Research into Road Safety Performance Monitoring on South African Roads

PART A: LITERATURE REVIEW

Road Traffic
Management Corporation

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Prepared for:

Road Traffic Management Corporation
Research and Development
D Roux
Tel: (012) 999 5200
Email: Deonr@rtmc.co.za

Prepared by:

Techso (Pty) Ltd
W Ferreira
Tel: (012) 943 6244
Email: wim@techso.co.za

QUALITY CONTROL

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Appointment to assist the Road Traffic Management Corporation (RTMC) to conduct a literature review and develop a methodology to guide Traffic Offence Surveys (Road Safety Performance Monitoring) Part A: Literature Review		
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Authors: Ms Nene Ntlatleng, Ms Saajidah Williams Mr Wilko Mohr, Mr Anton Struwig Mr Wim Ferreira, Dr Johann Andersen		**Client:** Mr Thabiso Ndebele Mr Kevin Kara-Vala Mr Deon Roux
Signed:		
By Author:	Ms Nene Ntlatleng	
Reviewed By:	Mr Stefan Lotter	
Checked By:	Mr Wim Ferreira	
Authorised By:	Dr Johann Andersen	
Approved By:	Mr Deon Roux	

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ABBREVIATIONS

AARTO	-	Administrative Adjudication of Road Traffic Offences
ACC	-	Adaptive Cruise Control
ALS	-	Advanced Life Support
ANPR	-	Automatic Number Plate Recognition
APTMS	-	Advanced Public Transport Management System
ASOD	-	Average Speed Over Distance
ATMS	-	Automated Traffic Management System
BAC	-	Blood alcohol content
BLS	-	Basic Life Support
BRT	-	Bus Rapid Transit
CAS	-	Crash Avoidance System
CAV	-	Connected Autonomous Vehicle
CBRTA	-	Cross Border Road Agency
CDR	-	Call Data Record
CPS	-	Crash Protection System
CTO	-	Comprehensive Traffic Observations
DoT	-	Department of Transport
EMD	-	Emergency Medical Dispatch
EMS	-	Emergency Medical Services
ESC	-	Electronic Stability Control
ESRA	-	European (E-) Survey of Road users' safety attitudes
ETC	-	Electronic Toll Collection
eToll	-	Electronic Toll
ETSC	-	European Transport Safety Council
EuroNCAP	-	European New Car Assessment Programme
FMS	-	Freeway Management Systems
GDE	-	Goal for Driver Education
GPS	-	Global Positioning System
GSM	-	Global System for Mobile Communication
GSRRS	-	Global Status Report on Road Safety
HEMS	-	Helicopter Emergency Medical Services
HRS	-	High Risk Site
ICU	-	Intensive Care Unit
ISA	-	Intelligent Speed Assistance
ITF	-	International Transport Forum
LDWS	-	Lane Departure Warning System
MICU	-	Mobile Intensive Care Unit
MNO	-	Mobile Network Operator
MOU	-	Memorandum of Understanding
NaTIS	-	National Traffic Information System
NHS	-	National Health Service
NMT	-	Non-Motorised Transport
NRIMS	-	National Road Incident Management System
NRSS	-	National Road Safety Strategy
NSR	-	Network Safety Ranking

NTID	-	National Traffic Information Database
OBU	-	On-board Units
OD	-	Origin-Destination
OECD	-	Organisation for Economic Co-operation and Development
ORT	-	Open Road Tolling
OSD	-	Overtaking Sight Distance
PrDPS	-	Professional Driving Permits
PSAP	-	Public Safety Answering Point
RAP	-	Road Assessment Program
RIA	-	Road Safety Impact Assessments
RSA	-	Road Safety Audit
RSI	-	Road Safety Inspections
RSPI	-	Road Safety Performance Indicators Manual
RSPM	-	Road Safety Performance Monitoring
RTC	-	Road Traffic Crash
RTIA	-	Road Traffic Infringement Agency
RTMC	-	Road Traffic Management Corporation
SANRAL	-	South African National Roads Agency
SAPS	-	South African Police Services
SPI	-	Safety Performance Indicator
SPM	-	Safety Performance Monitoring
TARN	-	Trauma Audit & Research Network
TMC	-	Transport Management Centre
TOS	-	Traffic Offence Survey
UN	-	United Nations
UNDA	-	United Nations Decade of Action
US	-	University of Stellenbosch
V2I	-	Vehicle to Infrastructure
V2V	-	Vehicle to Vehicle
V2X	-	Vehicle to Others
VMS	-	Variable Message Signs
WHO	-	World Health Organisation
WIM	-	Weigh-in-Motion

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IMPORTANT NOTE ON NAME CHANGE

Since the inception of monitoring road safety concerns in South Africa, the focus has been on traffic offences linking to the level of lawlessness. The term *Traffic Offence Surveys* has therefore been utilised for purposes of describing the process of gathering and interpreting data relating to road safety. While offences are important to consider and form a major part of the road safety picture, there is more to road safety than just road user behaviour. Elements such as post-crash care and trauma management, as well as road infrastructure and vehicle safety are important to consider.

As part of developing a new methodology to aid the gathering of road safety information, the term *Traffic Offence Surveys* was found to be too narrow in application and the decision was made to coin the term ***Road Safety Performance Monitoring (RSPM)*** as a means to address road safety more holistically. The Part A document (Literature Review) still makes reference to *Traffic Offence Surveys*, yet facilitates the transition to the more inclusive description. The Part B document (Methodology), will exclusively make use of the new term.

1. INTRODUCTION

The Road Traffic Management Corporation (RTMC) appointed Techso to conduct a literature review and develop a sound methodology for Traffic Offence Surveys (TOS) in South Africa. TOSs are an important tool in measuring and obtaining representative offence rates on national, provincial and metropolitan level and give indication regarding specific areas of intervention.

Since 1975 many different TOS methodologies have been developed to assist in this process, yet a continuously changing environment and rapid advancements in technology require an updated methodology. The RTMC aims to implement a new methodology as based on international best practice guidelines, yet taking into account specifically developing countries and the local context of the South African road conditions.

1.1. Project objectives

The overall objective of this appointment is the development of a coherent and practical TOS methodology. This is guided by the 2016-2030 National Road Safety Strategy (NRSS) aimed at reducing road related fatalities with 50% by 2030. The NRSS is underpinned by the United Nations Decade of Action (UNDA), to which South Africa is a signatory.

The project is linked to the following NRSS Interventions that need to be implemented:

4A(ix) Conduct research into incentives for compliant road user (specifically fleet owners and drivers) behaviour (Behavioural economics research).

4C(vi) Identify and address of high-risk road users for focused interventions.

4C(iii) Urgently investigate the deficiencies in current enforcement practices and systems, and rectify.

One key element of developing TOS methodology documentation is the contextual relevance to South Africa as well as the pragmatic and useful approach that is to be implemented in order to make South African Roads safer for all road users.

1.2. Methodology followed during the project

In order to address the required objectives successfully, the following approach was taken:

1. Conduct a literature review and desktop study into TOSs
   - Review earlier South African methodology documents and identify gaps and impacts.
   - Study relevant international guidelines and best practices regarding road safety in general and the developing country context.
   - Conduct a focused literature review of international TOS methodology documentation and implementation strategies.
   - Consider the potential impact of new technologies and how these can be utilised in more successful TOSs.
2. Develop a sound TOS methodology for the South African context
   - Taking into account the literature review outcomes and integrating those into the methodology.

- Develop a methodology considering all elements of a TOS including sampling strategies, data collection methods, performance indication and quality control, data processing and analysis as well as the response to identified problem areas.
- Specifically, select and detail the Safety Performance Indicators (SPIs) that would make the most impact based on the 80/20 principle and according to best practice within the Safety Domains. Other SPI's can be included in future versions of the Methodology as and when this becomes necessary.

In order to most usefully lay out the project findings, these two sections are published as two separate documents.

PART A: Literature Review

PART B: Road Safety Performance Monitoring Methodology

This document discusses the process, findings and implications of the **literature review**.

1.3. Contents of the literature review

The literature review consists of the following sections:

1. Review of previous local Traffic Offence Survey methodologies
2. International review of Traffic Offence Survey methodologies and other documentation
3. Summary and input to the 2021 South African Traffic Offence Survey methodology
4. Further research opportunities

2. REVIEW OF PREVIOUS LOCAL TRAFFIC OFFENCE SURVEY METHODOLOGIES

Traffic offence surveys have been conducted in South Africa since the 1970's. The most recent methodology development was undertaken in 2013 by the University of Stellenbosch. This was in response to challenges regarding the coordination of the surveys and the quality of the data that was collected in 2011 and 2012. Due to several constraints the last fully independent surveys were conducted in 2010.

This chapter aims to summarise the various methodologies that were defined over the years, with specific attention given to the 2013 methodology as forming the basis for the current methodology development since no actual surveys were conducted based on that methodology. A few key gaps are identified and aspects of importance are highlighted that need to be taken into account.

2.1. Purpose of South African Traffic Offence Surveys

In order to combat the occurrence of road traffic crashes and to plan and undertake road traffic safety programmes and interventions, it is important to obtain information and statistics on road traffic offences. The original purpose of the TOS was to obtain representative national and provincial traffic offence rates which is an index of the general level of lawlessness on the road network on an annual basis. However, since the introduction of the Arrive Alive campaigns the purpose of the TOS has changed and a secondary purpose was incorporated. This secondary purpose was to measure the effect and impact of road safety and law-enforcement programmes on the level of lawlessness and the occurrence of traffic crashes.

The additional purpose of the TOS meant that it formed part of an outcomes-based road traffic management cycle (see Figure 2-1) whereby the results obtained from the TOS (along with data on vehicle licensing and roadworthiness, etc.) served as an intermediate outcome to achieve the final outcome of creating an analytical basis to strategically plan, improve and implement efficient and effective road safety interventions and allocate resources. Apart from functioning as an additional planning tool, the results of the TOS are also used as indicators for progress and monitoring and assessing the degree of lawlessness on South African roads. Furthermore, the output of the TOS (in conjunction with road crash and fatality statistics) also serve as indicators of the measure of success of road safety performance.

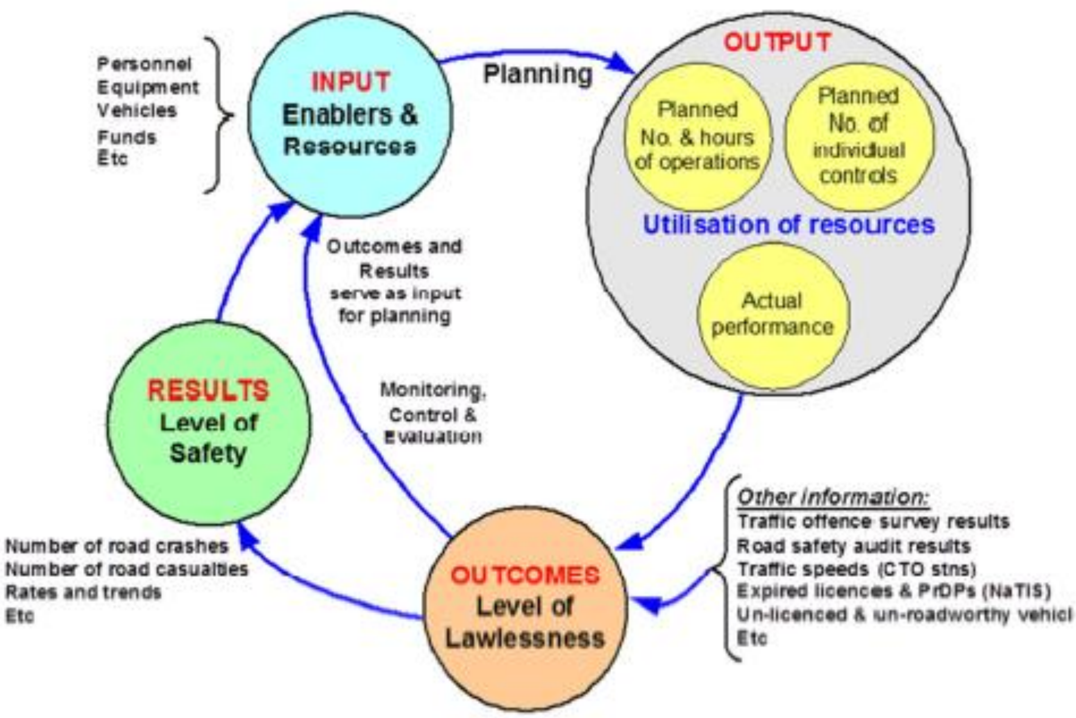


Figure 2-1: Road traffic management cycle

(Source: Consolidated National, Provincial, Metropolitan and Selected Local Authority Road Traffic Management Business & Financial Plan, 2008-2009)

