diagrams are sometimes cross referenced with a tabular listing of the associated accident data so that key information can be accessed easily.

5.6.3 Network Screening with Systemic Analysis.

A systemic safety approach works by identifying high-risk roadway characteristics/geometry, including curves, skewed intersection, or limited sight distance across the road network. Once these problematic roadway characteristics are known, locations with these characteristics can be identified, and countermeasures targeting them implemented so that accident risks are reduced across the road network (Federal Highway Administration 2013).

Systemic safety analysis is data based it is useful in situations where little data are available. Systemic safety analysis helps the practitioner link local roadway characteristics to expected accident types (this linking of roadway characteristics and accident types is done based on research done at the national level). Roadway characteristics data consist of road geometry details – such as curve radii, shoulder width, lane width, and super elevation – for the network under investigation and are required for the analysis. Typically, countermeasures identified through systemic analysis are low cost and can be readily implemented across the system (Federal Highway Administration 2013).

5.6.4 Systemic versus Spot Safety Analysis

Spot safety analysis is based on accident history at individual locations and results in identification of high accident locations. The systemic safety approach analyses accident history on an aggregate basis to identify roadways that have high-risk characteristics, and countermeasures to address these characteristics are identified. Plans are then developed to prioritise widespread implementation of countermeasures across the roadway network.

5.7 Identification of countermeasures

To identify countermeasures there is a need for an understanding of the factors that contribute to accidents at the site and link them to countermeasures designed to address the factors. Collaboration among road owners, stakeholders, and other safety partners in the countermeasure identification process can result in more comprehensive and effective multidisciplinary safety solutions and lessen the likelihood of “second guessing” after countermeasures are implemented (FHWA, 2006; Federal Highway Administration, 2013). Countermeasures can be identified by:

- Addressing a specific accident type of concern
- Considering conditions at a specific location; or
- Implementing known best practices.

Data to select remedial measures include:

- Accident modification factors (AMFs or CMFs) are applied to estimate the accidents that will take place even though the site has been treated. A **CMF** factor is used to compute the number of accidents expected after implementing a given countermeasure. The CMF is multiplied by the expected accident frequency without treatment. A CMF greater than 1.0 indicates an expected increase in accidents, while a value less than 1.0 indicates an expected reduction in accidents (Federal Highway Administration 2016).
- Accident reduction factors (ARFs or CRFs) or accident modification factors (AMFs) are used to predict safety benefits due to a reduction in the number of accidents (Gan 2005). This estimate is needed to perform an economic evaluation of a potential countermeasure.
- Countermeasures can be determined based only on the location characteristics of the accidents of concern. For example, common accident countermeasures have been determined for roadway features such as intersections and curves. This approach to selecting countermeasures is useful because it can provide guidance when little data are available. Using location characteristics to identify potential countermeasures is appropriate when limited data are available (Federal Highway Administration 2013).

"Best practices" are known to be widely applicable to many situations and to provide increased safety when installed properly. For example, if safety analysis shows that a particular site has experienced a series of road departure accidents, the agency may consider installing rumble strips or stripes which are known to reduce road departure accidents on two-lane roadways. Countermeasures can be applied to a specific location, multiple locations, or across the entire network depending on need, budget, and local priorities (Federal Highway Administration 2013)

Indirect safety measures have also been applied to measure and monitor a site or several sites. Also known as surrogate safety measures, indirect safety measures provide a surrogate methodology when accident frequencies are not available because the roadway or facility is not yet in service or has only been in service for a short time; or when accident frequencies are low or have not been collected; or when a roadway or facility has significant unique features (AASHTO 2009). The important added attraction of indirect safety measurements is that they may save having to wait for sufficient accidents to materialise before a problem is recognised and a remedy applied.

Past practices have mostly the following surrogate measures (in place of observed accident frequency):

- Surrogates based on events which are proximate to and usually precede the accident event. For example, at an intersection encroachment time, the time during which a turning vehicle infringes on the right of way of another vehicle may be used as a surrogate estimate.
- Surrogates that presume existence of a causal link to expected accident frequency. For example, proportion of occupants wearing seatbelts may be used as a surrogate for estimation of accident severities.
- Conflict studies are another indirect measurement of safety. In these studies, direct observation of a site is conducted to examine "near-accidents" as an indirect measure of

potential accident problems at a site. Because the HSM is focused on quantitative accident information, conflict studies are not included in the HSM.

The strength of indirect safety measures is that the data for analysis is more readily available. There is no need to wait for accidents to occur. The limitations of indirect safety measures include the often-unproven relationship between the surrogate events and accident estimation.

6 SOUTH AFRICAN ROAD SAFETY AUDIT AND NETWORK ASSESSMENT

6.1 Introduction

Transport, as a national function, is legislated and executed at the national, provincial, and local spheres of government. At a national level transport functions are executed through twelve national public entities, of which each has a specific mandate and legislation, enabling the implementation. The Department of Transport (DoT) is responsible for policy formulation, the creation of legislation and funding for transport related issues. The legislative framework for each government sphere consists of the acts passed by parliament and the national assembly and council of provinces as well as the acts passed by the provincial legislatures and those laws established by the municipal authorities.

In line with national legislation and policy frameworks, road authorities have a responsibility to provide effective and efficient transport which in turn is enabled by safe transport infrastructure. As such, the National Road Safety Strategy 2016-2030 make provision for activities that promote safer roads and infrastructure under Pillar 2 of the UNDoA, to which South Africa is a signatory.

An RSA considered worldwide as an effective tool to address design deficiencies at the onset of road projects, along with review of safety on existing roads is promoted as a tool to ensure the safe operation of future and existing road environments. Network screening, a routine line function of road authorities assist in the identification of hazardous sections and locations on the roadway that need remedial measures to address safety concerns. Although the benefits of RSA practices in South Africa have been promoted since the 1990's, the uptake thereof has been sporadic and inconsistent.

Chapter 6 provides an overview of South African legislation, policies and other best practices guidelines that support the uptake of RSAs and network screening practices in support of making the road network safer. In addition, the chapter considers RSAs and network screening practices, in the context of South Africa. Chapter 6 therefore highlights formal and informal approaches to RSAs and network screening and highlights selected research publications that in some form have addressed RSAs and network screening practices.

6.2 Role-players in the road safety audit and assessment

All three spheres of government have a key role to play in integrated land use and transport planning, coordination, implementation, and maintenance of an integrated transport system for South Africa (South African Government 2019). Integrated transport planning and implementation need a greater effort in coordination and collaboration within and between government structures. A coordinated approach is required to assist dysfunctional and nonperforming municipalities and Road Authorities to fulfil their mandates (Department of Transport, 2017).

Although the three spheres of Government and its agencies are autonomous, they are required to work together on decision-making, coordination of budgets, policies, activities, information sharing, and granting approvals, authorisation, exemption, license, or permission for the implementation of projects (Department of Transport 2015). The institutional relationships between the various Road Authorities play a significant role in the functioning of the road management environment. Although these roles and responsibilities are defined in the South African Constitution, the way in which road management works in practice is not always clear, the ownership is also not clearly defined and there are overlapping mandates (Department of Transport 2017).

6.2.1 National government

6.2.1.1 Department of Transport

The Department of Transport (DOT) is responsible for development of an efficient integrated transport system by creating a framework of sustainable policies and regulations and implementable models to support government strategies for economic, social, and international development (Pretoriaus 2014).

Considering the concurrent responsibilities as per the provisions in the Constitutional and the legislative mandates the DoT is held accountable for road infrastructure planning, maintenance, development and for the monitoring and evaluation of the socio-economic impact of road infrastructure projects to ensure that the roads are accessible and safe for all users (Department of Transport 2017). With regards to review of management and administration of agencies, the policy shall address the gaps, with regards, the responsibilities of the Department of Transport as per the requirements of the respective Acts (founding legislation of the various Agencies).

6.2.1.2 Road Traffic Management Corporation (RTMC Act 20 of 1999)

The Road Traffic Management Corporation (RTMC) was established in terms of Section 3 of the Road Traffic Management Corporation Act, No. 20 of 1999, for co-operative and coordinated strategic planning, regulation, facilitation, and law enforcement in respect of road traffic matters by the national, provincial, and local spheres of government.

The RTMC Act established the RTMC as a partnership between the three spheres of government to affect the pooling of road traffic powers and to promote road traffic management. The NRTA allocates various functions to the Shareholders Committee of the RTMC, which consists of the Minister, the nine Members of the Executive Council (MECs) responsible for road traffic and two representatives of the South African Local Government Association (SALGA). The RTMC has eleven functional units that include: road traffic law enforcement, training of traffic personnel, vehicle registration and licensing, road traffic information etc. According to the Draft South African Roads policy document (2018) the RTMC is also the custodians of road infrastructure assessments. As such the RTMC is responsible for providing guidance relating to audits on new road safety roads and road safety appraisals on existing roads. In future, modern designs will need to consider providing NMT infrastructure facilities on new roads and this will need to form part of the audit. Road safety appraisals on existing roads might highlight the need improve the road safety on the roads.

As such the RTMC is responsible for the coordination between the national, provincial and local spheres of government in the management of road traffic, to enhance the overall quality of road traffic management and service provision and, in particular, to ensure safety, security, order, discipline and mobility on the roads, to maximize the effectiveness of provincial and local government efforts, particularly in road traffic law enforcement, o create business opportunities, particularly for the previously disadvantaged sectors, to supplement public sector capacity, to guide and sustain the expansion of private sector investment in road traffic management (Department of Transport 2017).

One of the functional areas of responsibility allocated to the RTMC is that of “Infrastructure Safety Audits.” This corresponds with the SARSAM, and (by implication) therefore also sets the RTMC as the custodian of the SARSAM. SARSAM 2012 states that although the RTMC is in favour of the mandatory application of the principles of RSAs on all road projects in South Africa, it remains the prerogative of individual road authorities to embrace these principles and include them in the policies of that road authority. It is prudent to also point out that the non-acceptance of these guidelines may expose a road authority to increased risk of culpable liability. The SARSAM 2012 guidelines serve to set out the process with which a road authority should review the road environment conditions in establishing the possible foreseeability of hazardous conditions developing on a road and taking reasonable steps to guard against such conditions (Road Traffic Management Corporation 2018).

6.2.1.3 The Road Traffic Infringement Agency (RTIA)

The Road Traffic Infringement Agency (RTIA) was established by Section 3 of the Administrative Adjudication of Road Traffic Offences Act, 1998. The main objectives of RTIA are to11: o administer procedure to discourage traffic contraventions and support adjudication of infringements to enforce penalties imposed against persons contravening road traffic laws o encourage the payment of penalties imposed for infringements o undertake community education and awareness programmes (Department of Transport 2017).

6.2.1.4 The Cross-Border Road Transport Agency (CBRTA),

The Cross-Border Road Transport Agency (CBRTA), whose mandate is to regulate access to the market by the road transport freight and passenger industry in respect of cross-border road transport by issuing of permits, and to facilitate the unimpeded flow of passenger and freight movements by road across the borders of South Africa to contribute to the social and economic development initiatives as announced by Government.

6.2.1.5 South African National Roads Agency Limited and National Roads Act, Act 7 of 1998

In terms of the SANRAL Act the SA National Roads Agency (SANRAL) is responsible to plan, construct, maintain and finance national roads. In carrying out its functions SANRAL is obliged in terms of the Constitution to protect the safety of road users and other affected If SANRAL or any other road authority creates a situation that is harmful or potentially harmful, or allows such a situation to develop, for example potholes, it can be held liable for damages under the common law if persons are killed or injured, or there is damage to property.

SANRAL is the custodian and operator of the national road network and responsible for approximately 21 892 kilometres of roads that include the proclaimed national road network as well as toll and non-toll network. The SANRAL Mandate include (Ali 2016):

- Maintain, upgrade, operate, rehabilitate, and fund national roads.
- Levy tolls to service toll roads
- Advise the Minister on road related matters.
- Create public value.

In terms of the SANRAL strategic plan 2015 -2020, Strategic objective 2 entail the provision of safer roads. Ass such SANRAL has developed several policies and guidelines that specifically addresses road safety through improved understanding of road user behaviour, providing safer infrastructure as well as address post-accident care initiatives with the Road incident management system (Cable 2018). Stander et al indicated that SANRAL geometric design we rerevised in 2002 making use of international best practice were revised in 2002. The design philosophy which among others include includes (Stander 2015):

- To support road based public transport, geometric standards must be suitable for buses and minibus taxis.

- The network should achieve the lowest possible whole life costs.
- Geometric planning, which includes careful selection of the cross section, should be a strong element; - Classification of the various links of the road network, is essential.
- Complying with the needs of walking and cycling, especially in urban areas, is important.
- Achievement of a safe design, which implies catering for various design vehicles, but also human factors, is considered paramount. Sacrificing safety for whatever reason, is not viewed as acceptable practice.

In terms of RSAs, SANRAL published an RSA policy in February 2019 indicating that SANRAL adopts the SARSAM 2012 and that the policy provides additional RSA guidelines for road safety engineering practitioners working on SANRAL projects.

6.2.2 Provincial departments

Provincial routes in rural areas provide access to low density communities as well as tourism and heritage sites while major provincial routes link metropolitan, municipal or adjacent provinces (Joubert 2009). The provincial road authority is responsible for provincial roads in terms of provincial legislation (such e.g., Gauteng Transport Infrastructure Act 8 of 2001). The Provincial Infrastructure Act provide power to the MEC and regulates provincial road (and rail route) planning including the determination of routes and the acceptance of preliminary designs as well as the future management of land adjacent to the routes (Page 2009). Provincial authorities are responsible for (National Land Transport Act, 2009:28-29):

- the formulation of provincial transportation policy and strategy, within the framework of national policy and strategy.
- planning, co-ordination and facilitation of land transportation functions in the province and preparing the provincial land transportation framework.
- co-ordination between municipalities with a view to ensuring the effective and efficient execution of land transportation in the province and promoting provincial legislation with a view to promoting the objects of this NLTA.
- liaising with other government departments in the national and provincial spheres with responsibilities that impact on transportation and land use planning issues and bringing together key players.
- ensuring that municipalities that lack capacity and resources are capacitated to perform their land transportation functions.
- building capacity in municipalities to monitor the implementation of this Act.
- ensuring implementation of the provincial integrated development strategy and public transportation strategy, with due attention to rural areas, with the focus on less capacitated municipalities or those that do not fulfil their responsibilities in respect of transportation service delivery, either by direct implementation or assistance under paragraph
- performing the other provincial functions assigned to the MEC in terms of this Act.

The provincial authority is also responsible for monitoring local authority planning and implementation activities.

6.2.3 Local authorities

Local authorities are liable for municipal roads (Falkner 2012). Local authorities prepare a network Master Plan that shows the functional road classification of roads (functional classes 1 to 5 as defined by the Technical Recommendations for Highways (TRH) 26 (COTO, 2012). The National Land Transport Act (Act 5 of 2009) stipulates that the municipal sphere of government is responsible for, inter alia, developing land transport policy and strategy and promoting safety and security in public transport. In the broader sense, public transport should be seen to include the use of municipal roads by members of the public (Page 2009).

Local authorities are also responsible for the functions of transport law enforcement, network operations management and liaison, communication, and stakeholders. These functions are key to promoting road safety. The land transport act also makes provision for local authorities to develop and implement by-laws. As such, Local authorities are responsible for (National Land Transport Act, 2009:28-29):

- developing land transportation policy and strategy within its area based on national and provincial guidelines, which includes its vision for the area and incorporates spatial development policies on matters such as densification and infilling as well as development corridors.
- promulgating municipal by-laws and concluding agreements, as appropriate, in the municipal sphere.
- ensuring co-ordination between departments and agencies in the municipal sphere with responsibilities that impact on transportation and land use planning issues and bringing together the relevant officials.
- in its capacity as planning authority, preparing transportation plans for its area, ensuring the implementation thereof and monitoring its performance in achieving its goals and objectives.
- financial planning about land transportation within or affecting its area, with reference to transportation planning, infrastructure, operations, services, maintenance, monitoring and administration, with due focus on rehabilitation and maintenance of infrastructure.

6.3 Legal considerations

A road or local authority has statutory duties with respect to the planning, design, construction, operation, management, control, maintenance, and rehabilitation of roads that can also expose them to a civil lawsuit. A lawsuit is possible if an injured road user can show that a road authority has done something that a reasonable road authority would not have done or has failed to do something that a reasonable road authority would have done (Road Traffic Management Corporation 2012).

Road authorities in South Africa are subject to two pieces of legislation that govern conduct as far as potential exposure to liability is concerned. The primary legislation is the founding legislation for that authority, whether a provincial or local authority or for an Agency such as SANRAL or the RTMC. The governing legislation however makes the road authority responsible for the establishment and maintenance of road within that authority.

Road and local authorities can be subject to both criminal and civil law actions. Criminal cases against road authorities can be prosecuted like the prosecution that an individual can undergo (Road Traffic Management Corporation 2012).

Criminal Law is concerned with offences against public interests. Punishable criminal conduct is referred to as a “crime” or “an offence” and is prosecuted by the state in a public trial according to the CPA 51 of 1977. Civil cases are measured according to the law of delict. This law considers a wrongful action or an action in which the of negligence gives rise to a legal obligation between parties for which damages can be claimed as compensation for which redress is not dependent on a prior contractual undertaking to refrain from causing harm (Road Traffic Management Corporation 2012). The law of delict considers:

- Conduct - which may consist of either a commission (positive action) or an omission (the failure to take required action).
- Wrongfulness - the conduct complained of must be legally reprehensible. This is usually assessed with reference to the legal convictions of the community.
- Fault - once the wrongfulness of the conduct is established, it is necessary to establish whether it is blameworthy. However, in certain instances it is possible to find liability without fault, such as in cases of vicarious liability.
- Causation - the conduct that the claimant complains of must have caused damage; in this regard both factual causation and legal causation are assessed.
- Road infrastructure measures are therefore implemented within the realm of specific legal and frameworks:
- Guidelines and laws form the platform for acceptable Engineering Standards and Best Practices. Deviation from laws and guidelines are mostly not allowed except if there is a reasonable motivation that in most instances must address the safety aspect on the road. Road safety is important, and one cannot compromise this important safety aspect to save costs or due to a lack of capacity.

The legal framework is important as road authorities have a responsibility to ensure that remedial measures are safe and effective. Key questions to include when implementing remedial measures:

- Who is Liable if a person is injured / vehicle damaged because of a hazard in the roadway?
- Who is Liable if a road authority knows of an unsafe traffic situation and does nothing about it?
- Did the Engineer act reasonably? In other words, did the engineer tasked with implementation apply knowledge and skills with integrity and sincerity in the Interest of humanity, the environment, and the profession?

6.4 Legislation and regulatory context

6.4.1 Overview

Transport, as a national function, is legislated and executed at the national, provincial, and local spheres of government (South African Government 2019). At a national level transport functions are executed through twelve national public entities, of which each has a specific mandate and legislation, enabling the implementation. The Department of Transport (DoT) is responsible for policy formulation, the creation of legislation and funding for transport related issues. The legislative framework for each government sphere consists of the acts passed by parliament and the national assembly and council of provinces as well as the acts passed by the provincial legislatures and those laws established by the municipal authorities.

Act 108 of 1996 encompasses the Constitution of South Africa. The Constitution is regarded as the “highest” law in South Africa. Chapter 2 of the Constitution contains the Bill of Rights which stipulates (in Chapter 2.21) “that all citizens of South Africa have a right to freedom of movement”. Section 2(24) state that “all South Africans has a right to an environment that is not harmful to their health or wellbeing”. Chapter 3(40) stipulates that the Republic has three spheres of government, responsible for transparent and fair co-operative government and intergovernmental relations. The Constitution of the Republic of South Africa, 1996 stipulates that: “Everyone is equal before the law and has the right to equal protection and benefit of the law. Equality includes the full and equal enjoyment of all rights and freedoms. To promote the achievement of equality, legislative and other measures designed to protect or advance persons or categories of persons, disadvantaged by unfair discrimination may be taken."

Schedule 4 of the Constitution lists the areas of authority on which national and provincial government have concurrent competences, these include public transport (passengers), regional planning, development, and such public works that are relevant to the execution of provincial areas of competence. In addition, Chapter 9 makes provision for disabled people, highlighting that to not make provision for disabled people is discrimination and a violation of the Constitution. Chapter 3(40) stipulates that the Republic has three spheres of government, responsible for transparent and fair co-operative government and intergovernmental relations. Each sphere of government is responsible for establishing its own laws and policies for which the specific sphere is responsible.

6.4.2 National transport legislation

6.4.2.1 National Land Transport Act (Act 5 of 2009)

The governing legislation for transport in South Africa is the National Land Transport Act, Act 5 of 2009. The NLTA 2009 deals with land transport with a strong emphasis on public transport. The NLTA Amendment Bill of 2019 is currently under review by Parliament. The NLTA 2009 also delineates responsibilities between the different spheres of government and allocate land transport functions to the most competent and appropriate sphere of government.

The NLTA defines the responsibilities of each sphere of government as: National government is amongst others responsible for the formulation of national transport policy and playing a co-ordinating role between provinces to ensure the proper and effective execution of land transport functions between the different spheres of Government. Provincial government to formulate provincial transport policy within the framework of national policy; whilst Local government would similarly develop their land transport policies based on the national and provincial guidelines.

6.4.2.2 National Road Traffic Act (Act 93 of 1996)

The National Road Traffic Act (NRTA) Act 93 of 1996 serves to provide for road traffic matters, which shall apply uniformly throughout the Republic and for matters connected therewith. In general, this is a good and needs to be enforced. However, there are inadequate provisions (Department of Transport 2017).

6.4.2.3 Intergovernmental Relations Framework Act (Act 13 of 2005)

The Intergovernmental Relations Framework Act (Act 13 of 2005) provides a framework for the three spheres of Government and all organs of state to facilitate coordination in the implementation of policy and legislation, within the principle of cooperative governance set out in Chapter 3 of the Constitution. The Act makes provision for intergovernmental forums on National, Provincial and Municipal level. Regulation and control in context of service delivery, spending of budgets, potential job creation, stimulating the economy, etc., can be tedious, time consuming, costly, and counterproductive when addressing strategic planning and infrastructure development.

Intergovernmental relations encompass all the complex and interdependent relations among various spheres of government as well as the coordination of public policies among national, provincial, and local governments through policy alignment, reporting requirements, fiscal grants and transfers, the planning and budgetary process and informal knowledge sharing and communication among officials. Intergovernmental relations also refer to the fiscal and administrative processes by which spheres of government share revenues and other resources.

These overall objectives are to be achieved by an intergovernmental system that ensures mutual consultation on policy and legislation, resolving disputes, coordinated strategic planning, and accountability for performance and expenditure in terms of legislation.

6.4.2.4 Spatial Planning and Land Use Management Act (Act 16 of 2013)

The Spatial Planning and Land Use Management Act (SPLUMA), Act No. 16 of 2013 provides a framework for legislating land use and defines the interaction between various levels of government pertaining to land use. SPLUMA stipulates that national and provincial spatial development frameworks (SDFs) should be prepared to plan and provide for spatial development initiatives. At local authority level, municipalities are required to adopt a SDF as part of the local Integrated Development Plan (IDP). Integrated Transport plans (ITPs) form part of the spatial planning for transport at local level. Provincial legislation regulating land development, land use management, township establishment, spatial planning, subdivision of land, consolidation of land, the removal of restrictions and other matters related to provincial planning and municipal planning are listed as key factors to be considered through provincial legislation. Informal access to the national road network is prevented in terms of the SANRAL Act 78 of 1998, section 44.

6.4.2.5 The Infrastructure Development Act (Act 23 of 2014)

The Infrastructure Development Act provides for strategic infrastructure projects where every sphere and organ of government that the planning or implementation of infrastructure is in line with the strategic Infrastructure projects (SIPs) from the Presidential coordinating committee. Spatial and social infrastructure SIPs aim to improve spatial and social integration across specific district towns and regions.

6.4.2.6 Division of Revenue Act (Act 1 of 2018) and Provincial Road Maintenance Grant (PRMG).

In May 2012, the S'hamba Sonke Programme (SSP) was developed as a response to RISFSA recommendations regarding the backlog in roads maintenance, the deteriorating state of rural access roads, and the administration of the Provincial Road Maintenance Grant (PRMG).

The Division of Revenue Act in Transport Vote 35 (DoRA, 2017: pp. 173) refers to the fact that "*all Provinces will be expected to collect and provide information on the following:*

- road safety assessments, appraisals, and improvements.
- a representative sample of all roads to be assessed which is about 10 per cent of Provincial Road Network for field checking by an independent assessor as agreed by the Department of Transport (DoT) utilising the agreed rates to confirm the correctness of the assessment made.
- Provinces will be required to submit above data to the national data repository as per the format described in TMH18."

The need for independent road safety appraisals stems from the framework attached to the Provincial Roads Maintenance Grant (PRMG) as published in the Division of Revenue Bill, 2018 (National Treasury, 2018). One of the conditions included in the framework states that the framework must be read in conjunction with the practice note as agreed with National Treasury. Section 4 of the practice note referred to, includes a requirement for provinces to conduct road safety appraisals and improvements on existing road networks (DoT, 2018). In conjunction with this requirement, the framework attached to the PRMG requires provinces to submit an annual road safety audit report (National Treasury, 2018).

The DoT practice note states that "Provinces are required to: 4.3 Conduct Road Safety Appraisals and Improvements on Existing Road Network" (DoT, 2018). The definition of the road safety appraisal is like that of a road safety audit but include a review of historical evidence as well as contextual information. This allows for the introduction of road accident information and any other information that are relevant to the road safety improvement, to be combined with the pro-active approach in support of making the road safer. All road safety audits should be conducted in a way that addresses the needs of all road users. The audit process can be used on existing roads, streets, bicycle paths, etc. to identify potential safety problems for such a road user group or groups. The results may then be used as input into other road or traffic safety programs like Safe Routes to Schools or safety awareness programmes.

6.4.2.7 National Environmental Management Act (Act 107 of 1998)

The National Environmental Management Act (NEMA 107 of 1998) states that the legal definition of "environment" is the surroundings within which humans exist that are made up of:

- The land, water, and atmosphere of the earth.
- Micro-organisms, plant, and animal life.
- Any part of combination of the above and the interrelationships among and between them; and
- The physical, chemical, aesthetic, and cultural properties and conditions of the foregoing that influence human health and wellbeing.

National Environmental Management Act (NEMA) provides requirements for undertaking an assessment process to determine the impact that facilities will have on the environment.

6.4.3 National policies, strategies, and programmes

6.4.3.1 National Transport Master Plan (NATMAP)

The vision of the National Transport Master Plan (NATMAP) 2016 is:

"An integrated, smart and efficient transport system supporting a thriving economy that promotes sustainable economic growth, supports a healthier lifestyle, provides safe and accessible mobility options, socially includes all communities and preserves the environment."

The primary driver of the National Transport Master Plan (NATMAP) 2050, by the Department of Transport, is "to develop a dynamic long-term and sustainable land use multi-modal transportation systems framework for the development of infrastructure facilities, interchange terminal facilities and service delivery that is demand responsive to national / provincial/ district and /or any socio-economic growth strategies, and / or any sectorial integrated spatial development plans".

NATMAP defined several overarching objectives to support its strategic intent, including the following:

- Maximising utilisation of existing infrastructure facilities.
- Development of future infrastructure facilities and improve operations.
- Development of an up to date and accurate central land use / transportation data bank Geographic information system (GIS).
- Promoting effectiveness and efficiency of maritime transport.
- Integrating multi-modal public passenger transportation.
- Determining the economic role of transport; and
- Integration of transport and land use development.

6.4.3.2 National Development Plan and Sustainable Development Goals

The NLTSF supports the aims and priorities outlined in the NDP recognising its holistic view to encouraging sustainable development. The aim of sustainable development is to meet the needs of the present without compromising the ability of future generations to meet their own needs. The South African Government is committed to developing a sustainable future for the country. The NDP vision is that South Africa's transition to an environmentally sustainable, climate change resilient, low-carbon economy and just society will be well under way by 2030.

Transport policies contribute to a sustainable future by supporting a strong and prosperous economy and helping to promote safe healthy living. The impact of transport on the social, economic, and environmental fabric of our nation is fully recognised. A sustainability strategy should serve to provide a positive benefit to the communities not only in terms of job creation and poverty alleviation, but also in terms of ensuring safe, secure, and affordable access to the transport network. Sustainable development calls for an integrated approach, which considers the inter-relationship between transport, and the three key aspects of sustainability which are: the environment, the economy and society.

The Department of Transport is determined to secure positive change through planning for and ensuring cohesive interaction of social, economic, and environmental improvements, by addressing the following:

Committing at the United Nations Framework Convention on Climate Change (UNFCC) to reduce greenhouse gases by 34% from business as usual by 2020.

- Developing a Transport Sector Strategy on Climate Change and Environmental Protection
- Supporting green technology and clean fuels
- Developing an integrated public transport system
- Encourage a shift towards sustainable transport modes.
- Addressing congestion mitigation and improving air quality

Improvement of road safety have been included in the international agenda for sustainable development. However, despite the NSLTF (Department of Transport 2015, pp 41) referring to road safety as well as specific user groups (NMT, learner transport, public and freight transport) as problem areas, it has not been included in the sustainable development principles and strategies for South Africa. Lumped under transport safety and security the framework makes provision for addressing safety in design and network management for all road users with a specific focus on pedestrians and cyclists, vehicle standards, integrated and appropriate design in terms of both land use and user needs, the requirements of sustainable development, catering for human error, safety of all during construction (i.e., all road users and construction staff).

6.4.3.3 The White Paper on National Transport Policy of 1996 /Green paper on National Transport Policy 2017

The White Paper on National Transport Policy of 1996 stipulates how the management of the road environment and its users should take place within an overarching national policy, specifically focusing on roads infrastructure, road safety and NMT users. South Africa's roads network plays a key role in passenger transport, freight movement and economic growth in South Africa. While road transportation is an important industry in the country's national economy, various challenges inhibit the sector's contribution to South Africa's economic and social development objectives (Department of Transport 2017).

Goukamp (2019) states that the Roads Policy for South Africa is a review, update, and consolidation of the Road Infrastructure Strategic Framework for South Africa (RISFSA), the

National Road Safety Strategy (NRSS), and the Draft Non-Motorised Transport Policy of 2007 (Goukamp 2019). The Roads Policy promotes compliance with COTO technical policies and standards and charges all road authorities with the responsibility to maintain the integrity of the road. The objectives of the road policy is as follows (Goukamp 2019):

- Clear national directive on how to tackle road safety.
- Clear national directive on how improve the management of the road infrastructure.
- Determine financial options in the road infrastructure investments, road safety, law enforcement and enabling mechanisms to implement programmes and projects.
- Provide Policy certainty with clear and concise regulatory framework for roads.
- Ensure integration of plans for stream-lined and integrated service-delivery.
- Ensure integration of NMT as a recognised mode in the transport system.
- Maximise jobs creation and skills development.
- Ensure proper Monitoring, Evaluation & Reporting of transport programmes.

The strategic objectives to fulfil the policy are:

- To optimise current capacity and maintain and develop the road network.
- To improve road traffic safety, enhance road traffic discipline, protect the capital investment in the road system, and enhance administrative and economic order in the field of road traffic and transport.
- To optimise road transport law enforcement and promote and implement efficient, integrated, and coordinated road traffic management systems in the country, involving the role-players in all functional areas of road traffic management.
- To enhance the quality, productivity, and cost-effectiveness of road freight transport services by providing transport customers with a safe, secure, reliable, and cost competitive system.
- To advance human resource development and expand participation in the freight industry through the creation and growth of entrepreneurial opportunities, training, and skills development.
- To promote seamless integration and harmonisation of standards with neighbouring member states.
- To actively promote the movement of the appropriate type of freight from road to rail; and
- To encourage, promote and plan for the use of Non-Motorised Transport (NMT) where appropriate.

The policy acknowledges that the engineering discipline as a road traffic function involves transport and traffic engineering, operations management, and road vehicle engineering. The Government is cognisant of the need to apply sound engineering in the quest to improve traffic safety. The policy refers to the Safe System, the policy states that: “Traffic safety will be addressed in a balanced manner embracing the Engineering, Education, and Enforcement functions” (DoT, 2017 pp. 40). Furthermore, the policy states that only the highest design standards on South African roads will be maintained to ensure road safety. Traffic operations management will ensure road traffic quality and the orderly flow of traffic at acceptable levels of service. Road authorities will annually conduct a traffic quality audit of the road networks under their control, consisting of a systematic evaluation of all traffic quality and service level related aspects of the network.

With reference to RSAs, the policy states that development of safer road infrastructure for all users should be prioritised. In addition, that compulsory road safety audits will be undertaken and reviewed every five years in accordance with the policy intent of the Draft Non-Motorised Transport Policy.

6.4.3.4 National Land Transport Strategic Framework (NLTSF) of 2009

The National Land Transport Strategic Framework (NLTSF) is a legal requirement in terms of National Land Transport Act, 2009, NLTA, (Act, No.5 of 2009), section 34. The NLTA empowers the Minister to prepare a NLTSF at five-year intervals. It embodies the overarching, national five-year (2015 to 2020) land transport strategy, which gives guidance on transport planning and land transport delivery by national government, provinces, and municipalities for this five-year period.

The NLTSF is a framework for transport planning for all tiers of government and sets the overarching goals, vision, and objectives for each element of the transport system to be reflected in the Provincial Land Transport Frameworks (PLTFs) and Integrated Transport Plans (ITPs). The success in achieving these objectives depends on the implementation of the transport programmes and projects that emanate from the respective PLTFs and ITPs reflected through the key performance areas, defined in the NLTSF (Department of Transport, 2015).

Road safety audits form part of the engineering approaches to address road safety concerns:

- Creating a safe environment for pedestrians and cyclists where dedicated sidewalks and cycle lanes are mandatory requirements in all infrastructure development projects.
- Improvement of the road environment through proactive road safety audits on the strategic road network within each planning authority
- Construction work zone safety application to aim for zero incidents at work zones.

6.4.3.5 Road Infrastructure Strategic Framework for South Africa (RIFSA) of 2006

The Road Infrastructure Strategic Framework for South Africa (RISFSA) of 2006 provided the framework for the management of roads infrastructure. The Road Infrastructure Strategic Framework for South Africa (RISFSA) provides the framework for the management of roads infrastructure. The strategy was intended to develop and implement comprehensive and appropriate interventions to ensure service delivery efficiency and sustainability in the road networks system; and to promote coordination and a partnership approach to road network management. RIFSA makes recommendations to improve the planning and coordination of road management. A road agency model for provinces and local authorities has been proposed, as well as a functional road classification system, with the associated ownership and responsibility in terms thereof.

6.4.3.6 National Road Safety Strategy (NRSS) 2016 - 2030

As a participant of the United Nations Decade of Action for Road Safety 2011-2020 (UNDA) and more recently the Stockholm Declaration (UNDoA2 2020-2030), South Africa has endorsed the global undertaking lives and contribute to the prevention serious injuries. In accordance with this commitment, the NRSS 2016-2030 has been developed, embodying the principles of the Safe Systems approach and giving effect to the five pillars of the UNDA a guiding framework for actions to improve road safety. In accordance with the UNDA, these pillars remain consistent in the NRSS as Road Safety Management, Safer Roads and Mobility, Safer Vehicles, Safer Road Users and Post-Accident Response. The NRSS has taken into consideration previous efforts made toward addressing road safety problems in South Africa, by carefully reviewing previous road safety strategies developed.