2.2. Summarised review of methodologies and initiatives earlier than 2013

The 2013 methodology document made reference to the earlier TOS methodologies. The summary of those is captured in Table 2-1 below. The following aspects of the methodologies were summarised:

- Purpose of TOS
- Traffic offences surveyed
- Sample size
- Surveyed times
- Survey location
- Method of recording offences

Table 2-1: Summary of pre-2013 TOS methodologies

	Period of TOS methodology				
	1975	**1997-2001**	**2002-2006 (excl. 2004)**	**2007-2010**	**2011-2012**
Purpose of TOS	Determine certain offence rates	Conduct law enforcement operations (roadblocks) at selected locations. Determine relationship between level of law enforcement and no. of crashes and injuries. No offence monitoring surveys conducted	Determine general level of lawlessness with regard to identified traffic offences From 2005: Determine offence rates and trends on selected hazardous routes identified by RTMC. Also, measure impact of law enforcement programmes on level of lawlessness and crash occurrence	Determine general level of compliance on road and measure impact of law enforcement and road safety education	Determine general level of lawlessness on roads and determine the impact of intervention strategies to promote road safety
Traffic offences surveyed	Seat-belt wearing rates (all car occupants), alcohol drinking rates (drivers + pedestrians)		Speed (urban, rural), alcohol levels (drivers, pedestrians), seat-belt use (all occupants), vehicles ignoring traffic signals, overtaking on barrier lines, jaywalking, validity and presence of driver documentation (driving license, professional driving	Same as traffic offences surveyed from 2002-2006, with exclusion of jaywalking and inclusion of pedestrians disobeying traffic signals	Same as traffic offences surveyed from 2007-2010, with the inclusion of the use of child restraints, the use of cellular phone while driving

	Period of TOS methodology				
	1975	1997-2001	2002-2006 (excl. 2004)	2007-2010	2011-2012
			permits), presence and validity of vehicle documentation (vehicle license discs, correspondence between license disk and number plate), vehicle fitness (quality of tyres, vehicle lights), observations (animals on road, cyclists, presence of traffic officers on duty on rural roads)		
Sample size	Alcohol drinking: 400 driver, 400 pedestrians Seat-belt wearing: 400 passenger and commercial vehicles (all car occupants monitored)	Various traffic departments participating in Arrive Alive campaigns	Small and inexpensive samples used as provided same results as large samples 2002 sampling strategy: random sampling and selection of roads (based on crash history, traffic volume, etc.) for each province, major cities, towns and smaller towns	Same as sample size used from 2002-2006	

	Period of TOS methodology				
	1975	**1997-2001**	**2002-2006 (excl. 2004)**	**2007-2010**	**2011-2012**
Surveying times	Alcohol readings: Annually (August and September), Monday-Saturday Drivers tested: 20:00-01:00, Pedestrians tested: 17:00-19:00 Seat-belt wearing: Annually (August and September), Weekdays		Survey locations, days, times standardised to enable year-on-year comparisons Between September and November Wednesday evenings-Monday afternoons	Aim was to survey offences during same times used from 2002-2006 period, however, surveys conducted different times of the year	
Survey location	Alcohol drinking: 58 sites countrywide Seat-belt wearing: 120 sites countrywide		Local authority level, provincial level, national level. From 2005: additional hazardous locations included	2007: Same as sampling locations used from 2002-2006 2008-2010: fewer locations surveyed per town, only 60 km/h zones in urban areas surveyed 2008: only representative sample of additional hazardous locations surveyed	Surveys conducted in few provinces

	Period of TOS methodology				
	1975	1997-2001	2002-2006 (excl. 2004)	2007-2010	2011-2012
Method of recording offences	Alcohol drinking: Lion Alcolmeter SD-400 to conduct breath tests Seat-belt wearing: Vehicles stopped and checked	Data collected from various traffic departments participating in campaigns.	Unlicensed vehicle statistics: from National Traffic Information System (NaTIS) Speed offence data: from traffic monitoring stations on national roads Barrier line offences: Poisson distribution used, determined that no. of offences to be counted over a longer period than two-minute interval	Alcohol readings: 2007-Sentech Alcoscan AL-500 and later AL-6002008 onwards-AlcoBlow breath scanners Speed measurement: Genesis GHD radar gun Barrier line offences: no. of offences counted per two-minute interval From 2008-2010: no. of convoys crossing barrier lines recorded instead of no. of vehicles Pedestrians (from 2008-2010): compliance with signals recorded as offence instead of jaywalking	

2.3. University of Stellenbosch (US) Traffic Offence Survey methodology 2013

Chapter 4 and 5 of the 2013 methodology firstly detailed the key decisions that were made in regards to several TOS survey aspects and then provided and approach to be followed.

2.3.1. Summary of key decisions made

The following key activities were summarised in Table 2-2 in terms of the key decisions made:

- Safety performance monitoring (purpose and indicator types)
- Sampling strategy
- Data quality
- Data collection and processing

2.3.2. 2013 TOS methodology approach

In support of the key decisions that were made in the 2013 methodology, the following main activity approach steps were laid out in chapter 5 of the methodology:

- Selection of safety performance indicators
- Sampling strategy
- Survey procedures
- Data collections and recording
- Data processing and analysis

These are summarised in Table 2-3 of this report.

Table 2-2: Summary of key decisions made in the 2013 TOS methodology

Activities		Key decision made	Comment
1	**Safety performance monitoring (purpose and indicator types)**	Follow holistic approach and monitor road safety performance indicators as opposed to surveying road traffic offences. Surveys form part of outcomes-based traffic management cycle that informs road safety interventions. Set targets for safety performance indicators every 10 years in line with RTMC long-term strategy and UNDA goals. **Indicator types to be surveyed (from 2002 methodology):** Speed (urban, rural), alcohol levels (drivers, pedestrians), seat-belt use (all occupants), vehicles ignoring traffic signals, overtaking on barrier lines, jaywalking, validity and presence of driver documentation (driving license, professional driving permits), presence and validity of vehicle documentation (vehicle license discs, correspondence between license disk and number plate), vehicle fitness (quality of tyres, vehicle lights), observations (animals on road, cyclists, presence of traffic officers on duty on rural roads) **Indicator types for further consideration:** Emergency response time, fatigue, age distribution of vehicles **Indicators to be explored for further research:** Novice drivers, pedestrian behaviour (other than compliance with traffic signals), following distance, road congestion, drugs, unforgiving road infrastructure (medians, barriers, obstacles, provision and maintenance of pedestrian and bicycle paths) **From 2014 onwards:** List of indicator types to be surveyed every year, for a period of at least 3 years, each year during same months of year and at same locations Set targets for various indicator types that must be reviewed and is in line with RTMC's long-term strategy	• Confirm the holistic approach to road safety performance monitoring. • Overall and specific SPI related targets need to be reviewed in terms of period and outcomes. • Identify road safety domains to align targets with the 5 pillars of road safety and the Safe System Approach.

Activities		Key decision made	Comment
2	**Sampling strategy**	**Sampling method and sizes:** Sample sizes for traffic signal offence be based on the no. of red traffic signal phases during day and night time Pedestrian-related indicators specify compliance with pedestrian signals rather than jaywalking **Selection of survey locations and hazardous routes:** Survey hazardous locations in each province separately and compare results to those of base (control) set of locations • Specify how frequent survey locations must be reviewed • Establish consistent criteria for hazardous location identification • Develop criteria for key considerations during locations review	• Revisit sampling sizes for observed indicators • Identify existing SPM systems that generate road safety related data. (FMS) • The sampling strategy must differentiate between ad-hoc hazardous location investigations and regional/local base sampling.
3	**Data quality**	**Survey teams:** Use smaller RTMC team (5 members) working in conjunction with provincial teams (2 members) to plan and implement survey programme **Survey equipment:** Survey equipment to be bought by RTMC and to be used by team.	• Institutional and resource management plan to be developed to support the SPM system
4	**Data collection and processing**	**Equipment for speed surveys:** Use portable devices (e.g. radar gun) to collect speed data, explore how out of road/next to road devices (e.g. infrared detectors, cameras) can be gradually introduced **Data capturing methods:** Use paper form for surveys, introduce mobile devices, online software, video surveillance or use a combination of these options • Indicate all needs (from training to analysis) associated with various data capturing methods and how well each of these options may be gradually introduced	• Introduce technology for data collection such as speed over distance, overload control etc. to migrate to a paperless environment. • Integrated database and software platform

Activities		Key decision made	Comment
		• Indicate offences that do and do not support technological applications • Explore survey collection software that allows for automatic location detection during data collection • Explore usage of electronic/digital pens as means of data collection **Data analysis software:** Develop new analysis software • Explore most suitable software that is simple and user friendly	to support data management. • Facilitate the integration of various sources of road safety data, operational centres, ad-hoc initiatives into an accessible, compatible database.

Table 2-3: Summary of the 2013 TOS methodology approach per main activity

Activities		Approach methodology	Comment
1	**Selection of safety performance indicators**	<u>**Essential SPIs**</u> **Road user behaviour:** • **Speed** (driver compliance to speed limit, average and 85th percentile speed) • **Alcohol** (driver compliance legal alcohol limit, use of alcohol by pedestrians) • **Seatbelts** (driver and passenger compliance, use of child restraints) • **Barrier lines** (compliance in rural areas) • **Intersection** (driver compliance to traffic signals) • **Pedestrians traffic signal** (compliance to traffic signals) **Vehicle safety:** • **Tyres** (condition of vehicle tyres) • **Lights** (condition of vehicle lights) **Trauma management:** • **Response** (ambulance response times)	• Confirm the holistic approach to road safety performance monitoring. • Confirm existing list of SPIs and add additional as required according to best practice examples. • Identify a domain that would address interventions that are designed to reduce

Activities		Approach methodology	Comment
		Survey methods for essential SPIs provided. Monitor essential SPIs annually during same time of year and same survey location. **<u>SPIs for further consideration</u>** **Road user behaviour:** • Cell phone use • Driver fatigue **Vehicle safety:** • Driving licence or professional driving permits (presence and validity of documents) • Vehicle license (license disk present, valid and corresponds to number plate) • Age distribution of vehicles (% of vehicles not older than 5 years, average age of vehicle fleet) **Trauma management:** • National trauma registry: type and quality of data included Monitor SPIs for further consideration for a period of at least 3 years	safety risk exposure of road users.
2	**Sampling strategy**	**Sample sizes:** Sample sizes for various safety performance indicators surveyed previously in SA were retained as these were found to be valid and practical **Survey locations:** Use set of cities, towns and survey locations identified in 2002, include 86 new hazardous locations identified in 2005 in the monitoring process	• Review sample sizes • Review the proposed survey locations and hazardous locations
3	**Survey procedures**	**Survey schedules:** • SPI surveys conducted every year during same months of year. • Recommended period to conduct surveys is between September and November (relatively dry period in most parts of country, days are longer, does not include major school holidays).	• Review survey schedules and timelines. • Institutional and resource management plan to be developed

Activities		Approach methodology	Comment
		• Annual survey programme for each province should be jointly planned by RTMC and provincial and local authorities and schedule should be followed every year. • Contingency plans put in place to ensure required sample sizes at various locations **Survey teams:** RTMC assume responsibility for conducting all surveys in provinces. Provincial traffic authorities only provide assistance at roadblocks **Survey equipment:** • RTMC to supply all equipment to conduct SPI surveys • Users of equipment properly trained on how to check and calibrate equipment (e.g. breath alcohol measuring equipment) • Quality control during surveys ensured by conducting regular random checks and unannounced visits to survey teams. • Quality control inspectors to check that surveys conducted according to specifications, schedules being adhered to, correct use of equipment, suitable procedures followed to secure and transport completed forms.	to support the SPM system
4	**Data collection and recording**	**Survey instruments:** • Move from paper forms to electronic surveys using mobile devices and online software (allow transition period of 3 years) • Questionnaires to be practical and user-friendly. Practical training provided to survey teams to ensure forms are completed correctly. • Arrangements to be made for collection, safe transportation, and storage of completed forms. • Video surveillance used for some indicators • Data already being collected from other organisation in SA assessed and imported as alternative to survey data or as complementary dataset of particular SPI • Use speed data from SANRAL and other road authorities instead of data measurements from radar guns	• Review the use of data collection mechanisms as potentially simplified with technology application • Review the various data sources for each essential SPI after finalisation of indicators to be used.