Under Pillar 2, Safer Roads and Mobility the NRSS focuses on road design and the environment with the intention of protecting users. In line with the Safe System approach, this strategy acknowledges that people will make mistakes. As far as possible, road design must guard against these human errors which in fatal or serious injury. This requires, but is not limited to, intelligent and forgiving road designs, minimising risks associated with the road environment, identification of hazardous locations through regular road safety assessments of road networks, road safety audits on new and upgraded road infrastructure projects. The different tools are described as follows:

- A Road Safety Audit which is a formal and independent safety performance review of a road transportation project by an experienced Road Safety Auditor or Team of safety specialist, addressing the safety needs of all road users.
- A Road Safety Risk Assessment which is a methodological approach to assess road safety risk relating to the existing infrastructure. The assessment of risk related primarily to the components of exposure, probability and consequence.

In addition, the research and development is employed to ensure the provision of appropriate road infrastructure solutions for South African road safety challenges. The road infrastructure and environment in South Africa is estimated to have a 12.3% causal contribution to fatal accidents. Physical attributes on roads such as blind rises, blind corners and sharp bends tend to facilitate human error and these need to be addressed. There is a need to investigate the extent to which factors such as speed limits are factored into road design, this not discounting that human behaviour remains the leading driving element for speeding. Internationally speed limits have been reduced over the years in line with Safe Systems principles, yet in South Africa no such review has been officially carried out. The safety of both motorised and non-motorised road users is placed at risk due to some road network areas having insufficient lighting and due to poor protection against stray animals wandering onto the road.

Furthermore, South Africa has a shortage of road safety engineers – a challenge which might add to the road design issues made apparent in the data. The challenges presented by the road network system cannot be fully addressed without increasing the number of technical specialists in the field of road safety engineering.

6.4.3.7 SANRAL Policy on Road Planning and Design, 2003

SANRAL's Policy on Road Planning and Design (SANRAL, 2003) provide procedures for road planning and geometric design for proclaimed national roads. The Procedures for Road Planning and Geometric Design are intended to guide and inform applicants applying for approvals, permits or permissions required of the SANRAL, as well as provide guidance to designers working on SANRAL projects.

The SANRAL Geometric Design Guidelines are intended to provide planners and designers of SANRAL road schemes and projects, as well as associated road planning impacting on National Roads, with optimal guidelines to enable them to provide the SANRAL with fit for purpose, safe, cost effective and operationally effective designs. The policy states that safety is of paramount importance and that the 2003 policy needs to be incorporated with applicable policies such as the South African Road Traffic Safety Manual, and the Environmental Legislation.

6.4.3.8 SANRAL Road Safety Audit guideline 2019

The South African National Roads Agency Limited (SANRAL)'s policy is to conduct road safety audits on all road improvement or new road projects. This is in line with the South African Road Safety Strategy 2016 which states that road safety audits should be made compulsory by all road authorities (Cable 2018).

Cable (2018) highlighted SANRALs approach to address Pillar 2 within the NRSS and UNDoA as illustrated in figure 6-1.

Pillar 1 Road safety management	Pillar 2 Safer roads and infrastructure	Pillar 3 Safer vehicles	Pillar 4 Safer road users	Pillar 5 Post-crash care
	• Safety systems • Priority design interventions • NMT considerations • Head-on, intersection and run-off the road crashes		Road safety education and awareness (school programmes)	Incident management system
	Road safety assessments		Road user behaviour	Freeway management system (ITS)
	Road safety audits		Partnerships with law enforcement	
	Hazardous location programmes			

Figure 6-1: SANRAL approach to addressing Pillar 2 within the NRSS and UNDoA

Cable (2018) reiterates that SANRAL core business is to maintain and develop the primary road network. Priority is given to:

- Strategic road infrastructure (pedestrian infrastructure; hazardous location programmes.
- Road safety assessments – NETSAFE©
- Understanding road safety risk
- Road safety audit (policy/procedure)

The SANRAL strategic plan 2015/2016 – 2019/2020 made provision for the development of a RSA policy, and although SANRAL has adopted SARSAM 2012 as the official guidance in conducting RSAs on SANRAL projects, in February 2019, SANRAL published an RSA policy guideline (THE SOUTH AFRICAN NATIONAL ROADS AGENCY (SOC) LTD 2019).

In relation to the 2019 publication, RSAs may be conducted at all stages of the life cycle of a project. However, given current capacity constraints in the industry, SANRAL introduces RSAs at specific stages of specific projects which will provide the highest road safety return, for such investment. The SANRAL policy is to conduct road safety audits on all road improvement or new road projects.

For the purposes of this policy, RSAs are conducted for (THE SOUTH AFRICAN NATIONAL ROADS AGENCY (SOC) LTD 2019).:

- new road projects (Greenfields and new facilities)
- upgrading projects
- strengthening projects including rehabilitation, reconstruction (including partial reconstruction) and bridges.
- improvement projects including level of service, capacity, alignment and bridges.

In addition to making recommendations in terms of experience, the team and team leader the SANRAL policy also makes provision for the role of the engineering service provider (main consultant). These stipulations include:

The Engineering Service Provider must develop a Scope of Works for the Road Safety Audit Team. Such Scope of Works shall comprise but is not limited to the following:

- conduct a project information review.
- conduct site inspection/s.
- produce road safety audit report/s.
- issue the road safety audit report/s and discuss initial findings with employer and
- initiate and conduct a completion meeting.

In addition, the Engineering Service Provider is responsible for:

- recommend with motivation the road safety audit team composition.
- request quotations (or let a tender in terms of the supply chain management) and recommend an independent road safety audit team to SANRAL.

Furthermore, the Engineering Services Provider shall:

- compile and issue an audit brief to audit team.
- initiate and conduct a commencement meeting with the road safety audit team.
- attend a completion meeting if requested by the employer.
- review road safety audit findings and recommendations.
- compile and issue response report including risk assessment of safety concerns.
- implement design changes agreed to with Employer.

SANRAL specify that a proper close-out procedure to the Road Safety Audit process needs to be followed. The non-response by the Engineering Service Provider or SANRAL to the Road Safety Audit Findings, can have grave consequences.

The Regional Road Safety Engineering Focus Group representatives and the Regional Road Safety Audit Coordinator be informed regularly of:

- Road safety audits that had been done.
- Responses to the road safety audits in the respective region.

The following are the steps to be followed for Responding to a Road Safety Audit Report to ensure a proper close-out of the Road Safety Audit process:

Step 1: Issue of Road Safety Audit Report

The Road Safety Audit Team Leader shall send a draft report to the Engineering Service Provider. The Audit Team Leader shall discuss the draft report with the Engineering Service Provider prior to formal submission. The purpose of this discussion is solely to ensure that the findings and recommendations are within the scope of the Audit, as defined in the audit brief. Once the Road Safety Audit Report is issued, it is a final report – the report cannot be amended.

Step 2: Completion Meeting

After receipt of the final road safety audit report, the Engineering Service Provider must arrange for a completion meeting, attended by the SANRAL project manager, road safety audit team and the engineering service provider (design team leader). The completion meeting provides the opportunity to better understand the approach by the audit team in assessing the safety performance of the project.

Step 3: Response Report After the Completion Meeting

The Engineering Service Provider will produce a RSA Response Report for the SANRAL project manager, with recommendations on how each RSA finding will be responded to.

RSA finding recommendations are not mandatory, however due to the potential for litigation after an accident at an audited site, it is necessary that the audit findings and recommendations be given consideration, and the reasons for not accepting the recommendations forthwith, or for adopting another solution or delaying the implementation of the recommendations be well documented in the road safety audit response report. each finding in the road safety audit report can be dealt with by either:

- Accepting the problem and the proposed recommendation and initiating the remedial action.
- Accepting the problem in principle, but due to other constraints, implement changes that only go part of the way to resolve the safety problem, or implement a different solution than that recommended in the Audit Report.
- Not accepting the finding or recommendation at all.

In addition, it is important that the Engineering Service Provider on deciding and recommending to the SANRAL Project Manager the responses to the RSA findings, conduct a thorough Risk Assessment in line with the procedure contained in Section 3.10.2, of the SARSAM May 2012.

Step 4: SANRAL Project Manager Sign Off.

The relevant SANRAL Project Manager must in writing formally, Agree, Disagree or Amend the Engineering Service Provider's Responses to the RSA Findings, as contained in the Road Safety Audit Response Report. The SANRAL Project Manager must instruct the Engineering Service Provider to implement such Agreed, Disagreed or Amended Recommendations.

SANRAL together with its partners aim to develop Road Safety Auditor capacity, through the initiation and promotion of recognised and accredited RSA courses, and the creation of opportunities to gain appropriate road safety audit experience.

6.4.3.9 Guidelines for pedestrian and public transport facilities on the national roads (SANRAL 2017)

SANRAL has historically been responsible for managing class 1 roads that promote mobility rather than accessibility. The Road Network Incorporation Plan (2010) however allowed SANRAL to take over several provincial roads. These provincial roads are characterised by high densification, pedestrian generators such as schools, clinics and so forth that are adjacent or close to high mobility routes due to inefficient land use planning and no integrated planning between different government departments, animals and informal trading activities in road reserves, due to poor access management.

This guideline (SANRAL 2017 - amended to include provisions for cyclists) addresses the management and provision of pedestrian and public transport (PT) facilities on SANRAL's road network. The reason for the guidelines is to consider how to accommodate and mitigate NMT and public transport on national roads in a manner that improve road safety and to contribute to the overall transport system. This guide facilitates an understanding of the problem, including the legal and policy implications. A systematic approach is needed to determine the need for, and the type of facilities to be provided (South African National Roads Agency 2017).

In planning for NMT and PT on higher order roads, SANRAL guidelines propose a rational approach to the planning for these modes. The rational approach is based on obtaining all the relevant information pertaining to a corridor including between two and three kilometres either side of the SANRAL or in this case higher order road. This information must be collated on a plan, to provide the basis for integrating all the land use, road design and other issues that impact on pedestrian and public transport. The guidelines highlight that the road authority and/or road designer needs to take the needed steps in providing informal trading facilities in the road reserve or that the activities be moved to a more suitable and safer location.

The following are steps and actions to be taken (South African National Roads Agency 2017)**:**

- On a network level and define the study area. This will typically be an area of 5 km or 10 km in length along the road, and two to three kilometres either side of the roadway. The approach should be to work from a higher network level before zooming in on specific details.
- Assess the public transport routes and network; determine origins and destinations; identify the intersections on the SANRAL road network; identify locations of formal and informal stops used by public transport.
- Determine the land use that will affect the road – which can include traffic generators a few kilometres away such as shopping centres generating NMT or public transport vehicles.
- Define the road network within the study area. The higher order supporting road network needs to be assessed, as the lack of a supporting network can often influence the operations on the major road.
- On higher order roads, the main function of the road is mobility. Mobility is achieved by providing appropriate speeds, as high as conditions allow, and limited access.
- TRH26 document provides clear guidelines on access and intersection spacing. Illegal accesses should be identified and addressed, as they are often significant contributors to conflict on roads.
- A sketch plan of the area should be prepared. Define the study area by selecting geographical boundaries containing road and land use elements that will impact on each other.

Specific issues that need to be indicated on the sketch plan or on similar related plans include the following (South African National Roads Agency 2017):

a) Geometric Information

- Access and intersection spacing
- Geometric layout – lanes, gradients, curves (schematic)
- Space available for sidewalks
- Sight distances

b) Existing Pedestrian and Public Transport Facilities

- Pedestrian crossings
- Public transport facilities
- Location of public transport facilities
- Traffic Information
- Pedestrian desire lines and indicative volumes (low / high)
- Vehicle volumes
- Public transport movements – taxi and bus, formal and informal
- Location of supporting road network.
- Public transport routes (approved by local authority)
- Adjacent land use with specific focus on land uses that will generate pedestrian traffic across the road, including inter-alia water points, schools, clinics, etc.

c) Existing Road Safety infrastructure

- Fence type

- Obstructions / facilities / trees in the road reserve
- Median islands

d) Other relevant information: The sketch plan described above can, in most cases, provide a good understanding of the area of interest and provide insight into the pedestrian and/or public transport challenges and constraints.

Once the status quo information has been collated and the problem has been identified, the network and specific design guidelines can be used to develop solutions.

6.4.3.10 Non-Motorised Transport Policy (2007 and 2008)

The Draft NMT policy was developed in 2007 and provided policy directives for animal-drawn transport, cycling, walking, eco-mobility, and innovative solutions. The review, ***Non-Motorised Transport Guidelines*** (2008) stipulate that NMT is any means of transport not supported by a motor. This includes cycling, walking, skateboard, wheelchairs and making use of animal-drawn carts or hand-pushed trolleys. Most people use a mix of motorised transport and NMT to travel. NMT is a mode of transport and in many instances; it is the only available mode or transport and/or the most affordable one.

6.4.3.11 Pedestrian and Bicycle Facility Guidelines (1997 and 2014)

A change in basic assumptions is needed where NMT and public transport facilities are not provided on an adhoc, case to case reactive manner, but that the planning and provision for NMT and public transport that prioritises people, the environment and quality of life. Table 6-1 illustrate the dimensions that need to be considered when planning for NMT.

Table 6-1: New way of street designs to incorporate NMT (Phayane 2015).

Physical dimensions	Social dimensions
• Mobility • Traffic focus • Large in scale • Forecasting traffic	• Accessibility • People focus • Compact urban form • Multi-modal travel
Conventional approach	Sustainability approach
• Segregation • Street as traffic generator and conduit • Demand based • Minimising travel time • Free flowing traffic	• Greater integration • Street as a public space • Management based. • Contextualising travel time • Traffic calmed

6.4.3.12 NMT facility guidelines: planning, design and operations (2014)

NMT facility guidelines: planning, design and operations (2014) is a revision and update of the existing Pedestrian and Bicycle Facility Guidelines (2003) which does not seek to set out a new policy but give effect to existing policy by providing guidance for a more balanced approach to the design of towns and cities for the benefit of NMT users. The main purpose of the new NMT Guidelines is to provide guidance on the planning and design for safe pedestrian, bicycle, and other alternative low carbon modes of transport, both across and alongside roads and streets. Furthermore, the guideline will strengthen the provision of well-designed bicycle and pedestrian facilities and infrastructure to improve the physical environment and safety of NMT users. The new NMT facility guideline manual (2014) is linked to other planning tools and standards such as the South African SADC Road Traffic Signs Manual

6.4.3.13 Design standards for universal accessibility

Design standards for universal accessibility should include reference to:

- SANS 784:2008, Design for Access and Mobility, Part 4: Tactile indicators (South African (SABS 2008)
- SANS 10400-S: 2011, Facilities for persons with disabilities (South African Bureau of Standards, 2011): This is standard forms part of the National Building Regulations and refer to facilities that should be provided for persons with disabilities.

The national building standards refer to requirements for:

- Signage to cater for sight-impaired person.
- Parking requirements
- Requirements for access spacing for impaired people.
- Obstructions restricting travel on pathways.
- Floor and ground surfaces including changes in the level of the ground/surfaces which should cater for the disabled.

6.4.4 Technical Recommendations and Methods for Highways

In an important attempt to resolve this issue, RISFSA has recommended the uniform proclamation and reclassification of the South African road network, together with a streamlined assignment of roles and responsibilities. A methodology for the functional classification of roads has been developed; Road Classification and Access Control Manual (TRH26). Although the functional classification has in fact taken pace, the actual devolvement of roads has not taken place (Department of Transport 2017).

6.4.4.1 TRH 26 South African Road Classification and Access Management Manual

The design of roads in South Africa is informed by the function that the road plays as defined by the South African Road Classification and Access Management Manual, TRH 26.

Table 1 shows the Road Hierarchy as defined in the Technical Recommendations for Highways (TRH) 26. Class 1 to Class 3 roads are high speed roads, designed for mobility of motorised transport, with speeds ranging from 60 km/h to 120 km/h.

In terms of the South African National Road Traffic Act, 1996 (Act No. 93 of 1996), pedestrians and cyclist are not permitted on freeways (Class 1 roads). Class 4 to Class 6 roads are designed for accessibility and accommodate both motorised and NMT users. NMT infrastructure is usually provided along class 4 to Class 6 roads where there are observed or anticipated NMT activities.

Table 6-2 illustrate the functional classification for roads.

Table 6-2: South African Road Classification (Committee of Transport Officials 2014)

Class of Road	Function/Priority	Description	Authority
Class 1	Mobility – for motorised transport	Principal arterial (Freeway/Highways)	National, Provincial and Municipal
Class 2	Mobility – for motorised transport	Major Arterial	National, Provincial and Municipal
Class 3	Mobility – for motorised transport	Minor arterial	National, Provincial and Municipal
Class 4	Access/Activity	Collector street	Municipal
Class 5	Access/Activity	Local street	Municipal
Class 6	Access/Activity	Walkway	Municipal

TRH26 guidelines ensure that all classifications are made according to RIFSA standards put forth by the Department of Transport to be used nationally. RIFSA standards require data that is not older than two to five years (depending on the asset), the Road Asset Management System (RAMS) must be updated every two years (Veramoothea, Breytenbach, and Baloyi, 2015).

6.4.4.2 TMH 16 Volume 2 South African Traffic Impact and Site Impact Assessment Standards and Requirements Manual

Road design and assessment standards and requirements depend on the functional classification of roads and the classification must therefore be in place before traffic assessments can be undertaken. Differentiation is made between roads in urban and rural areas according to the different classes of roads for Which the TMH16 provide requirements and standards (Committee of Transport Officials 2014).

This applies to both Traffic Impact and Site Traffic Assessments. These activities consider design speed, design vehicles and capacity in relation to the functional classification of the road. A capacity analysis must be undertaken for those elements of the transportation system and all modes of transport in the study area that may not meet the capacity requirements (Committee of Transport Officials 2014). For both TIAs and traffic site assessments TMH 16 provide guidance on requirements for the provision of:

- road access and intersections
- access and intersection spacing and separation.
- intersection control and improvement warrants
- intersection and access configuration
- traffic management
- pedestrian and bicycle facilities
- public transport facilities
- Parking Provision and Design
- Drop-off facilities

- road and intersection geometric design (site assessments only)
- driveway design (site assessments only)
- access throat lengths (site assessments only)
- Heavy Goods Transport (TIAs only)

In terms of traffic impact assessments TMH16 makes provision for a road safety assessment (or audit) to be undertaken with the purpose of identifying locations where the heavy good transport could significantly affect road safety. Only the specific impact of heavy good transport must be evaluated.

6.5 South African road safety audit practices

6.5.1 Road safety Audit Guidelines for Road Authorities in South Africa (1997)

In 1997 the Department of Transport published a set of guidelines to assist road authorities with the conduct of RSAs. Schemers (1997) states that traditionally the focus was on blackspot identification and implementation of low-cost engineering measures to improve hazardous locations (Schemers 1997). Road safety audits, on the other hand is “an independent qualified examination of accident potential and safety performance of a road project.

Schemers highlighted that at the time it was difficult to determine causes of accidents since there was little accident data to assist accident investigators to pinpoint contributory causes. Nonetheless improvements to the road environment was deemed a suitable solution to curb traffic accidents.

This guideline document considered international best practices from countries leading the implementation of RSAs and provided road authorities with information pertaining to the definitions (RSA on new as well as existing roads); purpose; advantages and disadvantages of implementing an RSA process as well as an overview of the RSA stages. At the time the guideline made provision for four stages (Schemers 1997):

- Stage 1: Basic planning stage
- Stage 2: Detail design stage
- Stage 3: Completion of construction or pre-opening
- Stage 4: Monitoring of safety on existing roads

In addition, the guidelines provided information regarding:

- organisation of RSAs
- specialist RSAs / RSAs conducted
- Legal framework and accommodating RSAs in the legal framework.
- Quality assurance
- RSA steps and execution for both new and existing roads
- A list of check and prompt lists deemed important.

6.5.2 South Africa Road Safety Manual (SARSM 1999)

The South Africa Road Safety Manual (SARSM) was compiled in 1999 as a best practice guideline to Road Safety Assessments and design (F. V. Labuschagne 2002).

Road Safety Audits were introduced as Volume 4 of this manual, with the aim of reducing accident risk and improving road safety performance. The manual defines a Road Safety Audit as “a formal examination of a future or existing road/traffic project/any project where interaction with road users takes place, in which an independent, qualified examination team reports on the accident potential and safety performance of the project (COLTO, 1999).

Visser and Prinsloo (1999) provide the introduction to Design for Safety Volume 7 of the South African Road Safety Manual by stating the publication is aimed at assisting road designers to evaluate the road safety situation on existing roads and the safety potential of new roads (Visser 1999).

Volume 7 of the Road Safety Manual stipulates that audits will firstly be used to identify accident spots for remedial treatment on existing roads. In preparation for new roads (during the various planning and implementation stages) auditing will be done to ensure that “safety conscious design is incorporated, and to recommend design changes at little or no cost.” In addition, at all stages of design, audit checklists will be used to enhance decision-making that could affect road safety.

Volume 7 Design for Safety provides the reader an overview of the various geometric and other design elements have on accident rates and provides an indication of appropriate design standards that should be used, depending on road classification, traffic volumes, terrain, and location. The authors stipulate that the limitations of the vehicle, the driver and the road need to be considered, including the assumptions made when determining design standards.

Furthermore, the publication states that the safety performance of the road network will be judged according to certain performance indicators, which will signify whether the assumptions or the design standards are appropriate or not. In the case of existing roads, remedial measures may be recommended; in the case of new roads, design changes may be required. As a result, a safer road environment can be ensured, and accidents can be prevented (Visser 1999).

Van As, Steynberg and Scheepers (2003) stated that RSAs are undertaken during various phases of a project. During the planning and design phases of a project, the plans and designs of the project are examined for safety problems. The RSAs can be undertaken during the various planning and design phases, such as the preliminary or feasibility phase, draft design or basic planning and the detailed design phases. Van As et al (2003) recommended that:

- More than one audit can be undertaken during the planning and design phases to ensure that road safety needs are addressed.
- During the construction phase of a project (SARSM Stage 4 safety audit), only aspects related to construction activities are examined.
- The audit team should report on design deficiencies but that this is not the purpose of the audit (design deficiencies should have been identified during the planning and design phases of the project).

The South African Road Safety Manual (1999) also provides for a Stage 5 pre-opening road safety audit during which a final audit can be undertaken before a road is opened. According to the South African Road Safety Manual (1999), a Stage 6 Road safety audit can also be undertaken for an existing road as part of the planning and design process (Van As, Steynberg and Scheepers 2003).

6.5.3 South African Road Safety Audit Manual (SARSAM 2012)

6.5.3.1 Background to the 2012 Guideline

The SARSAM-2012 was published by the RTMC as a comprehensive guide for the formal road safety audit process of transport infrastructure projects at the various design stages and when roads are upgraded or rehabilitated as well as for the road safety appraisals and assessments of existing roads ((F. Labuschagne 2018).

The SARSAM-2012 is structured in four parts (Road Traffic Management Corporation 2018):

Part A provides a background to Road Safety Audits and the process of road safety auditing.

- Chapter 1 (Road Traffic Safety Management) provides an overview of reactive and proactive approaches to road safety improvement.
- Chapter 2 (The Road Safety Audit concept) discusses the concept of road safety audits as well as the purpose and value of undertaking road safety audits. It also introduces the different role players in the Road Safety Audit process and their responsibilities. This chapter specifically addresses the role that checklists or prompt lists play in the Road Safety Audit.
- Chapter 3 (The Road Safety Audit Process) explains the process of a typical Road Safety Audit and identifies the responsibilities for each step in the process.

Part B provides the detail description on conducting Road Safety Audits:

- Chapter 4 (Road Safety Audits on New Projects) describes the Road Safety Audits that may be conducted on road projects during the planning, design and construction process. It describes Stages 1 to 5 Road Safety Audits ranging from Feasibility/ Preliminary design audits up to Pre-opening stage audits.
- Chapter 5 (Road Safety Audits on Existing Roads – Road Safety Appraisals) describes the Road Safety Audit process as applied to existing roads. It explains some deviations to the normal road safety process allowing for accident history and other sources of information and providing for an alternative Road Safety Audit reporting structure.
- Chapter 6 (Other Road Safety Audits) discusses the conditions that may lead to conducting other road safety audits that may be focused on addressing areas such as intersections or specific locations.

Part C describes the legal environment within which Road Safety Audits have to be conducted.

- Chapter 7 (Legal implications of Road Safety Audits) introduces the legal environment pertaining to the law of delict and negligence on the part of the road authority and the risk of liability on the grounds that the road authority did not comply with a legal duty (or duty to care) to provide or; maintain safe road facilities.

The Appendices to the Manual provide references, prompt lists, examples, and templates to aid road authorities, design organisations and Road Safety Auditors.

6.5.3.2 NRTETC Resolution to review of SARSAM 2012.

Although currently not compulsory, the SARSAM-2012 are used by most road authorities as a guide to conduct RSAs on new, upgrading and rehabilitation road construction projects and is used for road safety appraisals on existing roads (Road Traffic Management Corporation 2018). In 2017, the National Road Traffic Engineering Technical Committee (NRTETC) took a resolution that the SARSAM-2012 need to be reviewed. As such, the review of the SARSAM-2012 need to consider (Labuschagne, 2018):

- experiences from its application over the past 5 years,
- address deficiencies, and
- Restructure the document to provide a more pragmatic approach for road safety audits, appraisals, and assessments in South Africa.
- in future it should be compulsory for road authorities to perform road safety audits.

6.5.3.3 Recommendations for the review

Overall, it was recommended that the updating of the SARSAM will take two forms:

- A TMH document for RSAs on new roads and upgrades.
- A TRH document to guide road safety investigations and road safety network level assessments.

In addition, the recommendations stated that no road safety statistics should form part of the introduction of the updated SARSAM and that the review of the SA Road Safety Manual 1999 (section 1.5.1) should follow a separate and independent process from that of the updating of the SARSAM. The principles and recommendations are briefly discussed in the section below[1].

a) Format, structure and applicability

SARSAM should become part of the national series of TMH documents for Road Safety Audit of new roads and upgrades and a parallel and supporting guidelines document in the TRH series to address safety assessments on existing roads.

The intent is to revise SARSAM 2012 to incorporate the following sections:

- Part A: Background to RSA as part of road safety management and Safe System approach
- Part B: RSA process and team (also addressing the close out process as an important aspect of the process)
- Part C: Post-audit process
- Part D: Appendices which should address monitoring, evaluation and feedback to give account of impact of RSAs and to inform future improvements of the method(s)

Best practice application of the principles with supporting advisory information; TRH and TMH documents. The TRH structure should allow for:

- Guidelines for road safety management, policies
- Road network accident risk assessment and management, etc.
- Costs and benefits of RSAs
- Photos
- TOR Examples
- Example of RSA
- Prompt Lists

b) Style

The RSA Manual needs to be re-written in TMH style with consideration of:

- Background
- Context
- Mandatory actions
- Supporting information and guidance and typical forms to standardise the structure of the RSA report.

A parallel TRH guideline needs to be developed to address road safety inspections and road safety appraisals which are less formal and significantly more constrained as far as potential

[1] Source: Labuschagne (2018)

mitigating measures are concerned. There is also a need to note differentiation of road safety inspections and road safety assessments.

c) Content

The revised SARSAM guidelines should have a:

- Road safety basis: RSA needs to be explained as a pro-active tool to be set within the Safe System approach to traffic safety; addressing the philosophy of the Safe System approach.
- Costs and benefits of RSA: Description of cost and benefits to be included in TRH document.
- Safety risk assessment: Review the current Risk Assessment matrix to ease the utilisation thereof for use by the RSA Team in prioritising the perceived level of risk associated with the audited condition of every identified safety concern. There should be clarity regarding the risks of types of accidents versus the reporting on, or prioritisation based on only those accidents with a high severity outcome.

d) Definitions

Definition of an RSA (New road): Expand the current definition to include the Safe System context. Include new roads, upgrades, rehabilitation, and maintenance that are likely to include contemporary design elements.

Definition of an RSA (Existing Road): Define in TRH and retain the definition for road safety auditing of existing roads with reference to:

- Road Safety Investigations (Old Appraisals)
- Road Safety Assessments (Network Level)

e) Role of the RSA Team

Clarify the role of the RSA team further to the RSA definition:

- explaining the fact that it is a focused role player that advises the client on aspects specifically applicable to road safety of all road users.
- its role being to assess the proposed scheme or existing road for safe fitness for purpose,
- rather than compliance with design standards task to include comments on the safety of provided measures and on measures that should be included to reduce the severity of accidents.
- Include 'Design Considerations' and the need for design consistency.

f) RSA Team qualifications

RSA team leader/ members be registered with the Engineering Council of South Africa (ECSA) in a sub-discipline for Road Safety Auditor,

subject to compliance with specified qualification, experience and RSA skills and experience and retain registration with ongoing approved Continuous Professional Development.

The Audit Team Leader must (THE SOUTH AFRICAN NATIONAL ROADS AGENCY (SOC) LTD 2019)**:**

- Be a registered professional engineer or professional engineering technologist with the Engineering Council of South Africa (ECSA), and
- Have at least 10 years of experience in road safety design and/or traffic and transportation engineering and/or geometric design; and

- Have successfully completed a recognised road safety audit course to the equivalent of at least five Continues Professional Development (CPD) points.
- Have undertaken at least two formal road safety audits within a period of two years as the audit team leader or audit team member.

g) RSA Stages

Recommendations pertaining to the RSA stages in South Africa include:

- Retain existing RSA stages but expand on possible other special audits and stressing the need for Interim RSAs in case of phased development of schemes.
- Stage 6 (existing roads) to needs to be moved to the TRH Document.
- Consider amendments in line with approval processes of Standards for Infrastructure Procurement and Delivery Management (SIPDM).

h) RSA on Existing roads

Guidelines should be provided in a TRH series document for the inspection and assessment of existing roads, combined with information that may be used to improve the quality of road safety engineering decision making.

i) Thematic RSA or Other RSAs

Thematic RSA needs to be addressed in TRH document and there needs to be consideration in terms of an extension on TMH16 (in TRH form) to ensure a focus on road safety.

j) Interim RSA or safety advice

The principle of Interim audits should be expanded to promote the earlier reach out to the RSA Team to retain flexibility in design prior to locking designs.

k) Inclusion of recommended remedial measures in RSA report

Recommended remedial measures appropriate to the level of risk should be included for each safety concern and stage of design/ construction unless specifically excluded in the RSA brief. The level of typical recommendations would be at conceptual design from where the designer must take it further.

6.6 Road network safety screening

6.6.1 Introduction

A Road Safety Engineering Assessment is a screening process to establish the safety status of sections of an existing road network. It is a set of predefined key indicators to determine the feasibility of safety improvements of such a section. The road safety engineering assessment process provides a list of prioritised locations and deficiencies that should be further investigated (Road Traffic Management Corporation 2012)

6.6.2 Guidelines for road network screening South Africa.

6.6.2.1 South African road safety manual (SARSM 1999)

SARSM 1999 describes road safety engineering assessment on rural roads (Volume 2) and urban roads (Volume 3). At the time this was considered a best-practice guideline document that describes the road safety engineering assessment process for the rural road network. According to the SARSM 1999 a road safety assessment reports only on the accident history and a limited number of pre-defined key safety performance indicators of a road (Committee of Land Transport

Officials 1999). While a road safety engineering assessment Is evaluated safety on a network level to identify hazardous locations and safety deficiencies on the network.

The guideline was developed to assist road authorities with the evaluation of the efficiency of the traffic operations and road safety aspects of rural roads in their area of authority. The procedure was to be used in conjunction with data from existing road and traffic management systems. Provision were made for data collection where no formal systems have been implemented yet. The objectives were:

- To provide procedures to evaluate the total network to determine which road segments take the highest priority for the implementation of remedial measures.
- To assess the operational and safety conditions of a road network i.e. A road safety assessment, manually as a first step towards a computerised system if existing relevant management systems are not yet in operation.
- To assist the road authority in identifying any existing safety deficiencies of design, layout and road furniture which are not consistent with the road's function and use.

Although the road safety assessment is aimed at highlighting problems which are considered so urgent that they require immediate attention, many items identified will in fact be items of routine maintenance. The benefit of the Road Safety Assessment process is thus to ensure that optimum road safety is pursued through a programme of maintenance, rehabilitation and upgrading. Considerations included:

- Background to road safety engineering assessment on rural roads
- The assessment process.
- Assessment of geometry ·
- Assessment of roadside furniture
- Assessment of road signs and markings
- Assessment of driver expectancy
- Assessment of the environment
- Assessment of pavement conditions
- Assessment of operating conditions
- calculations involved in the road safety engineering assessment process.

The outcome of a road safety engineering assessment was a road safety assessment report that:

Reports on the safety status of the road network.

- Lists and prioritises the hazardous locations that will require a road safety audit which is a more detailed (project level) analysis of the location.
- May have include a map indicating hazardous locations of the total road network.
- Identified the network level safety deficiencies in the road traffic management process of the authority.

6.6.2.2 South African Road Safety Audit Manual 2012

SARSAM 2012 defines a road safety engineering assessment as a screening process to establish the road safety status of sections of an existing road network. It is a network-based process performed on selected sections of the road network using a set of pre-defined key indicators to determine the feasibility of safety improvement of such a section. The road safety engineering assessment process provides a list of prioritised locations that should be further investigated.

6.6.3 Methodologies

6.6.3.1 South African Road Assessment Programme (SARAP)

The International Road Assessment Programme (iRAP) is a scientific tool used to conduct road assessments and recommend remedial actions. The Programme helps identify hazardous locations and develop road safety plans and interventions integrating engineering, enforcement, and education. Furthermore, in the programme the road system is designed to expect and accommodate human error and in the event of an accident, the impact energies remain below the threshold likely to produce either death or significant injury. (Road Traffic Management Corporation 2013)

The SARAP Safer Road Investment Plans will provide the confidence for the South African government and financing institutions to leap-frog existing practice and invest in large scale and accelerated provision of safer road infrastructure. The SARAP investment plans intended to demonstrate that by investing in safer roads, the South African Government can remove the enormous road accident burden on families, communities, workplaces and the health and insurance sectors. At the time it was envisioned that the setting of ambitious policy targets such as no “one or two-star roads by 2020”, or “minimum three-star standards for all new road designs”, SARAP aimed to provide the mechanism and catalyst for change that will provide a legacy of safer roads for future generations.

Factors contributing to road accidents in South Africa included speeding as well as reckless and negligent driving. The type of accident that needed to be addressed included (Road Traffic Management Corporation 2013):

- Head on accidents
- Multiple vehicle accidents
- Accidents involving fixed objects.

Star Ratings are considered an objective measure of the likelihood of a accident occurring and its severity. Star ratings draw on road safety inspection data and the extensive real-world relationships between road attributes and accident rates. Research shows that a person’s risk of death or injury is highest on a one-star road and lowest on a five-star road (Road Traffic Management Corporation 2013). By measuring the risk associated with road attributes, Star Ratings can provide a better indicator of the influence of road attributes on risk than accident numbers alone. The focus of Star Ratings is on attributes that influence the most common and severe types of accidents for vehicle occupants, motorcyclists, pedestrians, and bicyclists.