Activities		Approach methodology	Comment
		• Data from Road Freight Association and RTIA should complement data collected during roadblocks **Data sources for essential SPIs:** • **Speed** (data from road authorities-automatic vehicle counting stations, ad hoc measurements) • **Alcohol** (recorded by screening devices at roadblocks) • **SPIs observed during roadside surveys (**Seatbelt use, barrier line compliance, driver compliance with intersection traffic signals, pedestrian compliance with traffic signals) • **Tyres and vehicle lights** (conventional vehicles observed during roadblocks, data for heavy vehicles acquired from SA Freight industry) • **Emergency response times** (data from provincial health authorities, private and public emergency services)	
5	**Data processing and analysis**	• Paper-based survey forms processed using Microsoft Excel and Access • Use compliance targets for SPIs rather than offence standards in offence index calculation • Provincial and national indices for performance indicators calculated using targets set for indicators, standardisation factors and a weighting system.	• Explore specific software application to consistently analyse the survey results • Enhance reporting and visualisation of the survey results

2.4. Key comparison of pre-2013 vs 2013 Traffic Offence Survey methodologies

Following the above general summary of the various TOS methodologies, several important components are discussed separately to indicate the differences between the two groupings of methodologies. The 2013 TOS document (Road Traffic Management Corporation, 2013) should be consulted for further insights. A brief insight is provided here, followed, importantly, by the subsequent approach defined in the 2013 document. This in turn will have impact on the approach followed in this literature review and methodology development.

2.4.1. Fluctuation of rates and indices

Pre-2013 summary:

In 2003 an index number system was introduced to represent the combined results of the offence study in a single number for each province and for the country as a whole to aid in yearly comparisons.

As summarised in the 2013 TOS methodology, there have been fluctuations in the observed rates and indices resulting from the surveys. The reasons therefore are:

- Surveys not being conducted during the same months, on the same routes and locations and at the same times of the day and week,
- Sampling accuracy not being consistent and
- Changes in survey methodologies.

2013 TOS approach:

The 2013 document recommended a new list of indicators as summarised in Table 2-3 above. This list included other essential and relevant road safety indicators with the aim of setting interim targets to achieve a final aim of reducing road related fatalities.

To counter some of the fluctuation in results the following steps were proposed:

- Consistent sampling timelines
- Practical and user-friendly questionnaires
- Adequately trained survey team
- Good relations with province to ensure good data quality
- Technology aided sampling to increase accuracy – research required.

2.4.2. Traffic offence targets and standards

Pre-2013 summary:

The following were the summarised targets set by the RTMC as defined in the 2013 document:

- Exceeding the speed limit: Maximum 5% defective rate (i.e. not more than 5% offenders)
- Wearing of seat belt: Maximum 15% offence rate
- The use of child restraints: Maximum 15% offence rate
- Exceeding the legal breath alcohol limit: Maximum of 0.4% defective rate at any time of the day of night (i.e. not more than 1 offender in 250 drivers tested found over the legal limit)
- Crossing on a barrier line: Maximum of 1% barrier line offences (1 offence for every 100 convoys observed)

- Vehicles disobeying traffic signals: Maximum of 1% of red phases with an offence
- Pedestrians disobeying traffic signals: Maximum of 1% of red phases with an offence
- Driver licence present and valid: Maximum 1% offence rate
- The validity of the vehicle registration disks and correlation between the registration disk and number plate: Maximum 1% offence rate
- Public Driver Permit present and valid: Maximum 1% offence rate
- Worn vehicle tyres: Maximum 1% defective rate
- Vehicle lights defective: Maximum 1% defective rate
- The use of cellular phones while driving a vehicle: Maximum 1% offence rate

2013 TOS approach:

The 2013 methodology recommended the use compliance rates rather than defective rates when setting targets for safety performance indicators. Additionally, prior target emphasis was focused on combating lawlessness rather the general safety compliance.

The following targets were set during the 2013 methodology:

- Speed: Driver compliance to speed limits - **95%**
- Alcohol: Driver compliance to breath alcohol limit - **99.6%**
- Seatbelts: Drivers and passengers wearing seatbelts. The use of child restraints - **85%**
- Barrier lines: Drivers complying to barrier lines - **99%**
- Intersections: Drivers obeying traffic signals - **99%**
- Pedestrian signals: Pedestrians obeying traffic signals - **99%**
- Tyres: Vehicle tyres without defects - **99%**
- Lights: Vehicle lights without defects - **99%**
- Ambulance response times: To be determined after first measurement

2.4.3. Weighting system

Pre-2013 summary:

The weighting system ensures that the individual offence rates are seen in the correct proportion to each other when inserted into the combined index. The way this was dealt with has changed over the years due to changes in the survey methods.

Initially there was no weighting, then a weighting was proposed in proportion to the different vehicle categories on the road, whereafter it was proposed that the AARTO demerit points should be used to weigh the individual offence rates into the index. This was not done in the latest surveys due to zero weights associated with some offences. Further research was recommended in this area.

2013 TOS approach:

<u>Weighted sampling:</u>

When surveying, the proportion of different road users in the population (strata) should be determined by traffic counts. This will determine the proportion of different road users in the stratified sample that is required. When calculating weighted average compliance rates for each safety indicator, locations with higher traffic volumes will contribute more to the result than sites with lower traffic volumes.

Weighted index calculations:

The following weightings were defined in the 2013 methodology to be used for the calculation of an overall index. Some of the weightings still had to be calculated.

Table 2-4: 2013 TOS methodology proposed weightings

Safety performance indicator	Categories	Weighting
Speed	Urban	5
	Urban, Day	2
	Urban, Night	3
	Rural	5
	Rural, Day	2
	Rural, Night	3
Alcohol	Driver, Night	12
Seatbelts	Driver, Front Passenger	2
Barrier lines	Rural, Day	2
	Rural, Night	-
Traffic signals	Day	1
	Night	-
Pedestrian traffic signals	Day	-
	Night	-
Worn tyres	All	2
Defective lights	All	1
Driver licences, PrDPs	All	2

2.4.4. Calculation of Indices

Pre-2013 summary:

The traffic offence indices were calculated as follows:

- The first step was to define the standards / targets that are pursued with regard to the different offences.
- The second step was to measure and report the actual offence levels.
- The third step was to standardise the offence results, i.e. to express the results for the different offences in the form of indicators which could be mutually compared. This was done by expressing the actual offence levels (indicators) as a factor of the standard. The following is an example of how the calculations were done: If the standard for speed offences is a maximum offence rate of 5% for speed, and if 20% were actually exceeding the speed limit on the road, the standardised speed indicator would be 4 (i.e. 20% divided by 5% - this means that, in this example, the speed offence level is four time higher than the standard. Indicators for all offences were calculated in the same way for each province and for the country as a whole.

- The last step was to add the offence indicators that were calculated and reported together into one single index number (combined road traffic offence index) for each province and for the country as a whole.
- While calculating the overall index numbers, a process of weighting was also followed. This means that, while adding the indicators together, a greater importance was attached to some of the offences than to others in accordance with the importance of each specific offence as a contributor to unsafe conditions on the road.

2013 TOS approach:

The calculation of an index was found to be a rather cumbersome and complex process and it was recommended that the calculation of indices should be automated as part of the data analysis process to limit user inputs and reduce the potential for errors.

Past methodologies used offence standards in the calculations while the 2013 methodology makes use of compliance targets for safety performance indicators.

The 2013 methodology redefined the steps required for calculation of an index as follows:

- Define the targets that are pursued by the RTMC with regard to the different safety performance indicators.
- Measure and report the actual indicator levels obtained from surveys or other sources.
- Standardize the results by dividing the target by the actual indicator level. The following is an example of how the calculations were done: If the target for exceeding the speed limit is 85% and 60% of drivers were actually exceeding the speed limit, the standardized factor would be 1.4 (85 divided by 60). Factors for all indicators are calculated in the same way for each province and for the country as a whole.
- Define a weighting for each safety indicator. Multiply the weighting by the calculated standardized factor for the particular indicator type. Repeat this for all indicator types. Add all the results together to form one single index number (combined road traffic compliance index). The process can be used to calculate indices for each province and for the country as a whole.

2.5. Important aspects to consider from previous methodologies

The following points are important aspects pertaining to the review of the previous TOS methodologies. These need to be considered as part of the new methodology development.

- The purpose of the offence survey is important as it guides the development of the TOS methodology. This should be taken into account when developing the new methodology.
- A standardised sampling method is needed (months of year, days of week, time of day, survey locations) to enable year-on-year comparisons of results.
- Sample sizes need to be re-examined as there is uncertainty in the sample size required.
- Traffic volume counts should be determined at each location (preferably, during the same month, day and hours during which the survey will be conducted) to enable weighted rates to be calculated. Locations with higher traffic volumes carry more weight than locations low traffic volume.

- There are discrepancies in the determination/observation of traffic offences and consequently, there is a need to specify what counts as a traffic offence (e.g. different definitions of what counts as a barrier line offence/ pedestrian non-compliance)
- There should be a continued emphasis on compliance rates rather than defective rates as laid out in the 2013 methodology.
- A holistic approach to road safety performance monitoring is required to incorporate other categories impacting on road safety and not just “offences” which typically focus on road user behaviour.
- Also, the concept that traffic offense surveys are aimed at quantifying levels of lawlessness (as shown in Figure 2-1) needs to be revised to be more inclusive of other aspects of road safety.
- Considering the bigger picture of road safety requires the development of specific road safety *domains* which in turn categorise the specific safety performance indicators.
- It is difficult to obtain the required data, of acceptable quality, from authorities outside the direct jurisdiction of the DoT or RTMC. Data obtained from provinces are unreliable and of poor quality since there is little incentive to produce good data. Attractive incentives are needed to produce good quality data.
- Random and unannounced spot checks should be done to ensure survey procedures are followed correctly and to reduce the likelihood of data fabrication.
- The new methodology should explore the use of advanced technology (e.g. mobile applications, video technology etc) for automating data collection.
- A number of decisions were made during the 2013 methodology development and it needs to be considered whether these are still relevant to the current situation and to what extent these need to be incorporated into the new methodology.

3. INTERNATIONAL REVIEW OF SAFETY PERFORMANCE MONITORING

The aim of this chapter is to assess the current international documentation relating to road safety performance monitoring and all related aspects thereof. A key question to answer as part of this chapter is whether the literature review findings in the 2013 Traffic Offence Survey (TOS) methodology are still relevant in order to either incorporate or discard the findings presented in that document. In addition, where gaps or additional areas of research are identified and required, they will be incorporated into this chapter.