6.6.3.2 SANRAL NETSAFE

The purpose of the NetSafe model is to predict accident rates and frequencies from highway and environmental characteristics (SANRAL 2019). The model is used to predict the number of accidents over period intervals of one year that can be expected over a particular road section.

The SANRAL NetSafe model is applied to safety assessments to be undertaken for:

- On a network level, the assessments can be undertaken with the purpose of identifying and prioritising hazardous locations on the road network and where road safety improvements are likely to be the most beneficial to improve safety concerns (SANRAL 2019)
- The assessment of a proposed geometric design of a road with the purpose of identifying possible hazardous locations.
- The cost-benefit analysis of alternative road improvements.

The NetSafe model utilises estimations of accident rates and frequencies to explain accident rates in relation to road related factors. The model was designed, based on the HSM 2010 with parameters of the model adjusted for South African conditions. The adjustments and extensions of the HSM model are in some instances based on data but in some judgement had to be applied. Future research is required to develop models using accident statistics. Such research will only be possible if the accident reporting system in the country is improved to ensure that all data are captured, including the exact locations of accidents (SANRAL 2019).

6.7 South Africa research and publications related to RSA and road network screening practice.

6.7.1 South African road safety audits in previous publications

Since the publication of the 1999 Road Safety manual, road safety audits have slowly started to feature in scientific South African literature. In comparison with the rest of the world, South African contributions related to the topic is but a drop in the bucket.

Road safety audit was used as a key word to search South African peer reviewed collections for applicable publications. These publications were mostly included in the Southern African Transport Conference (SATC) collection from the year 2000 to 2016. A total of 148 publications that mentioned “audit” were selected and reviewed. Only forty of these publications provided RSAs as tool to prioritise road safety.

With the topic of RSAs being a new safety engineering tool, emphasis was placed on the benefits that a RSAs have, especially in the absence of quality road and traffic data (including accident data which traditionally was considered the most direct measure of road safety; exposure data as well as increases in underreporting of accidents). The sentiment being that the qualitative nature of the RSAs made it an excellent tool to develop performance indicators for road safety. In addition, since resources in the road sector will continue to become scarce, that the use of performance measurement will be important as authorities responsible for road safety will need to prioritise interventions (Lotter 2000).

Dhliwayo (2000) provides an overview of RSAs highlighting the benefits of road safety auditing for the African Union, recommending that RSAs should be adopted as good practice by African Member States. Dhliwayo (2000) also states that RSAs will minimise the risk severity of road accidents that may be affected by the road project at the site or on the nearby network, and the need for remedial works after construction, reduce the whole-life costs of the project, and improve the awareness of the safe design practices by everyone involved in the planning, design, construction, and maintenance of roads. However, emphasises is placed on the need for a RSA policy, finance, and strategies (Dhliwayo 2000).

In 2002, Labuschagne, Van As, and Roodt provided an overview of the status of road safety audit and assessment in South Africa (F. V. Labuschagne 2002). The research explores and details the underlying reasons for the low interest that at the time were displayed by road authorities to utilise RSAs as a road safety tool. The study made used of a survey of road authorities at national, provincial, and local spheres to explore issues regarding:

- Who is responsible for RSA in road authorities?
- Awareness regarding RSA as a technique to improve safety.
- Knowledge or availability of training and extent to which training took place.
- The scope and extent of implementation of RSA.
- Scope and extent of institutional support, including budget allocation.
- Perceptions of the usefulness and cost efficiency of RSA.

The study results indicated that not all road authorities took the responsibility for RSA to heart and that taking of formal responsibility for the implementation of RSAs varied greatly. In addition:

- Although 70% of the respondents are aware of training, only 58% of the authorities indicated that someone has had training, resulting in about 24 trained officials.
- Institution support and dedicated budget allocation occurs in only 5 of the 17 biggest road authorities in South Africa.
- While 47% of the respondents perceive RSA as useful, 60% were uncertain of the cost efficiency of undertaking them. A further conclusion was that South Africa does not have professionals with the expertise that meets the requirements of the SARSM of specifically RSA.
- Few persons in South Africa regularly undertake quality road safety studies, and few persons would gain Road Safety Audit experience if such audits were not undertaken regularly in the country.

Lastly the study indicated that concerns were expressed regarding the technical soundness of the RSA process as applied in South Africa. In 2010, Labuschagne, Grosskopf and Moyana (2010) repeated the survey amongst road authorities to understand the lack of interest and the low level of implementation of RSAs. This research resulted in recommendations that informed changes to the RSA manual/guidelines (GROSSKOPF 2010).

VanderSchuuren and Irvine (2002) reflected on whether South Africa was ready for an international comparison by partaking in the European PROSPER (**P**roject for **R**esearch **o**n **S**peed adaptation **P**olicies on **E**uropean **R**oads) initiative, specifically in terms of "Road Speed Management Methods Assessment". The paper discusses the range of problematic factors that plague South African road safety. One of the comments included the fact that the road design also influences the safety on roads. A key concern highlighted as a secondary issue was the fact that although South Africa was encouraging RSAs to take design issues into account, RSA was not compulsory which means that new bad (dangerous) designs nor 'repairs' on existing dangerous designs are done. In addition, the study identified the lack of qualified personnel who can perform audits as a serious threat (VanderSchuuren 2002).

Ismail and Venter (2007) provided an overview of the role and function of the South African Road Traffic Management Corporation. RTMC was established in terms of Section 3 of the Road Traffic Management Corporation (RTMC) Act, 1999 and commenced with the preparation of a Business Plan and Strategy for its operationalisation in April 2005. The overriding aim of the RTMC was to overcome the current fragmentation of traffic management functions across hundreds of provincial and local jurisdictions, and to bring a new professional coherence and improved morale into the entire system. Monyana (2008) stipulates that one of the functional areas of responsibility allocated to the RTMC, is that of "Infrastructure Safety Audits." RSAs play a key role in diagnosing the safety of the road network, both as far as existing roads and upgrading projects on the road and transport road network screening are concerned (Labuschagne et al, 2002; Moyana 2008). Plaatjies (2010) highlighted that as part of the National Training Framework for Road and Traffic Management Practitioners, there was a need for RSA training as well as accreditation. This formed part of the long term view to develop human capital within the road traffic management fraternity (Plaatjies 2010).

Johnson (2015) highlighted the need for RSAs and that interim approach by Road Safety Authorities while formalising and institutionalising RSAs that all new, upgrading and maintenance road projects shall be road safety audited in accordance with the procedures of the South African Road Safety Audit Manual, 2010. In 2018, Roux (2018) stated that road safety audits, appraisals and network level assessments will be formalised to assist in the endeavours to provide a road environment designed to optimally limit harm and injury to road users. These approaches will be formalised in line with the 'Safe System' approach as well as the National Road Safety Strategy. In addition, at the time the RTMC was establishing an accreditation body for Road Safety Auditors and the review and updating of the South African Road Safety Audit Manual 2012. The National Road Traffic Engineering Technical Committee and the RTMC further identified the need to review and update/enhance SARSAM 2012. The updating of the SARSAM will include experience gained, to address deficiencies and/or to repackage the document to provide a pragmatic approach for road safety audits, appraisals, and assessments in South Africa in line with international best practices. The updated/enhanced SARSAM will be published as Technical Methods for Highways (TMH) & Technical Recommendations for Highways (TRH) documents published by the RTMC under auspices of the Committee of Transport Officials (COTO). The presentation will discuss the key elements and progress relating to RSA registration as subcategory with ECSA, the Review of the SARSAM as well as the processes for the SARSAM to be updated and published as THM/TRH documents (Roux 2018)

6.7.2 RSAs inclusion in road safety strategies and policies

Watson (2000) provided an overview of elements that needs to be included in road safety strategies. The paper provide an overview of the status of the 3 E's (Engineering, Education and Enforcement) in South Africa as well as making recommendations in terms of what is needed to address road safety in South Africa. In terms of engineering approaches, Watson (2002) highlights that often safety features are included in road design but are not constructed because of cost factors. Maintenance is limited to fixing potholes and clearing drains and replacement of traffic signs and guardrails, road markings and other necessary features are neglected. Road Safety Audits should be performed at the design, construction, and maintenance phases of road projects, but in developing countries, cost sometimes prevents this process from taking place. In addition, Watson states that in 2001 KwaZulu-Natal hosted RSA workshops, where practical training on audits at all three phases was done. Specific attention should be given to pedestrian usage during these audits, especially in rural areas where communities and facilities used by them (schools, shops, shebeens) are badly placed in relation to highways. In South Africa audits of existing roads are necessary as often roads were designed primarily for fast movement of troops, and without taking the needs of communities into consideration (Watson 2000).

Elsenaar (2002) highlighted the fact that road deaths and injuries are a global health problem and provided an overview of the role that the World Roads Organisation (PIARC) plays. Elsenaar compares success factors in countries with good safety records, highlighting the need for cooperation between disciplines and organisations to implement knowledge in favour of road safety. RSAs are highlighted as a good practice, which has proved to be an effective tool in the design process, that helps to avoid mistakes in the design in a stage that these can easily be corrected in the final design (Elsenaar 2002).

Although not part of South African practices, Kraay (2002) provided an overview of the Dutch Road safety policy 2001-2020. However, this was the first introduction to the sustainable safety principles and the international move towards the Safe System. The Netherlands was the first country to formulate quantitative targets for road safety. In 1987 the first Long-Range Plan for Road Safety *MPV* was published. The target formulated in this for the year 2000 was 25% fewer road accident victims compared with 1985. Provides an overview of the Safe System and sustainable safety. Reference is made to RSAs in context of policy Better embedding of road safety in policy areas outside the direct road safety policy can be more effective. The relation with spatial planning and urban development will be further investigated and the aim at that stage was to introduce a road safety audit for spatial plans. (Kraay 2002).

During the development of a Road Traffic Safety Management Strategy for the Western Cape Province, Page et al (2005) highlighted that the design and implementation of road infrastructure should be done with road safety in mind. The implication was that RSAs (like Environmental Impact Assessments) should be done in the initial stages of infrastructure planning. Integrated plans (National Department of Transport, provincial traffic, and provincial education) should be developed for the activities involved at weighbridges and for the management thereof (Page, De Beer, Ribbens, 2005).

In terms of measuring road traffic safety performance, Botha (2005) highlighted that it is the responsibility of the road authorities to ensure that all road design requirements are met, and the safety performance is measured by undertaking regular RSAs and assessments.

6.7.3 RSAs application and results

A research paper presented by Van Rooyen (2002) provided a description of the road safety problems the Germiston area, part of the Ekurhuleni Metropolitan area, experienced in terms of urban freeways, referring to these freeways as the “The killing fields of Germiston” (Van Rooyen, 2002). This paper highlights the role and responsibility that the different departments (4E’s) must address the road safety situation on these freeways. Van Rooyen states that Engineers should not shift the focus of highway safety problems to enforcement agencies. Also stating recommendations would be made to the responsible authorities (The National Department of Transport and the Gauteng Provincial Department), to take decisive action to rectify certain deficiencies which may precipitate the occurrence of road accidents, and to minimise delays caused by such accidents and other incidents as enforcement should be the last option. Enforcement was considered a last resort, after it can be stated categorically that all.

other remedies in respect of road (highway) safety and design have been explored and attended to. The 4th “E” (Evaluation) is critical, as it seems as if the provincial authorities do not regularly evaluate the acci accident risk and accident numbers. One of the ten recommendations to improve the situations was that comprehensive road safety audits be conducted at regular intervals by independent consultants to ensure the optimisation of all resources (Van Rooyen 2002).

Van As et al (2003) provided feedback in terms of RSAs undertaken by the Gauteng Department of Public Transport, Roads and Works (Gautrans). These RSAs were conducted in line with the SARSM methodology developed by the National Department of Transport. In addition to providing feedback regarding safety improvements the authors also stated that the aim of the project was to evaluate and test the road safety audit methodology. An important conclusion of the project is that road safety audits can have significant advantages. All road authorities should consider implementing road safety audits on all projects involving changes to the road network. All projects should preferably be audited, from the smallest to the largest. A few modifications to the road safety audit methodology proposed included recommendations pertaining to the provision of a methodology for the undertaking of site inspections, changes to checklists used for road safety audits, and a change to the approach to safety audits on existing roads. These recommendations included:

- Road safety audits: Can be of excellent value in improving road safety in South Africa. Road authorities should consider implementing road safety audits on all projects involving changes to the road network. All levels of projects should preferably be audited, from the smallest to the largest. Road safety audits should, in fact, become a standard practice with the intention that all plans and designs for changes to the road network must be audited.
- Road safety assessments: The identification of projects for road safety audits by means of Volumes 2 and 3 of SARSM can be a costly undertaking. Consideration should be given

to other methodologies for this purpose, such as traditional hazardous location studies, which are used for the identification and prioritising of road safety projects. Once such locations have been identified, traditional road safety assessments can be undertaken with the purpose of pinpointing specific safety problems.

- The term "Road Safety Assessment" should also be reserved for the traditional approach to the safety evaluation of existing roads.
- Site inspection procedure: The SARSM does not provide detailed instructions regarding site inspections during road safety audits. A procedure was developed during the project which was found to be both practical and of great assistance in identifying safety deficiencies. Consideration should be given to the implementation of this procedure as a standard method during road safety audit projects.
- Checklists: No road safety audit should be undertaken without reference to a checklist. Various problems were, however, experienced with existing checklists during the project, with the result that a new checklist had to be developed. This checklist addressed most of the concerns expressed by the audit team. A single checklist can now be used for all stages of road safety audits, while the term "reminder list" has been adopted to replace the term "checklist". It is proposed that consideration should be given to incorporating this reminder list in local audit methodologies.
- Check against standards: An important conclusion of the project was that a road safety audit is not simply a check against design standards. Such standards may be appropriate under specific conditions but may not be applicable to all situations.
- Existing road safety audits: Consideration should be given to the use of the traditional hazardous location study and road safety assessment methodology rather than road safety audits for the location and prioritising of roads in need of safety improvements.
- Road safety audits should be restricted to planning and design projects only (as well as construction activities) and should only be undertaken on existing roads if such an investigation forms part of a planning or design phase audit.

Roodt (2014) states that road safety engineering should entail a roads development plan which requires that systematic attention be paid to upgrading the road infrastructure and signage based on continuous audits of hazardous locations (Roodt, 2014). Sekgothe and Maluleke (2005) describes safety as an indespensible requirement that support the functionin of the road traffic management system. The paper describes several principles to ensure a Safe System and highlights that road safety audits are needed to ensure that roads are constructed safe. As such the authors state that infrastructure investment is specifically safety oriented, there is a compelling case for mandatory safety **audits** in the design process for all transport infrastructures. Similarly, Ojungu-Omaru and VanderSchuren (2006) recommends that to improve the road safety situation there is a need to conduct RSAs at the worst known road sections and intersections in accordance with the South African Road Safety Manual. (Ojungu-Omaru 2006). Nyarirangwe (2009) also emphasises that while accident investigation helps in planning remedial solutions, a more proactive involving regular road safety audits and assessments is strongly recommended to ensure that roads are designed and constructed safe.

Ribbens and Pillay (2008) proposed a ward based (grid) approach to identify existing road safety problems in the City of Johannesburg. The authors stated that conventional approaches have always been through the identification of hazardous road sections based on accident records, or alternatively, road safety **audits**/assessments to identify potential problem areas. Vorster and Van As (2008) provided an overview of approaches used (community road safety strategies) by the City of Tshwane to in the absence of quality road and traffic data address road safety by involving the community in the identification of and recommendations pertaining to unsafe road locations and situations. As part of the recommendations, Vorster and Van As (2008) stipulates that there is a need for research in support of the development of guidelines that at local authority level can be used to do RSAs, road safety assessments, hazardous location identification and safety inspections. Grey and Ncunyana (2008) discusses the role of municipalities in transport service delivery in the Amathole district municipality. In terms of safety the authors state that the local authorities have a key role to play in ensuring that transport is safe. One of the recommendations was that the authorities should employ RSAs to ensure the construction of inherently safe roads.

Non-motorised transport (NMT) safety can be addressed with an RSA at design stage (Groenewald, et al. 2012; Groenewald 2014). In preparation for the 2010 soccer world cup Ribbens and Gamoo, (2006) highlighted the need to provide safe and secure non-motorised transport infrastructure and amenities. The authors recommended a comprehensive approach is required about the planning and design of non-motorised infrastructure by host cities; and highlighted that NMT audits at sport stadiums, public transport facilities and other public spaces would be key to ensure NMT safety at these facilities.

In 2014 Labuschagne and Ribbens stated that to make environments safe for NMT users, there is a need to consider the walkability of residential neighbourhoods. One of the proposals was to include a walkability audit as part of a formal examination to ensure NMT safety. To address NMT safety along railway lines Venter et al. (2014) made use of RSAs to conduct a status quo assessment of all the formal level crossings within the City of Cape Town.

Conradie, Ras, and Mentz (2008) and describe the development of a programme that made use of agent-based simulation for traffic safety assessments. RSA reports were used alongside traditional data in the development of the KRONOS simulation. Labuschagne and Pallet (2010) describes the way Intelligent Transport Systems (ITS can be used to monitor traffic in South Africa. The authors refer to the fact that advanced simulation models and road safety audit procedures are becoming more prevalent in road design processes to optimise the safety performance of new road infrastructure and traffic improvement projects.

Vorster and Seymour (2013) provided an overview of key design elements that could improve the safety of the bus rapid transport system which was planned for the Tshwane Metro. The paper highlights the importance of RSAs during the design stage to ensure that the BRT systems operations.