Where the research conducted in 2013 is still on par with current international best practice standards, these findings are referred back to in this document and are not necessarily presented with the same amount of detail again. **It is therefore important to consult the 2013 TOS methodology in conjunction with this document.**

The following sections are presented in this chapter:

- Best practice principles and initiatives in road safety
- International review of safety performance indicators
- Best practice examples of measuring safety performance
- Survey sampling methods
- Data collection, processing and analysis methods
- Technological advancements and possibilities
- Collaboration and a central traffic data platform

3.1. Best practices in road safety

The term "best practice" originates from the English-speaking world of business administration and generally refers to the exemplary, tried-and-tested methods, practices and procedures within companies. In the context of road safety, best practice refers to methods and measures that, when implemented, demonstrably reduce crashes, fatalities and the severity of injuries. This section contains a review of the approaches and practices followed by countries with the best road safety records in the world. Countries that have followed these safety approaches and strategies have seen a radical decline in traffic fatalities. The best practice strategies adopted will be examined according to the five pillars that guide national road safety activities as outlined in the Decade of Action. Wherever possible, the "best practice" examples are supported with meaningful figures demonstrating that the measures described really have resulted in fewer crashes, fatalities and injuries.

Figure 3-1: Five Pillars of a Decade of Action for road safety

3.1.1. Five pillars of a Decade of Action for road safety

The five pillars of the UN Decade of Action embody the principles of the Safe System approach and are road safety management, safer roads and mobility, safer vehicles, safer road users and post-crash response. For each pillar reviewed, a description of the pillar will be provided, international and African best practices for each pillar will be discussed and the current status of South Africa in terms of the pillar will be reviewed.

The second UN Decade of Action (2021-2030), introduced towards the end of 2020, was also considered in this literature review. In the second UN Decade of Action the 5 pillars remain the same as in the first UN Decade of Action (2011-2020). The only difference between the first and second UN Decade of Action is that the objective to halve traffic deaths and injuries (from its baseline) by 50% was renewed and extended to the year 2030.

3.1.1.1. Pillar 1: Road safety management

In order to significantly reduce the number of road deaths and serious injuries, strong management in all aspects of road safety is required.

Shared responsibility

The integration and coordination of road safety efforts across multiple sectors is promoted as international best practice. This integrated approach to road safety management recognises that addressing the road safety crisis is a shared responsibility and requires a holistic and multisectoral approach that involves governmental and non-governmental stakeholders (e.g. employers, community, motoring and insurance organisations, civil society) (van Schagen & Machata, 2010). In addition, a lead agency is required to coordinate and harmonise road safety efforts across these different sectors to ensure maximum efficiency and long-term sustainability of the efforts. In order to maximise the efficiency of road safety efforts, it is also recommended that road safety be integrated into other policies such as education, health, social policy and employment, police and judicial cooperation, urban planning, environment, research, insurance and taxation (van Schagen & Machata, 2010).

Shared road safety vision

To achieve sustained reductions in traffic fatalities and serious injuries, a long-term vision and strategy for road safety is required (McKibbin, 2016; van Schagen & Machata, 2010). A road safety vision is a description of a long-term aspiration of what the optimum state of the road transport should be. It is also grounded on a well-established theory on how the various elements of the road safety system should function to promote the highest level of safety. The vision provides a foundation for road safety plans and programmes and guides road safety efforts. Three of the best performing countries, Sweden, the United Kingdom and the Netherlands, have all created road safety visions. These road safety visions are discussed below.

A) Safe System

The Safe System approach to road safety is the leading philosophy and approach to improving road and travel safety. This approach adopts a holistic view of the road transport system and has at its core an ethical imperative that stresses the unacceptability of death and serious injuries resulting from a traffic crash. The Safe System approach is a shift away from the traditional approach to road safety which focuses primarily on the road user and achieving behavioural change. It adopts a more expanded and systematic approach that holds the transport system designers responsible for the safe use of the road network. In this way, road safety goes beyond road users' adherence to and compliance with traffic rules and regulations and acknowledges that many factors contribute to safe mobility-including roadway design, speeds, behaviour, technology, and policies. Instead of only relying on public education, training, regulation and enforcement to promote road safety, other factors such as transport governance and planning, road design and protective road infrastructure are also incorporated.

The Safe System approach is built on five key principles. *Firstly*, the Safe System approach starts from the premise that human error is inevitable and avoidable and the road system should therefore be designed in a way that anticipates and accommodates human fallibility. *Secondly*, the Safe System approach takes cognisance of human physical frailty and vulnerability to injury and the fact that the human body has a limited physical ability to tolerate crash forces before harm occurs. Consequently, the Safe System approach seeks to design and operate vehicles and road infrastructure in a manner that accommodates human injury tolerances with the goal of reducing fatalities and maximising the survivability of crashes. *Thirdly*, the Safe System approach uses a systematic and integrated approach to road safety where responsibility for the safety and efficiency of the transportation system is shared amongst the designers, builders, operators and users of the road system. This means that system-wide intervention strategies are required to avoid fatal and serious injury crash outcomes. *Fourthly*, the Safe System approach marks a shift from a sole focus on crash reduction to the elimination of death and serious injury. To this end, the road system should be designed in a manner that is not only safe but also forgiving of human error. *Finally*, the Safe System approach is a proactive rather than reactive approach to road safety that prioritizes safety and advocates for the design of an error-tolerant traffic system that ensures that road users' mistakes do not result in death or severe injuries.

The central tenet (belief) of the Safe System approach is that people are fallible and will at times make mistakes that can lead to crashes. Given this reality, the road system needs to put layers of protection in the form of safe roads, safe speeds, safe vehicles and safe road users to prevent traffic fatalities and serious injuries. These layers of protection constitute the design elements of the Safe System approach and are shown in Figure 3-2 and discussed in greater detail in the next sections.

Figure 3-2: Design elements of the Safe System approach

The Safe System approach is a systemic approach to road safety that integrates core management elements and action areas to create a safe mobility system (see Figure 3-3 below).

Figure 3-3: Principles, core elements and action areas of the Safe System approach

The core elements of the Safe System approach include setting strong, achievable and accountable targets, enhancing economic analysis to identify the economic benefits of improved road safety, identifying priority areas to maximise impact, establishing a lead agency for governance and management, evaluating programs to identify evidence-based measures, and ensuring that infrastructure planning and investment consider safety an integral element of mobility.

The action areas of the Safe System approach are integrated and go beyond merely trying to change road user behaviour through education and enforcement alone. The action areas include addressing underlying factors- such as land use and mobility- to reduce vehicle dependence and promote safe, healthy and environment-friendly travel modes, comprehensive speed management to set safe speeds, intersection design to allow people to cross safely, road design that accounts for human error, improved public transport, safe vehicle design and technology and better coordination and quality of post-crash emergency response and care.

The Safe System approach has been adopted globally by a number of different countries. Countries with the best road safety records such as Sweden (which adopted Vision Zero as a road safety strategy) and the Netherlands (which adopted Sustainable Safety as a road safety strategy) are built on the Safe System approach.

B) Vision Zero

Vision Zero is a Swedish government policy, adopted in 1997, that aims to reduce fatalities and serious injuries from road traffic crashes to zero by the year 2020. According to this policy, traffic deaths are preventable and unacceptable. Proponents of Vision Zero provide a new framework for thinking about road safety by shifting responsibility of road safety away from the individual road user to the designers of the system (Kim, Muennig & Rosen, 2017).

Vision Zero is based on the following core principles (Kim *et al.*, 2017):

- **Ethics**: Human life and health are paramount and are prioritized over mobility and other objectives of the road transport system.
- **Responsibility chain**: The providers of the system and the road users are both responsible for the safety of the road transport system. System providers are ultimately responsible for the safety within the system as a whole and the road users are responsible for obeying the rules and regulations set by the system providers. However, if the road users fail to obey these rules due to ignorance, acceptance or ability, the responsibility falls back on the providers of the system to improve the system (e.g. roadway environment, polices, etc.) to reduce the severity of crashes.
- **Safety philosophy**: Road users are fallible and prone to committing errors. However, the road safety system should be designed in such a way that minimises the harm of potential human error and counteracts devastating consequences by integrating human failure and vulnerabilities into its approach. The limitations of road users must be anticipated and corresponding safety measures must be integrated into the traffic system in the planning, designing and building phases to counteract death and severe injuries.
- **Driving mechanisms for change**: The providers and enforcers of the road transport system must work together and do their utmost to guarantee the safety of all road users.

Since its implementation of Vision Zero, Sweden has consistently been one of the countries with the lowest number of traffic fatalities and has the best road safety record in the world. In fact, Sweden is heralded as European Union’s road safety champion. Since the year 2000, the number of traffic fatalities have been reduced by 50%. The latest traffic deaths statistics show that Sweden has 2.8 traffic fatalities per 100 000 population (World Health Organisation, 2018). The Vision Zero approach has proven to be highly successful and the model has been held up by many as best practice. Consequently, it has been adopted in numerous other countries.

C) Sustainable Safety

Similar to Vision Zero, Sustainable Safety is a proactive approach to road safety. It was first introduced in the 1990s and is the leading road safety vision in the Netherlands. The central objective of Sustainable Safety is to achieve a casualty-free traffic system by minimising the consequences of human error so that it does not end in death or serious injury (van Schagen & Machata, 2010). Human factors are the primary focus of this approach and the maximum safety of the road transport system is achieved by adapting the traffic system to the needs, competencies, limitations and vulnerabilities of the road user.

The implementation of Sustainable Safety relies on five main principles:

- **Functionality** (roads should be defined according to their main function: through-roads, distributor roads, access roads in a hierarchically structure road network)
- **Homogeneity** (of mass, speed and direction of road users. Equality in speed, direction and masses at medium and high speeds)
- **Predictability** (of road course and road user behaviour by a recognizable road design)
- **Forgiveness** (of both the road/street environment and the road users. Injury mitigation by forgiving roadsides and crash prevention by forgiving (potential) errors/violations committed by road users
- **State awareness** (by the road user. Users should be helped to assess their own task capability for participating in traffic)

Since its implementation more than 10 years ago, a number of traffic safety measures were introduced. Some measures included improving infrastructure safety (e.g. categorisation of road network and construction of traffic calming measures such as 30- and 60- km/h zones), increased traffic enforcement and improving crashworthiness of vehicles. These measures had a positive effect in traffic safety and each individual measure prevented casualties. Moreover, the fatality rate decreased from 7.3 fatalities per billion kilometers travelled in 1998 to 4.7 billion in 2007. It is estimated that together the measures prevented 300 to 400 fatalities in 2007 (32% to 34% fewer than expected) and 1 600 to 1 700 fatalities from 1998 through 2007.

Shared targets

In addition to adopting a long-term vision for road safety, it is also considered good practice to establish targets. Targets are used to specify the desired safety performance. Experience from several countries show that quantified targets can be of paramount importance in facilitating the implementation of road safety strategies and measures and more effective use of resources. A target should be challenging enough in order to avoid complacency but accepted as achievable in order to gain the support of all stakeholder.

In terms of approaches to target-setting, observed best practice suggests a process that includes:

- An appraisal of current road safety performance through high-level strategic review

    - What is working and where is there room for improvement?
- Adopting a far-reaching goal for the longer term
    - E.g. Vision Zero and Sustainable Safety
- Analysing what could be achieved in the interim and proposing targets
    - Analysis of empirical RTC data by key stakeholder in order to identify the most important road casualty problems
- Agreeing targets across the road safety partnership and ensuring stakeholder accountability for results
- Ambitious, achievable and empirically-derived road safety targets should be adopted to drive improved performance and accountability

3.1.1.2. Pillar 2: Safer roads and mobility

While road crashes are overwhelmingly caused by human error, the greatest untapped potential to prevent death and injury is through the roads themselves. One of the most important measures for the reduction of fatalities is to put in place a good infrastructure regime. Roads and road features play a vital role in reducing crashes and/or injury outcomes in the event of a crash and are also critical for long term and sustainable trauma reduction. Safe road infrastructure is designed to eliminate the factors that contribute to accidents and to make hazardous sections of roads safer with the aim of mitigating as far as possible the severity of accidents.

Road infrastructure is the central element of a road transport system. It includes the basic facilities, services and installations needed for the functioning of transport on the roadway (van Schagen & Machata, 2010). Road infrastructure is a wide area and covers land use and network planning, (re)construction and design of road sections and intersections, signing and marking, maintenance, and, last but not least, quality assurance procedures like safety audits, safety impact assessments and safety inspections. In general, the road infrastructure would need to be designed and operated in such a way that road users understand what they can expect and what is expected from them, taking into account the limited human information processing capacity and resulting mistakes human beings are capable of (van Schagen & Machata, 2010).

According to van Schagen & Machata (2010), road safety can be enhanced in various stages of road projects. These stages include the:

- **Planning Stage** - through land use control policies; providing by-passes for congested towns and linking them by spurs; and creating self-contained zones to avoid nonessential traffic in the neighbourhood
- **Design Stage** - designing "self-explaining roads" and "forgiving road sides" by selecting the most desirable design standards (and NOT the minimum standards) involving:
    - Design speed
    - Horizontal and vertical geometry
    - Cross-sectional elements
    - Design of at-grade and grade separated junctions
    - Provision of service roads for segregation of slow and fast traffic
    - Designing effective road furniture, vis-à-vis guard rails, traffic signage, roadside illumination provisions, etc.

- **Construction Stage -** Proper separation of the construction zone through effective barricading; construction of proper traffic diversions; provision of road signage; environmental controls for reducing noise, dust, etc.
- **Maintenance and Operation Stage** - providing an Automated Traffic Management System (ATMS) for safe operation of Traffic and Incident Management. This includes providing Mobile Communication Systems, Variable Message Signs, Weigh-in-Motion System, and Central Control Room.

Best practice measures to improve road infrastructure safety

Land use and network planning

The integrated approach to land use planning and road safety seems to be a promising avenue because these two fields are closely connected. Elements that need to be taken into account are the distance between work and residential areas and the location of daily services, such as schools, homes for the elderly, medical centres and shopping areas, in relation to living areas. Furthermore, it is important that for longer and frequent trips, the fastest route coincides with the safest route, i.e. that the required distance on the more dangerous lower order roads is limited in favour of the safer higher order roads.

Proper land use planning may be an efficient way to prevent road safety problems in a sustainable way because the decisions can be taken before the urban development of a lot or an area, or before a new road is built. Generally, it is not easy to come up with an optimal road network, particularly not when dealing with an existing network that has evolved during many decades, and sometimes even centuries. However, that does not mean that nothing can be done about existing networks. One important improvement can be achieved by reconsidering the current road classification, allowing for a limited number of road categories only and avoiding multi-functional roads, and subsequently ensuring that the design and lay-out of a road reflect its true function. The latter may require upgrading some roads and downgrading others (van Schagen & Machata, 2010).

The Netherlands is cited as a best practice for land use and network planning (van Schagen & Machata, 2010). As a first practical result of the Sustainable Safety Vision, all Dutch road authorities recategorised their roads into one of three road categories, each with its own and exclusive function: through roads for long distance travel, access roads for opening up residential areas and rural settlements, and distributor roads connecting the former two road types. On access roads motorised vehicles and vulnerable road users have to interact; therefore, vehicle speeds were lowered: 30km/h in built-up areas, 60km/h in rural areas. On through roads, with grade separated intersections and physical separation of opposing traffic streams and no access for slow moving traffic, speed limits were 100 or 120 km/h. On the sections of distributor roads, separated pedestrian and bicycle facilities allow vehicle speeds of 50 km/h in urban areas and 80 km/h in rural areas. At intersections on distributor roads-, slow- and fast-moving traffic has to merge again, so speeds were reduced, e.g., by a roundabout. Each road category was clearly recognisable by typical road design characteristics and road markings. Categorising the road network allowed for the (re)design of the road environment in a way that reflected their function and prompted the desirable traffic behaviour. These changes increased the consistency and predictability of the road network which helped to reduce possibilities for human error and increased overall safety of the road network.

(Re)construction and design

Safe road design is based on two principles:

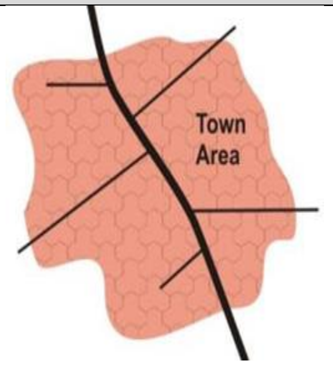
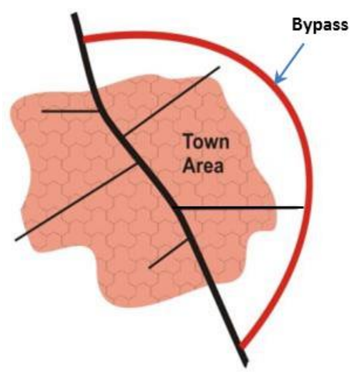
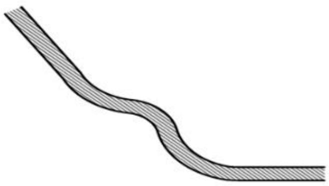
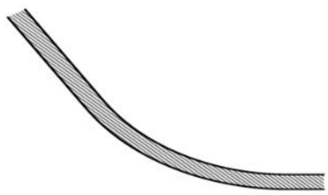
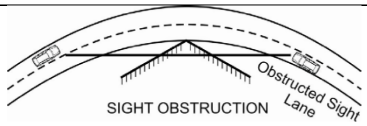
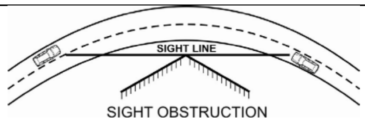
- Geometric design consistency (the design characteristics need to consistent with the function of a road and the behavioural requirements)
- Global design consistency (the design consistency needs to be consistent along a particular stretch of road)

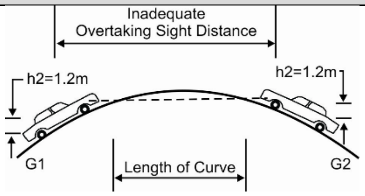
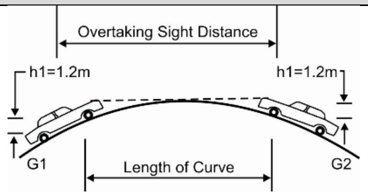
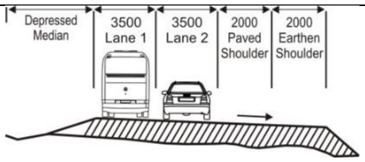
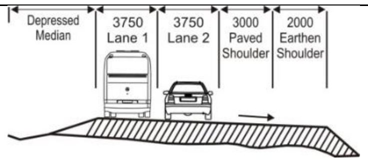
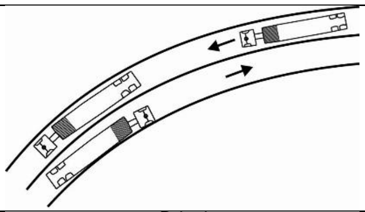
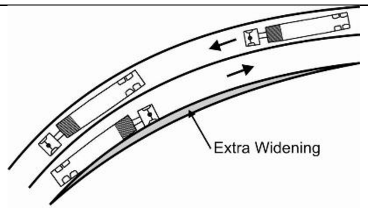
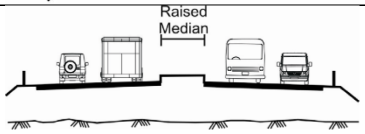
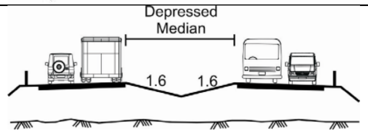
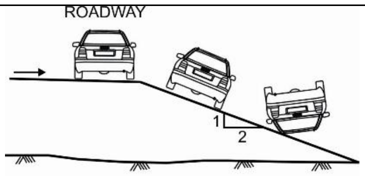
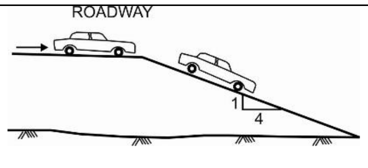
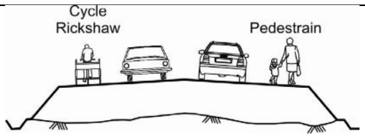
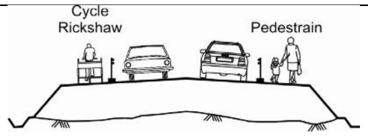
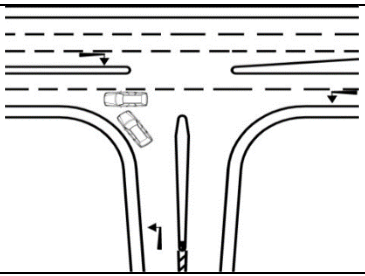
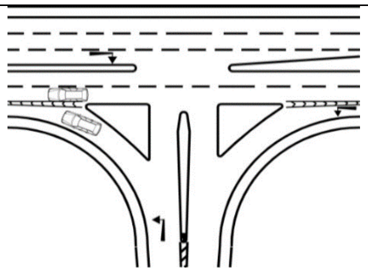
Some examples of remedial measures for specific (re)construction and design include design speed, the implementation of roundabouts, the provision of service roads for segregation of slow and fast traffic and designing effective roadside furniture.

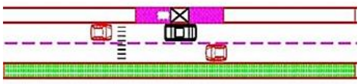
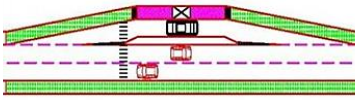
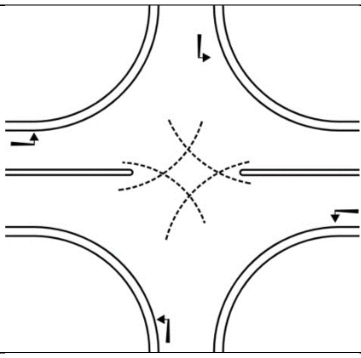
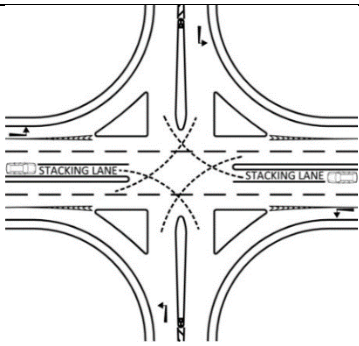
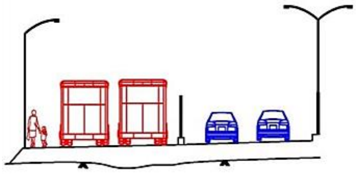
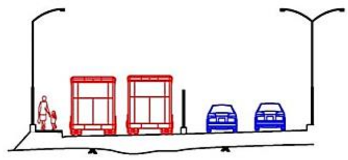
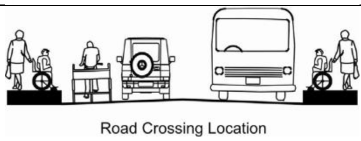
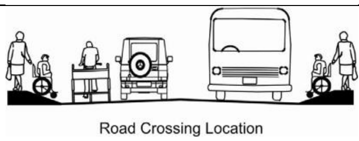
<u>Key elements of safe road infrastructure design</u>

Some of the key elements of safe road infrastructure design (Kapila, Prabhakar & Bhattacharjee, 2013) are presented in Table 3-1 below.