6.7.4 Network safety screening projects and research

Roodt (2012) used a set of methodologies as set out by the Highway Safety Manual 2010 to evaluate or predict safety performance on road sites on two road sections of the Route 44 (provincial road M 27) in the Western Cape. The respective SPFs modified by CMFs were used to estimate the number of accidents. These were compared to the average number of accidents reported over the last 5 years, subject to the proviso that the reported accident data may not be as accurate as that of the USA. The evidence presented in this paper indicated that the safety performance functions that were investigated cannot be transferred to the South African situation directly from the USA where they were developed. The logic of the HSM 2010 methodologies seems to be robust. The ranges of values of accident modification factors seem acceptable. This study did not attempt to explain the reasons why the predicted accident frequency differed from the actual number of accidents, as the road sections on which it was tested is not a representative sample. Local research into the shape and size of the safety performance factors and the calibration of accident modification factors should be promoted. The basis of such research is accident statistics, and every effort should be made to improve the quality of our data capturing system (LdV 2012).

Das and Burger (2017) explored the contributing accident factors with reference to urban factors such as land use, urban form, urban pattern, accessibility, and density on the occurrence of traffic accidents have been least explored. This investigation examined the influence of the major urban factors that cause traffic accidents and how road safety can be improved in the suburban arterial roads. A case study was performed using the Bloemfontein city of South Africa.

The findings showed that the level of accessibility (number of accessible roads) from residential areas to arterial roads is a major variable in traffic accident causation. Road geometry variables such as the median width and road width influence the occurrence of traffic accidents to a certain extent. Reduction in the number of access roads from the suburban residential areas to the arterial roads, provision of adequate medians in roads with no divided facility along with urban planning interventions, such as appropriate urban pattern, and avoidance of location of urban functions in convoluted areas will enable reduction in the occurrence of traffic accidents and improve road safety in the cities of South Africa (Das 2017).

7 WAY FORWARD AND SUMMARY OF KEY FINDINGS

7.1 Way forward

Chapter 7 provided an overview of key findings from the literature, concluding with a review of suggested changes to the SARSAM 2012, with motivation from the literature review. The literature review will be used to inform the development of the Position Paper. The Position Paper is published as a separate document.

7.2 Summary of key findings in support of the development of the position paper

7.2.1 Adoption of best practices and alignment with the Safe System approach

Road safety management forms an integral part of the transport and traffic management system. The review highlighted several global strategies that have proved to be successful in addressing road safety.

The Safe System (derived from Vision Zero and the Netherlands' sustainable road safety principles) is globally considered a best practice, and activities in support of road safety improvements need to be aligned with Safe System principles. The Safe System forms the basis for the UNDoA strategy, operationalised through the RTSMS. As indicated earlier the pillars of the UNDoA are the activities executed to safely manage the road network (entry and exit of vehicles and drivers to the road network as well as managing post-crash care initiatives).

Road safety activities (also road and infrastructure related including planning, design, construction, maintenance, and operations) need to take cognisance of the fact that humans are fallible, make mistakes and should therefore be protected from the impact that the force of accidents have on the human body, leading to death, injury and disabilities. This said, the review also highlighted the fact that even when a road is designed and constructed to all safety standards (and considered safe), accidents do still occur, meaning that there is a need to take cognisance of contributory factors (human, vehicle, and environment) that influence the occurrence of accidents.

To ensure that road safety is addressed within the transport system, there is a need to incorporate Safe System principles and frameworks in policies and strategies aimed at supporting road safety activities throughout the road safety value chain, at all levels of government.

7.2.2 Global road safety engineering approaches in support of eliminating or reducing road trauma.

Road safety engineering is a component of road safety management within the larger transport system. The review has mentioned several engineering tools that can aid in the provision of safer roads and infrastructure.

RSAs are considered a qualitative, proactive, cost effective road safety engineering tool that considers safety from inception of road project. By implementing an RSA, potential deficiencies that can influence future safe operation of the road is addressed at the onset. Similarly, provision is made for independent safety reviews or appraisals for existing roads (before opening or already in operation) thereby ensuring that road safety is addressed throughout the lifecycle of the road.

A review of best practices guidelines from around the world indicated that although there are differences in terms of the number, and the implementation of RSA stages, as well as differences in terms of roles and responsibilities during the RSA process, there seem to be consensus that an RSA can be intrinsically linked to all stages of a road project, in support of addressing safety.

However, indications are also that although utmost care is taken to design, construct and maintain safe roads and environments, no road can be considered perfectly safe. As such provision is also made for the routine inspections as well as the periodic screening of road networks to identify specific locations or sections of the road where sub-optimal road safety performance needs to be addressed. Hazardous locations or sections are then addressed by implementing the best cost-effective remedial measures in support of improving roadway safety.

One of the key elements that make RSAs so successful is the fact that it entails an independent process, by qualified auditors (and specialist teams) that are independent from the project. These independent auditors can make specific recommendations that are road safety focused. The process followed is meticulously documented, and the outcome for the RSA is an RSA audit report. This RSA audit report needs to be formally acknowledged and the owner of project is required to formally respond to the findings. Countries and regions however again differ in terms of the degree to which the recommendations are addressed.

Where RSAs for planned new or existing roads, is a formal process that require the appointment of independent auditors (or team of specialists), road network screening is a line function that are mostly executed by road authorities. The network screening process can be considered reactive as well as proactive. Although this is also a formal process, it is done periodically, to identify safety deficiencies on the road network. The screening process results in a list of problematic areas on the road network that the road authority is responsible for. This list assist authorities to identify and address specific sections or locations that are considered unsafe. These sections or specific locations are prioritised within the road authority's road safety management plan and addressed through specific remedial measures. The review shows that although there are instances in which observations and other qualitative methods are used, screening methods to identify the hazardous locations tend to be quantitative in nature, using statistical models, which need quality road and traffic data as input. Use is made of safety performance measures/ indicators or targets to benchmark and evaluate roadway safety performance.

7.2.3 South African commitment to address traffic deaths and injuries through the provision of safer roads and infrastructure.

South Africa as a signatory to the UNDoA (1&2) is committed to address the high number of road deaths and severe injuries caused by road traffic accidents. The Safe System forms the foundation of the NRSS 2016-2030 and as such South Africa has started to address road safety in a targeted and strategic manner. The NRSS contains action plans and focused activities, within the five pillars that aim to address safety on South African roads. Several pieces of legislation and policies were highlighted in Chapter 6, that aids in this endeavour.

With specific reference to safer roads and infrastructure, provision is made for all spheres of government to in play a role in addressing this unsustainable situation. As such all-road authorities have a duty to plan, design, construct and maintain a safe road environment for South African road users. The review highlights that government entities with the mandate to improve the transport and road safety environment, have made road safety a priority through strategic plans and policy frameworks.

7.2.4 South African RSA and network screening practices.

South African best practice guidelines have been advocating for the use of RSAs since the late 1990s. Despite earlier publications highlighting the benefits in terms of safety as well as reduced costs, the uptake of RSAs as a formal process within South African road projects seems to have been sporadic.

Infrastructure safety audits (RSAs) form part of the RTMC mandate (one of the ten functional areas for which the RTMC is responsible). The RTMC in 2012 published the SARSAM 2012 to assist and guide road authorities with the implementation of RSAs. RSAs are not compulsory but indications are that to date the SARSAM-2012 is used by most road authorities as a guide to conduct RSAs on new, upgrading and rehabilitation road construction projects and is used for road safety appraisals on existing roads (Road Traffic Management Corporation 2018). The implementation of RSAs is also included in the NRSS 2016 - 2030 under pillar 2 which makes provision for safer roads and infrastructure.

In line with the NRSS and SARSAM 2012, SANRAL has also made RSAs a requirement for the planning and construction of new roads, upgrades and reviews of existing freeway projects. In 2019 SANRAL published an RSA policy indicating that SANRAL adopts the SARSAM 2012 and that the policy provides additional RSA guidelines for road safety engineering practitioners working on SANRAL projects.

The SARSAM-2012 is structured in four parts (Road Traffic Management Corporation 2018):

- Part A provides a background to Road Safety Audits and the process of road safety auditing including a description of reactive and proactive approaches to road safety improvement, the RSA concept, purpose as well as roles and responsibilities and an overview of the RSA process.
- Part B provides the detail description on conducting Road Safety Audits for new road projects during the planning, design, and construction process. It describes Stages 1 to 5 Road Safety Audits ranging from Feasibility/ Preliminary design audits up to Pre-opening stage audits. In addition, this section provides and overview of RSAs on Existing Roads as well as referring to RSAs undertaken for other purposes such as focusing on specify areas such as intersections or specific locations.
- Part C describes the legal environment within which Road Safety Audits must be conducted. The last part of the manual contains a list of appendices for references, prompt lists, examples, and templates to aid road authorities, design organisations and requirements for road safety auditors.

Network screening and hazardous location identification has been applied more consistently through the years. Network screening methodologies such as SARAP and NetSafe have only been formalised in recent years.

7.2.5 NRTETC recommendations for SARSM 2012 review

In 2018 the NRTETC came to a resolution that the SARSAM-2012 need to be reviewed. This resolution forms the foundation and provide the direction for this project and subsequently this literature review. The revisions needed to incorporate changes in terms of the SARSAM structure, format, style as well as in terms of content which included redefining RSAs in respect to definitions pertaining to RSAs on new as well as existing roads. The revision called for a format and structure that made the inclusion of RSAs more authoritative. The revision also needed to consider the audit team and make recommendations toward the training, qualifications, and experience of the team leader as well as the audit team members. In addition, the new SARSAM need to provide guidance to practitioners in relation to RSA stages, thematic and other RSAs as well as information related to safety and inclusion of remedial actions.

As such, with reference to the above and the need for the review of SARSAM 2012 table 7-1 provides and overview suggested NRTETC changes and where applicable motivations in support of changes.

Table 7-1: Description of suggested NRTETC changes to SARSAM 2012 and motivations in support of changes.

Element (NRTETC, 2018)	Revision requirement (NRTETC, 2018)	Motivation for change (literature review 2021)
1. Format	• SARSAM to become part of the National series of TMH documents for Road Safety Audit of new roads and upgrades. • A parallel and supporting guidelines document in the TRH series to address safety assessments on existing roads.	Different publications have different structures however the literature review findings support RSA guidelines to be consistent in terms of content, approach, stages, and processes followed. Sets of documents have been published by: Austroads; CAREC and African Development Bank.
2. Applicability	• Best Practice application of the principles with supporting advisory information. • TRH and TMH documents	Literature review findings support preparation of guidelines that make use of international best practices and principles
3. Structure	Multi part document TMH: • Part A: Background to RSA as part of road safety management and Safe System approach • Part B: RSA process and team and should address the close out process as a pertinent matter. • Part C: Post-audit process should address monitoring, evaluation, and feedback to give account of impact of RSAs and to inform future improvements of the method(s) • Part D: Appendices	Literature review findings support structure that is inclusive of: • RSA guidelines in context of Safe System framework • RSA guidelines that clarify roles and responsibilities of RSA role-players • RSA guidelines that provide guidance in terms of RSA stages and the process to be followed as well as guidance on thematic RSAs.
4. Style of RSA Manual	• RSA Manual re-written in TMH style with consideration of background, context, mandatory actions, supporting information and guidance and typical forms	Literature review findings support RSA guidelines to be consistent in terms of content, approach, stages, and processes followed.

	to standardize the structure of the RSA report. • Develop a parallel TRH guideline document to address road safety inspections and road safety appraisals which are less formal and significantly more constrained as far as potential mitigating measures are concerned. • Note differentiation of road safety inspections and road safety assessments.	
5. Contents RSA explained in Safe System context and as proactive engineering tool.	• Pro-active tool to be set within the Safe System approach to traffic safety. • Addressing the philosophy of the Safe System approach as well - In line with Recommendation no 3 above	Literature review findings support: • RSA guidelines in context of Safe System framework • Explanation- and application of: • Safe System philosophy • Principles • Examples of context in which application need to be considered.
6. Contents: Costs and benefits of RSA	Include in TRH document	
7. Contents: Safety risk assessment	• Review the current Risk Assessment matrix to ease the utilization thereof for use by the RSA Team in prioritizing the perceived level of risk associated with the audited condition of every identified safety concern. • There should be clarity regarding the risks of types of crashes versus the reporting on, or prioritisation based on only those crashes with a high severity outcome.	Literature review findings support clarification of types of accidents as part of: • Screening and selection of priority locations in need of remedial measures. • Performance indicators in support of cost/benefit studies as well as evaluation and monitoring efforts.

8. Definition of an RSA (New road)	• Expand the current definition to include the Safe System context. • Include new roads, upgrades, rehabilitation and maintenance that are likely to include new design elements.	RSAs are recommended to be undertaken for all new road designs and their major rehabilitation and could be conducted as follows: • on new roads, motorways, highways, and other road surroundings/equipment, • before and during reconstruction and rehabilitation • inside and outside built-up areas.
9. Definition of an RSA (Existing Road)	Need different definition for road safety auditing of existing roads. • Road Safety Investigations (Old Appraisals) • Road Safety Assessments (Network Level) • Define in TRH (definitions for above) • Also consider notes under Recommendation No 8.	Definitions differ across guidelines and countries, need to standardise terminology as indicated in introduction of literature review.
10. Role of the RSA Team	• Clarify the role of the RSA team further to the RSA definition. • explaining the fact that it is a focused role player that advises the client on aspects specifically applicable to road safety of all road users. • its role being to assess the proposed scheme or existing road for safe fitness for purpose, rather than compliance with design standards task to include comments on the safety of provided measures and on measures that should be included to	Literature review support: • Clarification of roles and responsibilities of role players • Need to include specialised skills according to stages. • Purpose to be the identification of safety aspects to be corrected as early on as possible.

	reduce the severity of crashes. • Include 'Design Considerations' and the need for design consistency.	
11. RSA Team Qualifications	• RSA team leader/ members be registered with ECSA in a sub-discipline for Road Safety Auditor • subject to compliance with specified qualification, experience and RSA skills and experience • retain registration with ongoing approved CPD	Literature review findings support development of specific requirements for lead auditors (training, experience and accreditation), specialist advisors. and audit team member as well as the development
12. RSA Stages	• Retain existing RSA staging, expanding on possible other special audits and stressing the need for Interim RSAs in case of phased development of schemes. • Stage 6 Existing Roads to TRH Document. • Consider amending in line with approval processes of SIPDM	Literature review findings support RSA throughout the lifecycle of the road project to ensure safety in all aspects of the planning, design, construction and maintenance as well as operations
13. RSA on Existing roads	• Guidelines should be provided in a TRH series document for the inspection and assessment of existing roads, • combined with information that may be used to improve the quality of road safety engineering decision making. • Terminology as noted under Recommendation No 8.	Literature review findings support RSA guidelines to be consistent in terms of content, approach, stages, and processes followed.

14. Thematic RSA or Other RSAs	• Better suited in TRH document • Consider an extension on TMH16 (in TRH form) to ensure a focus on road safety.	Literature review findings support RSA guidelines to be consistent in terms of content, approach, stages, and processes followed.
15. Interim RSA or safety advice	• The principle of Interim audits should be expanded to promote the earlier reach out to the RSA Team to retain flexibility in design prior to locking designs. • Should be addressed under Recommendation No 3 to encourage appropriate interaction before formal/final audit.	Literature review support: • Purpose to be the identification of safety aspects to be corrected as early on as possible.
16. Inclusion of recommended remedial measures in RSA report	• Recommended remedial measures appropriate to the level of risk should be included for each safety concern and stage of design/ construction unless specifically excluded in the audit brief. • Level of typical recommendations would be at most a conceptual design – make provision for conceptual design– the designer must take it further.	

8 REFERENCES

AASHTO . 2004. *A Guide for Achieving Flexibility in Highway Design. .* Black’s Law Dictionary Ninth Edition, 2009.

AASHTO. 2009. *Highway Safety Manual – 1st Edition.* American Association of State Highway and Transportation Officials: Washington DC.

Academic Expert Group for the 3rd Ministerial Conference on road safety . 2019. “SAVING LIVES BEYOND 2020: THE NEXT STEPS Swedish Transport Administration.

African Development Bank (b). 2014. *Road Safety Manuals For Africa: Existing Roads - Proactive approaches.* Transport and ICT Department.

African Development Bank group. 2014. *Road Safety Manuals For Africa: New Roads and Schemes -Road Safety Audit.* African Development Bank group .

Ahmed. 2013. Road infrastructure and road safety *Transport and Communications Bulletin for Asia and the Pacific* 83,pp. 19 -25.

Ahmed, M., Huang, H., Abdel-Atya, M and Guevara, B. 2011. Exploring a Bayesian hierarchical approach for developing safety performance functions for a mountainous freeway. *Accident Analysis and Prevention* (43), pp. 1581-1589.

Ahmeda, I., Puan, O.C. and Ismail, C.R. 2013. A Comparative Review of Road Safety Audit Guidelines of Selected Countries.*Journal of Technology* 65 (3), pp. 67-74.

Al-Adhoobi, M., Jose, M and Singh, V. 2017. A review of international practices of road safety audits. *6th International IEEE.*

Alexander, G.J. and Lunenfeld, H. 1986. *Driver Expectancy in Highway Design and Traffic Operations.* Washington D.C: U.S. Department of Transportation Federal Highway Administration .

Ali, N., Mulder, I and Mathew, A. 2016. “Annual Performance Plan 2016/17 – 2018/19.” *Presentation To The Portfolio Committee On Transport .*

Ambros J. Sedoník, J and Křivánková, Z. 2018. How to simplify road network safety screening?” *Advances in Transportation Studies: An international Journal Section* B, 44, pp. 151 -158.

Ambros, J and Jurewicz, C. 2017. From Big Data to Speed and Safety: A Review of Surrogate Safety Measures Based on Speeds From Floating Car Data. *Proceedings of the 2017 Australasian Road Safety Conference.* Perth, Australia, pp. 1-2.

American Traffic Safety and Services Association. 2013. *Work Zone Road Safety Audit Guidelines and Prompt Lists.* Federal Highway Administration and U.S. Department of Transportation.