Table 3-1: Key elements of safe road infrastructure

Design/ Planning Element	Undesirable	Desirable	Principle applied
Alignment selection and land use			Major arterials and expressways should bypass major towns which should be connected by spurs. There should be clear zones identified for linear land use control.
Horizontal geometry			Consistency of horizontal geometry avoiding monotonous straight lines or abrupt change of speed
Horizontal geometry			Adequate off-set distance from natural road side features

Design/ Planning Element	Undesirable	Desirable	Principle applied
Vertical geometry			Undivided carriageways designed for desirable overtaking sight distance (OSD)
Cross-sectional elements			Wider lane widths and shoulders for high-speed roads
Cross-sectional elements			Inside widening for sharp curves
Cross-sectional elements			Wider depressed median for high-speed roads to prevent glare and jumping of vehicles
Cross-sectional elements			Recoverable slopes for out-of-control vehicles
Cross-sectional elements			Separate slow moving non-motorised traffic (cycles, rickshaws, etc.) from fast moving traffic
Entry/exit			Entry/ exit only through slip lanes with proper acceleration and deceleration lanes

Design/ Planning Element	Undesirable	Desirable	Principle applied
Passenger transit			Separate lay bye for buses and taxis to facilitate segregation and improve visibility
Junction design			Channelisation, provision of stacking lanes, adequate turning radii
Pedestrian facilities in urban areas			Provision of raised footpath for pedestrians in urban areas
Facilities for differently abled			Footpath merging in a slope with a cross street, bus bays flushed with foot boards etc.
Barriers			Barriers should be designed to deflect the vehicle and crash it
Road signs			The road signs should be standardised throughout the country
Traffic calming			Properly designed traffic calming devices like speed humps, rumble strips, small roundabouts

SANRAL is currently developing a design standard for public transport rest areas / stops along Freeways. This document when completed can assist in providing further guidelines in the future. Said document aims to address the management and provision of pedestrian and public transport facilities on SANRAL's road network. It has becomes evident that these issues cannot be ignored and need to be accommodated and mitigated to improve road safety and to contribute to the overall transport system (SANRAL, 2017).

Road infrastructure safety management

Apart from specific measures to improve road construction and infrastructure, road infrastructure management is also crucial to ensuring a properly functioning and efficient road infrastructure. Well-documented experiences from Europe and elsewhere shows that roadway safety management and formal systematic infrastructure safety procedures such as road safety impact assessment, audits and inspections are a demonstrably effective and cost-beneficial tool to prevent road crashes in the short term; provided that the corrective measures pinpointed through such procedures are adequately budgeted (van Schagen & Machata, 2010).

Road infrastructure safety management procedures support road authorities in the prevention and mitigation of future road crashes. These procedures are used as analytic tools that help government detect emerging safety problems early, that help in locating the most hazardous parts of the road system, that identify the most important factors contributing to roach crashes and injuries and that help to estimate the likely effects of specific road safety measures or a road safety programme consisting of several measures (Persia *et al.*, 2016).These procedures and others are proven to be effective in preventing road crashes in some (developed) countries, and have the potential to be just as effective in other countries.

According to Persia *et al.* (2016), there are various road safety procedures in each stage of road and infrastructure development. Good road infrastructure safety management is based road safety Impact assessment, efficiency assessment tools, road safety audit, network operation, road infrastructure safety performance indicators, network safety ranking, road assessment programmes, road safety inspection, high risk sites and in-depth investigation (Persia *et al.,*2016).

A schematic and brief outline of these procedures are given below (see Figure 3-4).

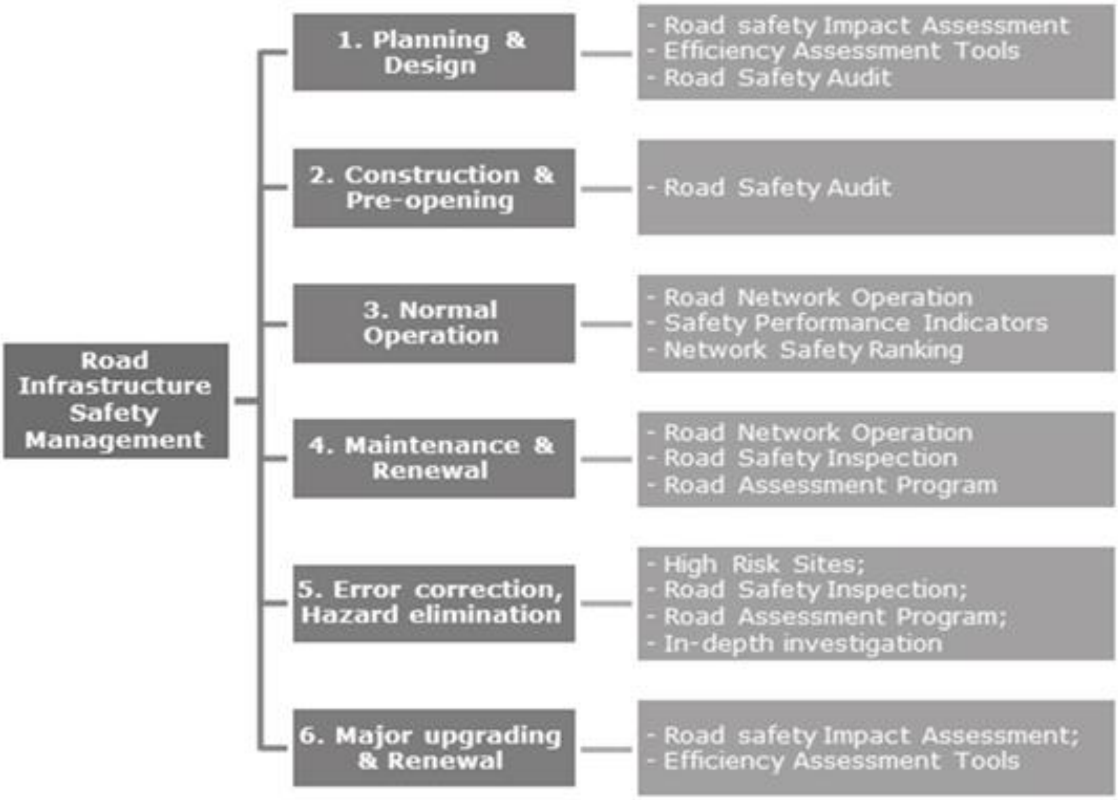


Figure 3-4: Road safety procedures in each stage of road development (Persia et al.,2016)

3.1.1.3. Pillar 3: Safer vehicles

The safety of the vehicle plays a crucial role in reducing the number of crashes and casualties. Vehicle safety comprises various measures to help avoid a crash (crash avoidance systems) and measures that reduce injury in the event of a crash (crash protection systems). The design of a vehicle affects the protection of occupants in case of a crash and the chance of serious injury to unprotected, vulnerable road users. Additional safety devices, such as seat belts and airbags offer additional protection to car occupants. For two-wheelers, protective clothing and helmets help to mitigate the consequences of a crash. And last but not least, intelligent driver support systems, including in-vehicle, between-vehicle and road-vehicle technologies, help the driver to perform his task safely, preventing errors and violations which may otherwise have resulted in a crash.

A) Safe vehicle design

The design of the vehicle offers the greatest safety benefit for mitigating the effects of a crash. The prevailing low standards of vehicles contribute to a significant number of crashes and casualties. It is therefore important to encourage deployment of improved vehicle safety norms and technologies for both passive and active safety. It is important to inform consumers about the safety performance of a car. This seems to have two consequences. *Firstly*, it creates a consumer demand for safer cars and it stimulates car manufacturers to take safety into account as a marketing strategy.

In Europe, the European New Car Assessment Programme (EuroNCAP) performs crash tests of the most popular cars sold in Europe to assess the protection they offer to its occupants and to pedestrians. Tests performed include a frontal impact test at 64 km/h into an offset deformable barrier, a side impact test at 50 km/h, a side impact pole test at 29 km/h and tests with pedestrian head and leg (partial) dummies at 40 km/h. Safety performance is evaluated for adults and children. Seat-belt reminders are also taken into account in the evaluation, and a general recommendation is given for vehicles with Electronic Stability Control (ESC). Based on the results, adult occupant protection, pedestrian protection, and child protection are evaluated on scales of 1 to 5 stars, the more stars - the better the protection. Test procedures evolve continuously to take account of new developments. the requirements regarding car design are set at an international (UN-ECE) and a European level.

B) Driver support systems

Driver support systems help drivers to drive their vehicle safely, e.g. by warning or intervening when a driver crosses the side line of his driving lane (Lane Departure Warning System),when the driver approaches too close to the car ahead of him (Adaptive Cruise Control or Collision Avoidance systems), when the driver exceeds the speed limit in force (Intelligent Speed Assistance), when the or passengers forget to use a safety belt (Seatbelt Reminders) or when the driver is about to lose control of the vehicle (Electronic Stability Control). Most of these measures are available in new cars by car manufacturers, or as an after-market (retrofit) product.

Driver support measures for speed compliance include intelligent speed assistance (ISA) systems. ISA is a general term for a system that aims to increase speed limit compliance. In general, ISA systems establish the position of a vehicle, and compare the current speed of the vehicle with the posted speed limit or recommended safe speed at that particular location. In case of excess speed, the system gives feedback to the driver about the speed limit in force or even restricts vehicle speed according to the speed limit in force. There is a wide range of ISA systems that differ in the level of support and the kind of feedback they provide to the driver. Within the African context, speed governors are used as driver support systems to encourage speed limit compliance. Speed governors are devices installed in cars that can forcibly limit the speed intelligently and safely. The device limits vehicles to a maximum speed of 60 km/h and has the capacity to trim down the speed to 25 km/h every time the vehicle attempts to exceed the set maximum velocity. It also has a storage computer which allows controllers or traffic offices to check the previous speed of the vehicle, and errors if the device was tempered with. In Kenya, Rwanda and Nigeria the installation of speed governors is mandatory for public service and other commercial vehicles to control the speed of business vehicles, which was viewed as one of the leading causes of fatal accidents.

The EU rules for fitting speed limiters to new cars will be adopted by the UK from 2022 and was welcomed by many, including the European Transport Safety Council, as a move that will save lives. However, this technology has its limitations. The AA pointed out that there are times, when overtaking for example, when temporarily exceeding the speed limit may be safer.

Speed assistance technology uses a Global Positioning System (GPS) to establish a car’s location and then sends it a message about the road’s speed limit. Cars can also be fitted with a camera to identify speed limit signs by the road. The car – rather than the driver – would use these two inputs to keep below the speed limit. The technology the EU proposes would allow drivers discretion, however, so a driver would have the option to override the reduction in speed by pushing the accelerator.

This technology, which is already available in some cars, can be seen as a step towards Autonomous Vehicles (AVs) which will need to respect speed limits. But there are still a number of more detailed issues to address to resolve the question of whether the pros outweigh the cons.

Driver support systems are very useful to prevent unsafe traffic behaviour as people make unintentional errors, and commit intentional violations. Both result in unsafe traffic behaviour. Vehicle 'locks' could help to prevent errors and violations from happening. Locks make it impossible for drivers to use their car if and when they are not allowed to. This can be realised, for example, by a smart card. It is a type of individual driver licence that prevents a car from being driven if the driving licence has been suspended or when there are particular driving restrictions (e.g. related to a graduated driving licence). Another example, is the alcohol lock that prevents a car from being started if the driver is under the influence of alcohol.

C) Connected and Autonomous Vehicles

Today, with the emerging connected and autonomous vehicle (CAV) technologies that are being deployed and further developed, there is the potential to significantly change road transportation as we know it. Negative issues associated with driving such as crashes, traffic congestion, etc. will be decreased considerably as human errors are taken out of the equation with the introduction of connected and autonomous vehicle technologies.

With connected vehicles, wireless technology is used to connect vehicles' locations and other information (e.g. latitude, longitude, brake status, length, width, etc.) to one another (V2V), to infrastructure (V2I), or to other modes such pedestrians and bicyclists (V2X). Additionally, information such as traffic information, signal phase and timing, speed limit and parking information are communicated from traffic management centres (TMCs) to roadside units and the on-board units (OBU) inside the vehicles.

In the case of an autonomous vehicles, it is typically equipped with its own standalone sensors and cameras that allow the safety features of the vehicle to function without direct driver input or interference. Although autonomous vehicles do not necessarily require the use of V2V, V2I and V2X communications, this will likely still be incorporated as an added safety feature, hence making them Connected Autonomous Vehicles (CAVs).

CAVs have the potential to significantly minimise congestion, allow for extensive platooning (driving groups of vehicles together), enable safe travel at higher speeds, improve fuel consumption, reduce greenhouse gas emissions and importantly reduce crashes. In general, CAVs thus have the potential to improve road safety dramatically and although this technology will likely still take some time to be prevalent in the South African environment, it is important to keep in mind with future Traffic Offense Surveys.

D) Vehicle conspicuity

For road safety it is important that the presence of other road users can be detected in time. Better and earlier detection of other traffic will lead to earlier action to avoid a collision or to decrease the severity of a crash because of lower impact speed. For motorised vehicles, lighting is the general way to increase conspicuousness. Lighting can also help to increase conspicuity during day time. Being visible is very important for bicycles as well, especially at night time. Their lights are generally much less blazing than the lights of cars and, in addition, only conspicuous from the front and behind. Bicycle side reflection can add to the visibility of bicycles. For all unprotected road users, pedestrians, moped riders and motor cyclists, reflective clothing will further enhance their conspicuity.

A best practice example for increasing vehicle conspicuity is daytime running lights (DRL). In Europe, DRL is a legal obligation for all motor vehicles to drive with low beam headlights or with special DRL lamps, regardless of the time of day or the light conditions. DRL aims at reducing daytime-crashes that involve more than one participant and at least one motor vehicle. DRL increases visibility and improves distance and speed perception of motor vehicles. It improves the possibilities for other road users to detect motor vehicles earlier and to adjust their own behaviour. In the EU, 14 member states have mandatory rules on DRL so far, with different requirements, and some Member States recommend the use of DRL.

Meta-analyses show that mandatory DRL will reduce the number of daytime multipart crashes with motor vehicles by 5 to 15%. The effects are greater for fatalities than for injury crashes, and greater for injury crashes than for property-damage-only crashes. There is some opposition against DRL because of potential adverse effects on specific types of accidents (pedestrian, cyclists and motorcyclist, and rear end collisions), but there is no scientific evidence showing adverse effects. The costs associated with DRL are mainly costs for fuel use and the ecological costs related to that. The meta-analyses showed that for small vehicles the fuel use would increase by 1.6%, for heavy vehicles by 0.7%. Estimated benefit-cost ratios range between 1.2 and 7.7.

3.1.1.4. Pillar 4: Safer road users

Road users are the primary and most important aspect of the transport system. Providing for user needs is the primary characteristic of a sustainable transport system. Road user behaviour is considered the main contributory factor to the majority of road accidents. Pillar 4 concerns problematic road user behaviour - such as speeding, non-use of seat belts and helmets, distracted driving, drink driving and fatigue - and how to influence it. This can be done through sustained enforcement of road traffic rules combined with public awareness and education activities to raise compliance with regulations that reduce the impact of the key risk factors.

A) Education and capacity building

Road safety communication campaigns have been found to be effective when combined with other countermeasures, particularly enforcement. Important tasks of road safety communication include promoting public acceptance of road safety measures (e.g. enforcement measures) and lessening the public's tolerance of risky behaviour. Media can influence attitudes e.g. by providing information about rules, explaining the consequences of risky behaviour, and giving information about police enforcement and possible punishments. Since the target of the campaigns are people or groups of people, and as their behaviour may differ from one country to another, the specific messages addressed to the target group chosen for a campaign may vary from country to country and even within a single country. Campaigns carried out at the European level and supported by European and international organisations (such as in the measures described below) contribute towards maintaining a high profile for road safety and thus towards mobilising the decision-makers at all levels.

In many cases, however, it is difficult to estimate the impact of the campaign itself, especially if the campaign is combined with elements of enforcement or other road safety targeted measures whose effects possibly overlap. Furthermore, the effects of a campaign have to be separated from general developments in road safety.

Education and awareness campaigns aimed at improving road user behaviour are best done in conjunction with engineering and enforcement interventions to maximise synergy and as part of a "safe systems" approach where providers of infrastructure have to take more responsibility for the safety of infrastructure they provide. For example, speed needs to be reduced in urban areas and linear settlements through engineering and enforcement methods. Ill-disciplined drivers and high-risk behaviours need to be deterred through effective and extensive data-led traffic police enforcement.

B) Enforcement of traffic law

It is widely recognised that large scale and visible enforcement, especially when targeting speeding, drink driving and non-use of seat belts is a cost-effective way to achieve substantial improvement in road safety within a relatively short period. It is for this reason that the European Commission has adopted a national enforcement plan that is known to have best practice in the enforcement of speed, alcohol and seat belt legislation.

Much is known about effective traffic law enforcement methods and these best practice enforcement measures are transferable to other countries. To control speeds, automated speed enforcement systems must be used, and offences must be followed up with procedures able to manage a large number of violations. For drink-driving, random breath testing with alcohol screening devices must be applied and reliable breath testing devices used. In the area of seat belt use, intensive enforcement actions of a specific duration must take place several times a year.

A study performed by ICF Consulting before the EU enlargement of 2004 showed that, annually, good enforcement practices could prevent 5,800 road deaths per year resulting from speeding, 4,300 road fatalities resulting from not wearing seat belts and 3,800 fatalities resulting from drink driving. In total, 680,000 injuries per year could be avoided.

C) Novice drivers

Traffic crashes are especially prominent among young and novice drivers (18-24 year-old) both internationally and locally. Based on evidence from previous research studies, the highest risk circumstances of young drivers – in particular male drivers – are associated with speeding, drink driving, non-wearing of seat belts, drugs, night-time driving and driving with peer-age passengers. Some of these circumstances and issues are best addressed by general road safety policy and enforcement action; others are best addressed by young driver-specific measures. In both cases, one of the aims is to provide safer driving conditions in which young drivers can acquire experience.

A general measure to reduce traffic crash risk among novice drivers could be already achieved with increased levels of accompanied practice prior to solo driving, as well as by stringent legislation and enforcement of the key road safety problems.

Specific measures to reduce traffic crash risk among novice drivers are likely to be:

- Specific maximum BAC level of no more than 0.2 g/l

- Improved driver training including possible post-test training measures
- Special demerit point systems

In some European States, novice drivers are subject to special demerit point systems that apply during the period of probation. This means that probationary drivers are potentially subject to punitive (e.g. loss of licence) or rehabilitative (e.g. mandatory traffic risk awareness training) measures if they lose a certain number of points, and the threshold for such measures is lower than it would be for other drivers.

In broad terms, the literature on driver education/training, testing and licensing issues suggests that

the ideal driver licensing process should include:

- A combination of professional driver instruction and accompanied driving at the pre-licence stage;
- Measures to encourage a significant amount of structured accompanied practice (i.e. accumulation of driving experience in safe, varied circumstances) in the pre-licensing phase;
- Focusing not only on vehicle control and driving in traffic, but also on the higher levels of the Goal for Driver Education (GDE) matrix21, and associated risks;
- Measures promoting the self-evaluation and independent decision-making of the learner driver;
- A close relationship between (clear) training goals, driver training and the test;
- Progressive or 'graduated' access to the driving licence, including post-licence restrictions for novice drivers (probationary period), additional training measures, etc.

3.1.1.5. Pillar 5: Post-crash response

Research has shown that a large proportion of traffic-related deaths can be prevented if a proper post-crash response is available. The investigation into pre-hospital deaths between 1987 and 1990 in the UK estimated that at least 40% of pre-hospital deaths might have been prevented by improvement in prehospital care (Hussain and Redmond, 1994). A similar trend was confirmed by Noland (2004) who acknowledged that a part of reduction in traffic fatalities over the past decades in some developed countries has been the result of improved medical care and technology. However, advances in medical care and technology may share credit with advances in other components of prehospital care systems.

The benefits of reduced emergency medical services (EMS) response times have been come under close scrutiny in a number of studies. The EMS response time is very crucial as it can affect the likelihood of survival from a traffic crash. A review of European studies estimates that 50% of traffic deaths are pre-hospital death, that is, death that occurred within a few minutes at the crash site or in transit to a hospital. It is estimated that, among these deaths, about 35 % occur after four hours and 15 % occur between one and four hours following a crash occurrence (European Transport Safety Council, 1999). Despite a lack of objective scientific evidences, the first 60 minutes following an injury occurrence is commonly termed "*golden hour*" which suggests that there is a better likelihood of survival if the emergency medical care is provided within 60 minutes of the injury occurrence (Lerner and Moscati, 2001).

In cases of major traffic injuries, post-crash care involves a chain of intervention activities starting by (1) actions taken by the patients themselves or more often by lay witnesses or bystanders, followed by (2) access to the emergency; (3) emergency rescue system; (4) prehospital medical care; (5) hospital trauma care; and (6) rehabilitation (European Transport Safety Council, 1999). The success of the whole post-crash care depends on the strength of the weakest link. A report by European Commission Directorate General for Mobility & Transport (2013) presented schematically this chain and its links in Figure 3-5 below.

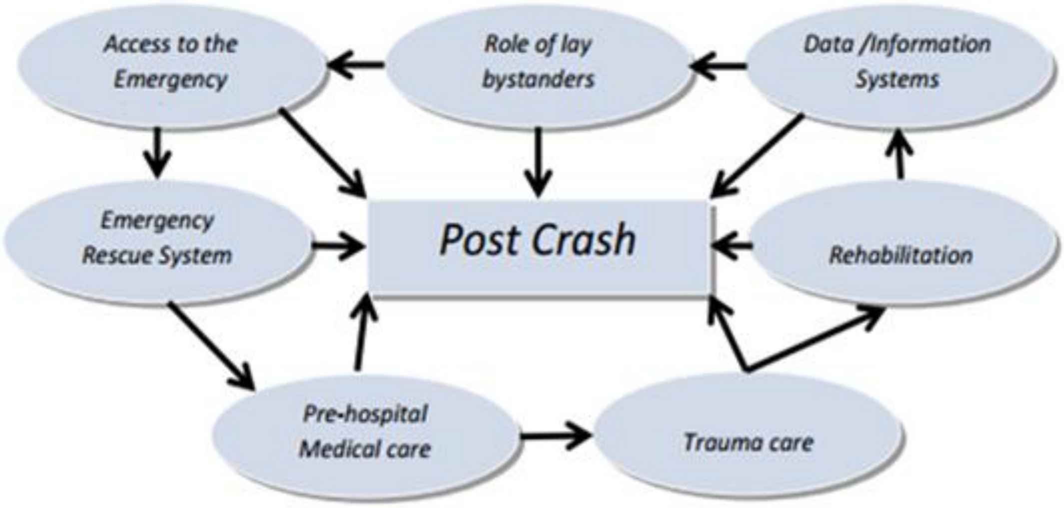


Figure 3-5: Chain of intervention action of post-crash care

It is believed that the best performing nations in post-crash care cautiously monitor the chain of intervention actions and their interactions and ensure that various aspects of the post-crash care systems are coordinated and timely delivered to patients. The following section provides a review of practices adopted by countries known to have successful post-crash care systems worldwide.

1. **Best initiatives to empower lay bystanders**

The chain of post-crash assistance starts with those who are present at the crash scene or those who arrive at the scene before any EMS response. Those people might be, patients themselves, lay witnesses or bystanders and their assistance may be crucial in saving lives. They can for instance use a fire extinguisher if the vehicle is on fire. They may also be involved in safeguarding the crash scene to prevent further crashes, controlling the crowd and applying the first aid (Peden et al., 2004). Another important role of bystanders is to contact EMS or other forms of assistance and should know how to give correct information regarding the injury.