Anarkooli, A.J., Milligan, C., Persaud, B., Penner, J and Saleem, S. 2019. Predicting Crashes with Safe Systems Surrogates Obtained from Video Analytics – Implications for Evaluation of Vision Zero Safety Treatments, *29th CARSP Conference,* Calgary, Alberta, pp. 1 -14.

Appleton, I. 2002. “Austroads Experience with Road Safety Audits.” Wellington, New Zealand: RPT Intertraffic Asia.

Archer, J. 2005. *Indicators for traffic safety assessment and prediction and their application in micro-simulation modelling.* Royal Institute of Technology: Stockholm, Sweden.

Arson, N. 2019. *The Safe System Approach - illiminating death and injury on Canadian roads.* Accessed 20 November 2020 from https://visionzero.ca/the-safe-systems-approach-for-road-safety.

Asian Development Bank. 2018. *CAREC Road Safety Engineering Manual Road Safety Audit.* Creative Commons Attribution 3.0 IGO license (CC BY 3.0 IGO).

Astarita, V and Giofré, V.P. 2019. From traffic conflict simulation to traffic crash simulation: introducing traffic safety indicators based on the explicit simulation of potential driver errors, pp. 1-35.

Atkinson, J., Chandler, and Rigdon, H and Donoughe, K. A. 2013. *Work Zone Road Safety Guidleines and Prompt lists.* Fredericksburg, Virginia.

Austroads. 2019. *Guide to Road Safety Part 6: Managing Road Safety Audits.* Austroads Ltd. Sydney Australia

Austroads. 2019. *Guide to Road Safety Part 6A: Implementing Road Safety Audits.* Sydney: Austroads Ltd.

Austroads. 2009. *Guide to Traffic Management Part 13: Road Environment Safet .* Sydney NSW Austroads Ltd., Australia.

Austroads. 2019. *Guide to Traffic-Management Part 1 Introduction to Traffic_Management AGTM01-19.* Austroads Ltd: Sydney NSW, Australia.

Beer, K. 2019. *Improving Road Safety With Safe System Assessments.* Australasia, Queensland: Institute of Public Works Engineering.

Beer, K., Moon, W., and Robertson, J. 2015. Safe System Auditing – principles to practice, Proceedings of the Australasian Road Safety Conference: Gold Coast, Australia, pp. 14 – 16 October.

Bevrani, K. 2013. *The development of a naturalistic car following model for assessing managed motorway Systems' safety effects.* School of Civil Engineering & Built Environment, Queensland University.

Bliss, m and Breen, J. 2009. *Country guidelines.* World Bank: Washington D.C

Bliss, T and Breen, J. 2012. Meeting the challenges of the Decade of Action for Road Safety. *IATSS Research,* 35, pp. 48-55.

Borsos, A., Birth, S and Vollpracht, H. 2015. The role of human factors in road design. *6th IEEE International Conference on Cognitive Infocommunications (CogInfoCom).* Gyor, Hungary, pp. 636-637.

Botha, G.J. 2005. Measuring road traffic safety performance. *Southern African Transport Conference: Pretoria*

Buttler, I. 2014. Safe System Approach - the expectations and challenges. *Fit to drive 8th International Traffic Expert Congress.* Motor Transport Institute Warsaw, pp. 1-21.

Cable, R. 2018. Road Safety Tools and the Current Status of Road Safety Audits in South Africa Session 2D: Road Safety Audit Workshop, 10 July. *Southern African Transport Conference .* Pretoria .

Cambell, J.L., Richard, C.M and Graham, S. 2008. *Human Factors Guidelines for Road Systems .* National Highway Cooperative Research Programme .

Central Asia Regional Economic Cooperation (CAREC). 2018. Road Safety Engineering Manual 1: Road Safety Audit. Asian Development Bank: Mandaluyong City.

Chaithoo, D.B., and D.R. Allopi. 2012. A software tool approach to re-evaluating superelevation in relation to drainage requirements and vehicle dynamics – a case study. *Southern Afrcian Transport Conference .* Document Transformation Technologies.

Charlton, S.G., Mackie, H.W., Baas, P.H. Hay, K., Menezes, M., and Dixon, C. 2010. Using endemic road features to create self-explaining roads and reduce vehicle speed. *Accident Analysis and Prevention* 42, pp. 1989-1998.

City of Illinois . 2015. "Complete Streets: Overall design and concepts ." : http://www.cmap.illinois.gov/programs-and-resources/local-ordinancestoolkits/complete-streets.

Committee of Land Transport Officials (COLTO). 2012. *TRH 26 South African Road Classification and Access Management Manual Version 1. 0.* Technical Recommendations for Highways Department of Transport: Pretoria.

Committee of Land Transport Officials. 1999. *South African Road Safety Manual (SARSM).* Department of Transport: Pretoria.

Committee of Transport Officials. 2014. *TMH 16 Volume 2 South African Traffic Impact and Site Impact Assessment Standards and Requirements Manual Version 1.01.* Department of Transport: Pretoria.

Conradie, D.H., L.H. Ras, and F. Mentz. 2008. The use of agent based simulation for traffic safety assessment. *Southern African Transport Conference .* Pretoria .

Road Traffic Management.Corporation, 2012. South African Road Safety Audit Manual.

Das, D.K and Burger, E.A. 2017. Appraisal of urban road safety factors in South Africa. *Municipal Engineer* 170 (1): pp. 6-15.

De Ceunynck, T. 2017. *Defining and applying surrogate safety measures and behavioural indicators through site based observations.* Doctoral Thesis, School of Transportation Studies, Department of Technology and Society, Lund University, Sweden.

Deng, F., Jordan, P and Goodge, M. 2012. Reducing Traffic Accidents in China: Strengthening the Use of Road Safety Audits. *China Transport Topics, pp.* 7.

Department of Municipal Affairs and Transport. 2018. *Road Safety Audit Manual .* Emirate of Abu Dhabi: Department of Municipal Affairs and Transport.

Department of Transport . 2008. *Draft National Non-Motorised Transport Policy.* Department of Transport: Pretoria.

Department of Transport. 2017. *Draft National Roads Policy for South Africa* Department of Transport: Pretoria.

Department of Transport. 2017. *Draft Revised White Paper on National Transport Policy.* Department of Transport: Pretoria.

Department of Transport. 2017. Draft Revised White Paper on Transport Policy. Department of Transport: Pretoria.

Department of Transport. 2015. *National Land Transport Strategic Framework.* Government Gazette.Department of Transport: Pretoria.

DeWar, D. 2017. Transportation Planning In South Africa: A Failure To Adjust. *WIT Transactions on The Built Environment* (WIT Transactions on The Built Environment) pp. 27-33.

Dhliwayo, M.E. 2000. Improving safety of use on SADC's roads. *19th Sourthern African Transport Conference:* Pretoria.

Economic and Social Commission for Asia and the Pacific (ESCAP). 2017. “Policies and issues related to road safety along the Asian Highway Network.” Bangkok, 13–15 December .

Edquist, J and Corben, B. 2012. *Potential application of Shared Space principles in urban road design: effects on safety and amenity.* Victoria: Monash University.

Elsenaar, P. 2002. Road safety improvements by transfer of knowledge, good practises, partnerships, and co-operation. *Southern African Transport Conference:.* Pretoria .

European Environment Agency. 2020. *Transport and environment report 2019: The first and last mile — the key to sustainable urban transport.* Luxembourg: Publications Office of the European Union.

Falkner, J. 2012. *RDDA South African Numbered Route Description And Destination analysis .* Pretoria : Department of Transport.

Fderal Highway Administration. 2009. *SafetyAnalyst.* Publication Number: FHWA-HRT-09-023, Office of Safety Research and Development: Mclean, Virginia.

Federal Highway Administration. 2016. Introduction to safety performance functions. *Crash Modification Factors in Practice FHWA-SA-13-016.*

Federal Highway Administration. 2019. *Improving Roadway Safety Performance, 1*9 February. Accessed 12 January 2021 from https://safety.fhwa.dot.gov/systemic/fhwasa17008/fhwasa17008.pdf.

2018. FHWA Road Safety Audit Guidelines.” 10 August . Accessed 01 December 2020 from https://safety.fhwa.dot.gov/rsa.

Federla Highway Administration. 2013. *Improving Safety on Rural Local and Tribal Roads — Safety Toolkit.* 4 October. Accessed 05 January 2021 from https://safety.fhwa.dot.gov/local_rural/training/fhwasa14072/sec4.cfm.

Federal Highway Administration. 2006. *Road Safety Audit Guidelines.* Federal Highway Administration.

FHWA. 2006. *Road Safety Audit Guidelines. Publication No. FHWA-TO-86-1. FHWA.* U.S: Federal Highway Administration.

Fournier, L. 2006. “PIARC Road Safety Audit Guidelines Seminar Canada Quebec .” October . Accessed 1 December 2020 from https://www.yumpu.com/en/document/read/27393202/piarc-road-safety-audit-guidelines.

Fwa, T.F. 2006. *The Handbook of Highway Engineering.* Boca Raton, FLorida, USA: Taylor & Francis .

Gan, A., Shen, J., Rodriguez, A. 2005. *Update of Florida Crash Reduction Factors and Countermeasures to improve the Development of District Safety Improvement Projects.* Tallahassee: State of Florida Department of Transportation .

Givechi, M. 2013. *What Are Human Factors and How Do They Affect Roadway Safety?* Fact Sheet, Kansas: University of Kansas Transportation Center for Road & Bridge Agencies.

Gómez Vélez, M and Sosa, A. J., Sánchez, D., Kogan, J (eds). 2014. *Road Safety Guidelines Multitaleral Development Banks.* Corporación Andina de Fomento.

Gordon, T., Bareket, Z., Kostyniuk, L., Barnes, M., Hagan, M., Kim, Z., Cody, D., Skabardonis, A and Vayda, A. 2012. *Site-Based Video System Design and Development.* Transportation Research Board National Academies of Sciences, Engineering, and Medicine Washington, D.C.

Gotts, B. 2004. *Network screening methods to identify roadway sites for safety investigation: An examination of some critical issues.* Ryerson University: Ontario, Canada.

Goukamp, M. 2019. “Draft Roads Policy for South Africa .” *KZN SARF Seminar.* Department of Transport .

Government of West Australia. 2012. South Australia’s Road Safety Strategy - 2020.”

Gregoriades, A. 2007. Road safety assessment using bayesian belief networks and agent-based simulation. Montreal, Quebec: IEEE International Conference on Systems, Man and Cybernetics, pp. 615-620. doi:Doi: 10.1109/ICSMC.2007.4413954.

Grey, N and Ncunyana, N. 2008. “The role of municipalities in transport service delivery: a case of Amathole district municipality. *Southern African Transport Conference:* Pretoria .

Groenewald, M. 2014. A systems approach to improving pedestrian safety in rural communities. *33rd Southern African Tarnsport Conference:* Pretoria.

Groenewald, Melissa, L. Lambert, A. Heyl, and A. Visagie. 2012. Solving road (and pedestrian) safety problems through sustainable job creation in our communities. *Southern African Transport Conference:* Pretoria .

Grosskopf, S.E., Labuschagne, F.J.J and Moyana, H. 2010. Road Safety Audits: The Way Forward. *Southern African Transport Conference:* Pretoria.

Grosskopf, Siegfried E., and J. Van Zyl. 2000. Is there room for innovation in the SA road traffic signs manual ? *19th Southern African Transport Conference:* Pretoria.

Guiebo, M. 2013. African Road Safety Charter, and TAH Harmonisation (Safety). *Africa Transport Policy Forum.* Dakar.

Hansen, F.D. 2006. Human error: A concept analysis. *Journal of Air Transportation* 11 (3), pp. 61-77.

Harkey, D.L., Srinivasan, R., Baek., J., Council, F.M., Eccles, K., Lefler, N., Gross, F., Persaud, B., Lyon, C., Hauer, E., Bonneson, J.A. 2008. *Accident modification factors for traffic engineering and ITS improvements.* NCHRP REPORT 617, Transportation Research Board: Washington D.C.

Hatzivalsamis, S. 2019. *Road Safety Audit Technical Directive and Guideline.* Northern Territory Government Department of Infrastructure, Planning and Logistics.

Hauer, E. 1998. *Safety in Geometric Design Standards.* University of Toronto: Toronto Canada

International Road Traffic Information and Data group. 2019. *New directions for data-driven transport safety.* OECD/ITF 2019.

International Road Traffic Safety and Analysis Group. 2019. *Road safety annual report 2019 South Africa.* OECD/ITF.

iRAP. 2017. *iRAP Star Rating and Investment Plan - Implementation and Support Guide.* International Road Assessment Programme.

IRAP Toolkit. 2010. *Road Safety Management.* Accessed December 09, 2020. http://toolkit.irap.org/default.asp?page=management&id=4.

Ismail, A., and P.R. Venter. 2007. The role and function of the South African Road Traffic Management Corporation. *Southern African Transport Conference:* Pretoria .

Jamille, V., Xavier, M., Craveiro Cunto, F. 2017. Comparative Analysis of Performance Measures for Network Screening: A Case Study of Brazilian Urban Areas. *Journal of Advanced Transportation*, pp. 1-8.

Job, S., Gaicd, F., Dipan B and Dahd, A. |. 2020. *World Bank launches road safety performance and appraisal tool.* Accessed on 1 December 2020. https://blogs.worldbank.org/transport/world-bank-launches-road-safety-performance-and-appraisal-tool.

Johannson, R. 2009. “Vision Zero – Implementing a policy for traffic safety.” *Safety Science*,47 (6), pp. 26 - 832.

Johnson, B. 2015. Road Safety audits. *Southern African Transport Conference:* Pretoria .

Jones, J.R. 2013. *A Method to Quantify Road Safety Audit Data and Results.* Civil and Environmental Engineering, Utah State University. https://digitalcommons.usu.edu/etd/1544.

Joubert. 2009. Needed: A paradigm shift in the provision of road infrastrucutre in Gauteng Province. *28th Southern Transport Conference:* Pretoria, pp. 75-82.

Jovanov, D (ed). 2018. *Practical Guide For Road Safety Auditors And Inspectors.* Belgrade: Automobile and Motorcycle Association of Serbia - Center for Motor Vehicles.

Jrew, B.K., Al-Masaeid, H.R. Hussein A. and Ewadh, H.A. 2002. “Development of Safety Audit Indices for Rural Roads.”

Jurewicz, C, L Steinmetz, and B Turner. 2014. *Australian National Risk Assessment Model.* Austroads Ltd: Sydney Australia.

Kane, T. 2011. AASHTO’s Highway Safety Manual and Performance Measures / Targets. *International Road Forum, pp.* 1-22.

Karndacharuk, A and Hassan, A. 2017. *Road Transport Management Framework and Principles.* Austroads: Sydney Australia

Kathmann, T., Ziegler, H and Pozybill, M. 2016. Road safety screening on the move.” *Transportation Research Procedia* 14, pp. 3322 – 3331.

Khorasani-Zavareh, D. 2011. “System versus traditional approach in road traffic injury prevention: a call for action. *Journal of Injury and Violence Research* 3 (2), pp. 61.

Kraay, J.P. 2002. “Mobility and road safety: Dutch Road Safety Policy 2001 -2020. *21st Southern African Transport Conference:*Pretoria .

Kumfer, W., LaJeunesse, S., Sandt, L and Thomas, L. 2019. Speed, Kinetic Energy, and the Safe System Approach for safer highways. *ITE Journal. pp.* 32 -36.

Labuschagne, F and Ribbens, H. 2014. Walk the talk on the mainstreamimg of non-motorised transport in South Africa. *Southern African Transport Conference:* Pretoria .

Labuschagne, F.J.J. and Pallet, K. 2010. Intelligent vehicle based traffic monitoring - exploring application in South Africa. *Southern African Transport Conference.* Document Transformation Technologies: Pretoria

Labuschagne, F.J.J. 2018. Review of the SARSAM 2012: Road Safety Audits in South Africa Workshop. *Southern African Transport Conference:* Pretoria .

Labuschagne, F.J.J., Van As, S.C., Roodt, LdV. 2002. The status of road safety audits and assessment in South Africa. *21st Southern African transport conference:* Pretoria .

Lau., F and Kuziemsky, C (editors). 2017. *Handbook of eHealth Evaluation: An Evidence-based Approach.* University Of Victori: Victoria (BC) .

Ldv, Roodt. 2012. Application Of The Highway Safety Manual 2010 To Two Road Sections In Western Cape. *31st Southern African Transport Conference.* Document Transformation Technologies: Pretoria.

Lerner, N., Llarenas, R., Smiley, A., Hanscom, F. 2005. *Comprehensive Human Factors Guidelines for Road Systems.*. Transportation Research Board: Washington, D.C.

Lorion, A. 2014. *Investigation of surrogate measures for safety assessment of two-way stop controlled intersections.* Masters of Applied Science, Civil Engineering, Faculty of Engineering, Ryerson University: Toronto, Ontario, Canada.

Lotter, S. 2000. Road safety performance measurement in South Africa. *19th Southern African Transport Conference:* Pretoria .

Main Roads Western Australia. 2015. *Policy and guidelines for road safety audits.* Road Safety Branch Planning and Technical Services Directorate.

Martens, K and Golub, A. 2018. A Fair Distribution of Accessibility: Interpreting Civil Rights Regulations for Regional Transportation Plans. *Journal of Planning and Education Research*, pp. 1 -20.

Martens, K. 2006. Basing Transport Planning on Principles of Social Justice. *Berkeley Planning Journal* 19 (1). https://escholarship.org/uc/item/0tg6v7tn.

McCarthy, T. 2011. *Risk Assessment Review.* ERA NET Project Nr: 823129.

Morrow, P.C. and Crum, M.R. 2004. Antecedents of fatigue, close calls, and crashes among commercial motor-vehcile drivers. *Journal of Safety Research,* 35, pp. 59-69.

Moyana, H. 2008. The role of the Road Traffic Management Corporation in research and education . *Southern African Transport Conference:* Pretoria.

Municipality of Abu Dhabi City. 2011. *Road Safety Audits Procedures for Abu Dhabi City Internal Roads.* Internal Roads and Infrastructure Directorate: Abu Dhabi City.

Nadler, B., Nadler F., Strnad, B. 2014. *Road Safety Inspections Manual for Conducting RSI.*: Research of the Austrian Road Safety Fund: Vienna.

NAMPORT. 2018. *The Trans-African highway network will connect the continent.* Accessed on 21 January 2021 from https://www.namport.com.na/news/321/the-trans-african-highway-network-will-connect-the-continent-report.

National Safety Council. 2011. “White paper: Understanding the distracted brain.” 1-30. http://www.nsc.org/safety_road/Distracted_Driving/Pages/CognitiveDistraction.aspx. .

Neuman, T.R., Schwartz, M., Clark, L and Bednar, J. 2002. *A Guide to Best Practices for innovative solutions.* National Cooperative Highway Research Programme NCHRP REPORT 480: Wahington D.C.

Noyce, D.A., Chitturi, M.V., Qin, L., Santiago, K.R. and Bill, RA. 2018. Virtual Road Safety Audits: Recommended Procedures for Using Driving Simulation and Technology to Expand Existing Practices.

NSW Centre for Road Safety . 2011. *Guidelines for Road Safety Audit Practices.* Roads Authority New South Wales.

Nyarirangwe, M. 2009. A causal-based multi-sectoral approach to the prevention of road traffic accidents and prioritization of response measures in South Africa. *Southern African Transport Conference.* Document Transformation Technologies: Pretoria.

NZ Transport Agency. 2013. *Road safety audit procedures for projects: Guidelines Interim release.* SAfer Journeys New Zealand.

Officials, American Association of State Highway and Transportation. 2011. *A Policy on Geometric Design of Highways and Streets.* AASHTO:Washington D.C.

Ogden, K.W. 1996. *Safer Roads: A guide to safer engineering.* Cambridge: Great Britian: University Press.

Ogden, K.W. 1994. *Traffic engineering road safety: A practiioners guide.* Commonwealth of Australia.

Ojungu-Omaru, I. and VanderSchuren, M.J.W.A. 2006. Ways of reducing accidents on South African roads. *Southern African Transport Conference:* Pretoria.

Oliver, P.A., E. De Beer, and H. Ribbens. 2005. Road traffic safety management strategy for the Western Cape Province. *Southern African Transport Conference:.* Pretoria.

Oneyear, N., Hallmark, S and Wang, B. 2016 . *Evaluating the relationship between the driver and roadway to address rural intersection safety using THE SHRPII database.* Ames, Iowa: Center for Transportation Research and Education Iowa State University .

Page, J.H. 2009. *A comparison of integrated transport and spatial planning tools: Case study of Eden District and Hermanus local municipality.* Thesis, North West University: Pothchefstroom.

Paré G., Trudel M.-C., Jaana M., Kitsiou S. 2015. Synthesizing information systems knowledge: A typology of literature reviews. *Information & Management.* 52 (2): 183 -199.

Persia, L., Usami, S.L., De Simone, L., De La Beaumelle, V., Yannis, G., Laiou, A. 2016. Management of road infrastructure safety.*Transportation Research Procedia 14 (2016) 3436 – 344* 3436 -3445.

Phayane, S. 2015. Non-Motorised Transport : The Need For Facility Guidelines That Create Safer Roads For Communities.Department of Transport: Pretoria:.

PIARC Techinal commititee C2 Safer roads and infrastructure. 2018. *Review of Global Road Safety Audits- with special reference to low and middle income countries.* Cedex, France: World Road Association (PIARC).

Plaatjies, P. 2010. National training framework for road traffic management. *Southern African Transport Conference.* Document Transformation Technologies: Pretoria.

Polidoria, C., Adesiyun, A., Cocuc, X., Saleh, P and Lemke, K. 2012. European Common Standardized Certification Methodology for Road Safety Experts. *Procedia - Social and Behavioral Sciences*, 48, pp. 85-94.

Pretoriaus, P., Pretorius, L., Swanepoel, A and Ven Der Merwe, B. 2014. *Roads infrastructure policy for South Africa: Draft Policy Framework.* Department of Transport: Pretoria.

Ramorobi, T., McGuigan, D and Mouws, J. September 2011. Prioritisation of non-motorised projects. *South African Journal of Civil Engineering, pp.*60 -64.

Reason, J. T., Manstead, A. S. R., Stradling, S. G., Baxter, J. S., & Campbell, K. 1990. Errors and violations on the road: A real distinction? *Ergonomics* 33, pp. 1315–1332.

Regal, D. M, Rogers, W. H, and Boucek, G. P. 1988. Situational awareness in the commercial flight deck – definition, measurement, and enhancement. *In Proceedings of the 7th SAE*

Aerospace Behavioral Technology Conference, Anaheim Convention Center, California, : Society of Automotive Engineers, pp. 65-69.

Ribbens, H., and L. Gamoo. 2006. The need to provide safe and secure non-motorized transport infrastructure and amenities.*Southern Afrcian Transport Conference:* Pretoria.

Ribbens, H., and S Pillay. 2008. Ward-based community road safety performance benchmarking, monitoring and intervention programmes in the city of Johannesburg. *Southern African Transport Conference:* Pretoria .

Richards, D.C. 2010. *Relationship between Speed and Risk of FatalInjury: Pedestrians and Car Occupants.* Transport Research Laboratory: London.

Road Traffic Management Corporation . 2013. SARAP. Pretoria.

Road Traffic Management Corporation. 2018. *Review of the South African Road Safety Audit Manual (SARSAM-2012).* Road Traffic Management Corporation (RTMC). http://www.rtmc.co.za/images/rtmc/docs/research_dev_rep/SARSAM-2012%20Review%20-%20March18_001.pdf.

Road Traffic Management Corporation. 2019. *Road fatality report: January to December 2018.* Pretoria: Department of Transport .

Road Traffic Management Corporation. 2012. *South African Road Safety Audit Manual.* Road Traffic Management Corporation. Accessed 2016. http://www.nra.co.za/.

Rolison, R., Regev,S., Moutari, S. and Feeney, A. 2018. What are the factors that contribute to road accidents? An assessment of law enforcement views, ordinary drivers' opinions, and road accident records. *Accident Analysis and Prevention*, 115, pp. 11-24.

Roodt, LdV. 2014. "Road safety, maintenance and claims for damages : lessons from cases and investigations" *Southern African Transport conference .* Pretoria .

Ross, A., Jovanov, D and Ivchenko, M. 2014. *Regional Road Safety Guidelines TRACECA Regional Road Safety Project.* The European Union TRACECA programme.

Ross, A., Jovanov, D., Brankovic, R., Volpracht, H., Trajkovic, F. 2016. *Road Safety Audits Practical Guide for Road Safety Auditors.* International Road Safety Centre.

Roux, D. 2018. Formalisation Of Road Safety Audit Processes In South Africa . *Southern African Transport Conference:* Pretoria.

Sabey, B. 1995. Engineering safety on the road. *Injury Prevention ,*1, pp. 182-186.

SANS 784:2008 Design for access and mobility Tactile Indicators. South African Buro of Standards .

Safarpour, H., Khorasani-Zavareh, D and Mohammadi, R. 2020. "The common road safety approaches: A scoping review and thematic analysis." *Chinese Journal of Traumatology* 23, pp. 113 -121 .

SANRAL. 2019. *SARDS: South African Road Design System Technical Reference Manual NetSafe Highway Safety model version 2.* SANRAL: Pretoria:

Schemers, G. 1997. *Road safety audit guidelines for road authorities in South Africa.* National Department of Transport: Pretoria.

Sekgothe, I., and J.K. Maluleke. 2005. Safety as an indispensable quality requirement in transport *Southern African Transport Conference:* Pretoria.

Shah, S.A.R., Naveed, A., Yongjun., Pirdavani, A. 2018. Road Safety Risk Assessment: An Analysis of Transport Policy and Management for Low, Middle and High Income Asian Countries.

Sitran, A., Delhaye, E and Uccelli, I. 2016. Directive 2008/96/EC on road infrastructure safety management: an ex-post assessment 5 years after its adoption.*Transportation Research Procedia* 14, pp. 3312 – 3321.

South African Government. 2019. *Transport* 3 September. https://www.gov.za/about-sa/transport.

South African National Roads Agency . 2017. *Guidelines for pedestrian and public transport facilities on National Roads .* Johannesburg: SANRAL.

Srinivasan, R, F Gross, B Lan, and G Bahar. 2016. *Reliability of safety Management Methods: Network Screening.* Federal Highway Administration: New Jersey.

Stander, H.J., Harmse, A.W., Kannemeyer, L and Van Renssen, F. 2015. South Africa - Country Report on Geometric Design.

Steinmetz, L., Jurewicz C and Taylor, S. 2015. *Safe System in the planning process.* Austroads Ltd: Sydney

Stipancic, J and Saunier,N. 2017. Surrogate Safety and Network Screening: Modelling Crash Frequency Using GPS Data and Latent Gaussian Models. *Conference of the Transportation Association of Canada.* St. Johns, pp. 1-19.

Sucha, M. 2015. Road design: Human factors perspective. Department of Psychology. http://psych.upol.cz/wp-content/u.

Summala, H. and Timo, M. 1994. Fatal Accidents among Car and Truck Drivers: Effects of fatigue, age, and alcohol consumption. *Human Factors - The Journal of the Human Factors and Ergonomics Society,* 36 (2), pp. 315-326.

Sustainable Mobility for All (TM). 2018. *A Review Of International Agreements, Conventions And Other Instruments To Achieve Sustainable Mobility For All.* Creative Commons Attribution 3.0 IGO license (CC BY 3.0 IGO) .

SWECO International and Nordica Consulting. 2003. *Review Of The Implementation Status Of The Trans African Highways And The Missing Link volume 1: Main Report .* Stockholm, Sweden: AfDB and UNECA.

Tekie, S.B. 2001. Role of the Road Management System in a commercialized environment (Namibian experience). *20th Southern African Transport Conference:* Pretoria.

The South African National Roads Agency (SOC) Ltd. 2019. *Road safety audit guideline.* SANRA: Pretoria.

The World Bank. 2014. *Making Roads Safer Learning from the Worlkd Bank experiences.* International Bank for Reconstruction and Development / The World Bank: Washington D.C:

Theeuwes, J and Godthelp, H. 1995. Self-explaining roads. *Safety Science, pp.* 217 -225.

Theeuws, J., Van der Horst, R., Kuiken, M. 2012. *Designing Safe Road Systems - A human factor perspective* 1st edition. CRC press Taylor and Francis Group Boca Rayton: Florida.

Tidström, C. 2013. Towards Zero Conference - Keynote address. Clarion Sign Hotel, Regeringskansliet: Stockholm 4- 5 June.

Transformative Urban Mobility Iniative. 2020. *The COVID-19 outbreak and implications to sustainable urban mobility – some observations.* 24 April. https://www.transformative-mobility.org/news/the-covid-19-outbreak-and-implications-to-public-transport-some-observations.

Transport Infrastructure Ireland. 2017. *Road Safety Audit Guidelines GE-STY-01027.* TII Publications.

Transportation Research Board. 2000. *Highway Capacity Manual.* National Academies: Washington DC.

Transportation Research Board. 2018. *NCHRP Report 600: Human Factors Guidelines for Road Systems: Second Edition.* Federal Highway Administration: Washington D.C .

Underwood, R.T. 1990. *Traffic management: an introduction.* North Melbourne, Hargreen Publishing Company: Victoria, Australia.

United Nations. 2017. *Road Safety Considerations in support of the 2030 Millenium Development Goals.* United Nations.

United Nations Economic Commission for Europe. 2018. *Road Safety Audit and Safety Inspection on the TEM network.* United Nations: New York & Genieva.

University of Wisconsin–Madison. 2020. *Development Of A Virtual Road Safety Audit Methodology.* Accessed on 2 December 2020 from https://topslab.wisc.edu/research/tse/development-of-a-virtual-road-safety-audit-methodology.

US Federal Highway Administration. 2009. Technical summary of the Surrogate Safety Assessment Model and Validation: Final Report, FHWA-HRT-08-051. *Technical brief* 10, pp. 1-4.

Van As, S.C., M. Steynberg, and J. Scheepers. 2003. Gautrans road safety audits number of road safety audits. *Southern African Transport Conference:* Pretoria.

Van Rooyen, B. 2002. The killing fields of Germiston. *21st Southern African Transport Conference:* Pretoria.

Van Schalkwyk, I and Roodt, LdV. 2000. "Macro-level evaluation of road safety interventions: an evaluation of Arrive Alive 1 (1997/1998) road safety campaign. *19th Southern African Transport Conference:* Pretoria .

Vander Schuuren, M., Zuidgeest, M., Phayane, S., Taute, A., Dingle, N., Ribbens, H., Pillay, K., Enicker., E.,Baufeldt, S., Jennings, G. 2014. *NMT Facility Guidelines: Planning, design and operations.* Department of Transport: Pretoria.

VanderSchuuren, M.J.W.A. and Irvine, C.C. 2002. "Is South Africa ready for an international comparison." *Southern African Transport Conference.* Pretoria.

Vardaki, Sophia, Fanis Papadimitriou, and Pantelis Kopelias. 2014. Road safety audit on a major freeway: implementing safety improvements. *European Transport Research Review* 6, pp. 387–395.

Vasconcelos, L., Neto, L., Maia Seco, A and Bastos Silva, A. 2014. Validation of the Surrogate Safety Assessment Model for Assessment of Intersection Safety. *Transportation Research Record: Journal of the Transportation Research Board,* pp. 2432.

Venter, C.J. and Schreuder, HdJ. 2005. "Implementation of traffic control measures systems as an interim labour-based alternative to ITS." *Southern Afrcian Transport Conference.* Pretoria.

Venter, Y., L. Hermant, K. Shirley, E. Tukushe, and Tuckweng Kok. 2014. Addressing non-motorised transport movement along and across railway lines in the city of Cape Town. *Southern African Transport Conference.* Pretoria.

Visser, D.P and Prinsloo, J.J.A. 1999. "Volume 7 Design for Safety ." In *South African Road Safety Manual*, Committee of Land Transport Officials (COLTO) National Department of Transport: Pretoria, pp. 1- 42

Vogel, T., Reinharz, D., Gripenberg, M., and Barennes, H. 2015. An organizational analysis of road traffic crash prevention to explain the difficulties of a national program in a low income country. *BMC Research Notes* 8, pp. 486.

Vollpracht, H., Pfeiffer, L., Baumann, R., Ross, A., Jovanov, D., Branković, R., Trajković, F., Calin, C., Moraru, R., Bricicaru, I., Kukić, D., Jasnić, S., Jovanov, J and Radović, N. 2018. *Practical guide for road sasfety auditors and inspectors.* Automobile and Motorcycle Association of Serbia - Center for Motor Vehicles: Belgrade.

Vom Brocke, J., Alexander, S., Niehaves, B.,Riemer, K., Plattfaut, R and Cleven, K. 2009. "Reconstructing the Giant: On the Importance of Rigour in Documenting the Literature Search Process."

Vorster, H.D., and J. Seymour. 2013. "Safe designs for BRT systems." *Southern African Transport Conference:* Pretoria.

Vorster, H.D., and S.C. Van As. 2008. Research needs on traffic management and safety: The local authority's perspective.*Southern African Transport Conference:* Pretoria.

Wang, W., Xi, J and Chen, H. 2014. Modeling and Recognizing Driver Behavior Based on Driving Data: A Survey. *Mathematical Problems in Engineering*, pp. 1-20. doi:http://dx.doi.org/10.1155/2014/245641.

Watson, P.W. 2000. “The Asiphephe Road Safety programme measured against issues for developing countries as identified by global road safety partnerships” *19th Southern African Transport Conference:* Pretoria.

Wegman, F., Bergblain, H., Cameron, C., Thompson, T., Siegrist, S., Weijermarse, W. 2015. “Evidence-based and data-driven road safety management.” *International Association of Traffic and Safety Science IATSS* (39), pp. 19 -25.

Wegman, F.C.M. and Aarts, L.T. (red.). 2006. *Advancing Sustainable Safety; National Road Safety Outlook for 2005-2020.* SWOV Institute for Road Safety Research: Leidschendam.

Wolhuter, K.M. 2015. “Handook of Geometric Design of Roads.” Boca Raton, Florida : CRC Press Taylor & Francis Group.

World Health Organisation. 2019. *Global Status Report On Road Safety 2018.* World Health Organisation: Switzerland.

World Health Organization. 2009. *Global Status Report On Road Safety: Time For Action .* World Health Organization: Switzerland.

World Road Organisation (PIARC). no date. https://roadsafety.piarc.org/en/planning-design-operation-risks-issue-identification/proactive-identification.

Wu, K.F and Jovanis, P.P. 2013. Defining and screening crash surrogate events using naturalistic driving data. *Accident Analysis and Prevention,* 61, pp. 10-22.

Xavier, J and Cunto, F. 2017. Comparitive analysis of performance measures for network screening: A case study of Brazilian Urban areas. *Journal of Advanced Transportation*, pp. 1-9.

Yannis, G., Gittelman, V., Papadimitriou, E and Hakkert, S.A. 2018. Road Safety Risk Assessment: An Analysis of Transport Policy and Management for Low Middle and High-Income Asian Countries. *Sustainability, pp.* 389-399.

Yannis, G., Weijemars, W and Kaupilla, J. 2012. A review of international sources for road safety measures assessment. *Procedia - Social and Behavioral Sciences* 48, pp. 2876 – 2886.