First aid education is one the best practices adopted in developed countries to build the capacity of bystanders. This program is very common in many European countries (van Schagen and Machata, 2010). The European first aid education targets specific groups such as scholars, drivers and non-driving adults. For scholars, the program offers first aid education once every year to maintain acquired knowledge. For drivers, mandatory first aid courses are integrated with driver training programs. This is done in many European countries such as Austria, Bosnia and Herzegovina, Estonia, Germany, and Hungary. Latvia, Lithuania, Slovakia and Switzerland and re-certification for drivers is at regular intervals. Lastly, optional first aid campaigns are targeted at non-driving adults (van Schagen and Machata, 2010). Apart from basic knowledge of first aid, many developed countries also include initiatives to teach drivers how to assess a crash victim and evacuate passengers in their driver training program (European Commission Directorate General for Mobility & Transport, 2013).

Although the benefits of the first aid education are internationally recognized (Kobusingye et al., 2005; Mock et al., 2002), there are concerns that more harm might be done unless bystanders are equipped with in-depth skills in basic life support (European Commission Directorate General for Mobility & Transport, 2013). In addition to these concerns, there no scientific evidence that driver first aid training would alleviate prehospital mortality (Mock et al., 2003). Rather, an inclusion of protocol of steps to be taken by bystanders in traffic crashes in national highway codes and in maintenance manuals of car manufacturers is deemed to be more helpful (European Transport Safety Council, 1999; Mock et al., 2002).

2. Best practices aimed at improving EMS accessibility

Accessing EMS systems in many countries is made by telephone and recent advances in mobile communication have improved EMS accessibility. However, crash notification is restricted by insufficient coverage of telecommunication networks, especially in geographically remote areas. Crash notification might also take longer in cases where all the car occupants are incapacitated. To deal with these limitations, developed nations are testing and promoting the implementation of in-vehicle emergency notification systems, commonly called eCall to enable faster and more adequate EMS response to crash scene.

The in-vehicle eCall is an emergency call triggered either manually or automatically via activation of in-vehicle sensors. When activated, a set of data is transmitted to an operator at a local emergency agency. The data transmitted contains information about the accident such as time, geographical position and driving direction using a GPS and description of the vehicle. At the same time, a voice connection is directly established, allowing the operator at PSAP (public safety answering point) to hear what is happening in the vehicle and communicate with the car occupants. The manual activation is performed by pushing the emergency button located in the vehicle. The automatic activation is triggered by a set of sensors in the event of car crash (Cabo et al., 2014; Geuens and Dumortier, 2010). An example of this emergency system is the Volvo OnCall integrated in the car and is activated either through a SOS button located on the central console of the car, or by sensors every time an airbag is deployed or when safety belt pretensioners are activated (Cabo et al., 2014).

Since 2010, the European New Car Assessment Programme (Euro NCAP) has launched a reward system (Euro NCAP Advanced) to motivate car manufacturers who invest in new advanced safety technology and make them available to consumers and society (European Commission Directorate General for Mobility & Transport, 2013). Several car manufacturers have received rewards points for integrating eCall in their products. Some of these car models include Volvo (Volvo OnCall), BMW (BMW Assist) and PSA Group (PSA Appel d'Urgence) (Cabo et al., 2014). The Volvo OnCall was made available in 2006 (Cabo et al., 2014) and was the first safety integrated in cars for theft alert, emergency support and roadside assistance. The European Commission (EC) has set out plans to ensure that all new vehicles in Europe are equipped with the eCall system with eCall legislation starting in 2015 (Beeharee et al., 2012).

The aim of eCall system is to reduce the response time of EMS. A number of studies have investigated the safety benefits associated with the reduced EMS responses provided by eCall systems. A reduction of around 45% of EMS response time is estimated as a result of implementing eCall systems and consequently, 2500 traffic fatalities would be prevented annually in Europe and injury severity would be reduced by 10% (Cabo et al., 2014). More specifically, a Finnish study estimated that eCall system have the potential to prevent 5 to 10% of motor vehicle fatalities and 4 to 8% of all road fatalities (Virtanen, 2005). In Australia, Wall et al. (2014) reported that the use of eCall systems would prevent 104 road fatalities (41 in urban areas and 63 in rural areas) annually.

Given the success of in-vehicle emergency notification systems, research initiatives are currently extending the eCall technology to protect motorcycle riders. In this regard, a recent study has explored a joint initiative in which three companies, NZI (helmet manufacturer), Lookwell (garment manufacturer and CAP (polymer manufacturer) intended to develop a rider eCall system consisting of sensors embedded into helmet and garment (Melcher et al., 2015).

3. Best practices of emergency medical and rescue services

In some countries, emergency calls are received and answered by emergency medical services, in others by law enforcement and fire services and then transferred to the EMS. Although there is no scientifically proven evidence, a direct communication between patients or bystanders is recommended for the sake of a faster emergency response (European Transport Safety Council, 1999). Once the emergency call has been received, a call receiver proceeds with a decision-making process to provide a timely and adequate response based on received information regarding the patient situation. In countries with high performing EMS, this task is performed by Emergency Medical Dispatch (EMD) systems.

Most developed countries (e.g. member States of the European Union and North America) have recognised the importance of EMD systems and guidelines for these systems have been established and incorporated in EMS standards. There is a diversity in how EMD systems are organized worldwide. In some EMS systems (e.g. Norway, Sweden, UK), medical emergency dispatchers are alerted by a separate call-taker (Castrén et al., 2008). The European EMD systems are responsible of taking incoming emergency calls, instructing the caller (those on the crash scene) before the EMS arrival, dispatching the appropriate EMS resources and instructing the ambulance crew (Lyon et al., 2013; Palma et al., 2014). The assessment of urgency of the reported incident is sometimes made by the use of a standardized interview protocol to reduce judgement errors. Handling emergency calls requires a certain expertise from the EMD operators. Operators at emergency medical dispatcher centres are well-trained to use appropriate conversation techniques enabling them to deal with emotional status of the caller and to obtain a better collaboration from the caller (Palma et al., 2014). A variety of computer-based systems are also used to categorize and prioritise levels of acuity and to support the decision-making process regarding the appropriate type of EMS response to provide (Sporer and Wilson, 2013).

While EMS systems are often perceived as the most important component of emergency services responding to crash events, there is no doubt that fire-fighting crews and rescue systems can also play a crucial role. In some instances (e.g. when the car in on fire, or when the car occupants are trapped in a vehicle, or in cases of rescue of submerged vehicle), the intervention of fire-fighters and other rescue teams precedes any medical support from EMS staff. It is recommended that fire and rescue crews are equipped with skills in providing basic life support and that an effective cooperation may exist between EMS personnel, firefighters and other rescuers (European Transport Safety Council, 1999).

4. Best practices of prehospital medical care

The best practices of prehospital care are largely distinguished by the quality of the medical care system and the ability and attitudes of its personnel (World Health Organization, 2005). According to the quality level of medical care provided, the World Health Organization (2005) distinguishes two level of health care: Basic Life Support (BLS) and Advanced Life Support (ALS). The particular health care technique applied depends on the injury severity of the patients.

The Basic Life Support (BLS) consists of non-invasive emergency medical procedures performed to restore or sustain vital functions (airway, respiration, circulation) of a patient, normally provided by first-responders until the arrival of more advanced and specialized medical care providers. These procedures include basic first aid, cardiopulmonary resuscitation, haemorrhage control, stabilization of fractures and spinal immobilization (Colwell and Soriya, 2012; European Commission Directorate General for Mobility & Transport, 2013). Advanced Basic Support (ALS) provides more sophisticated and invasive emergency medical procedures, such as intravenous fluids therapy and endotracheal intubation, performed by trained paramedics to stabilize and restore vital functions, with the use of specialized equipment (European Commission Directorate General for Mobility & Transport, 2013; Roudsari et al., 2007). These medical care procedures are performed at the crash scene and during transport to health facilities.

The professionalism of prehospital medical care systems, often measured by the medical equipment, the number of medical care personnel and their ability are used as the key indicator of the best performing medical care systems. In some European countries for instance (e.g. Belgium, Germany, France, Italy, Denmark), the ALS crews include trained physicians in Mobile Intensive Care Unit (MICU). In other countries such as the Netherlands and Sweden, highly trained nurses specialized in critical care are part of the MICU (European Commission Directorate General for Mobility & Transport, 2013; van Schagen and Machata, 2010). In South Africa, Gauteng Province the National Road agency with their Freeway Management System provide on scene prehospital medical care by providing Incident Response Unit (IRU) consist of a BLS as well as Medical Response Unit (MRU) consisting of ALS.

Based on the above-cited performance indicators, a study has tried to compare the professionalism of different prehospital medical care systems across 11 developing and developed countries (Roudsari et al., 2007). Prehospital medical care systems were rated according to levels of BLS, ALS (intravenous access and endotracheal intubation) provided to patients and the number of physicians (Doc-ALS) available to provide advanced medical care. Despite a noticeable heterogeneity within each prehospital medical care system, the study found that patients in Austria, Germany, the UK, USA and the Netherlands are being treated at higher frequencies by the ALS crews than in other countries. Prehospital medical care systems in Mexico, Iran and Canada were found to be mainly dominated by BLS (Roudsari et al., 2007). Same applies to patients on the Gauteng Freeways Medical Response Unit operated by an ALS medic are dispatched from the TMC for every crash detected and they provide first responder patient care. The MRU is operated by 1 ILS medic. The study reported that in Austria, Germany, Greece, the UK (London) and Canada ambulance crews consist of a team of 1 physician and the BLS personnel. In other countries, such as Australia, New Zealand, USA and the UK, prehospital medical care is of the ALS type, with 2 ALS emergency medical technicians.

The amended emergency medical services health regulation of 2017, the licensing of an emergency vehicle can only be issued to a registered medical service provider. SANRAL or their contractor not being registered as medical service providers cannot have vehicles licensed as emergency vehicles and therefore cannot provide a BLS function. To ensure compliance with the new health regulation it is proposed that SANRAL outsource the service through a medical profession entity. As such the composition of the service to will then include ALS, BLS and 2 non-medical support personnel.

Although the level of professionalism plays a key role in the efficiency of the prehospital medical care, there is little evidence that advanced prehospital medical care systems are inherently superior to systems that offer basic prehospital medical care (World Health Organization, 2005). Every crash patient doesn't need to be treated by an advanced medical care composed by paramedics, trained nurses or a MICU. In many countries with a higher demand of advanced trauma care, concerns are that the use of only advanced medical care systems may divert scarce resources that are needed by a large number of patients to prehospital medical care provided to fewer patients. Therefore, it may be advisable to improve skills of first responders (e.g. bystanders) and basic prehospital trauma care providers. This approach is supported by several research initiatives in different countries that showed that training bystanders and basic health care providers improved the efficiency of trauma care systems (World Health Organization, 2005). In South Africa BLS continue to fulfil a significant role in providing first responder medical assistance. Ambulances are operated by BLS's in line with their level of qualification and depending on the severity of injuries, ALS are dispatched.

However, where major crashes are detected, ALS services are dispatched immediately (both government and private) services. Therefore, there is a need to encourage greater level of professionalism of prehospital medical care systems and to develop standards for minimum requirements for advanced medical care interventions in many countries.

5. Best practices for EMS transportation units

Times required for EMS transportation units to arrive at the crash scene and to transport patients at a health facility are very crucial in influencing the patient's likelihood of survival. There is a wide variety of transport means utilised worldwide to transport patients to trauma care centres. In many developed countries, patients are transported by land ambulances and air ambulances depending on the level of injury acuity and travel distances between the crash scene and the health care facility (Roudsari et al., 2007) e.g. Roudsari et al., 2007). In developing countries, injured patients are brought to hospitals by commercial vehicles, law enforcement personnel, relatives using private motorized or non-motorized transport means (Joshipura et al., 2003; Kobusingye et al., 2005; Lungu et al., 2001; Macharia et al., 2009).

Standardization of the EMS vehicles and EMS response times are among performance indicators used worldwide for the rating of EMS systems (Gitelman et al., 2014). The National Health Service in England recorded an average of about 7 minutes in responding to life-threatening call (NHS, 2020).

When it comes to EMS transport units, a range of features such as the proportion of Helicopter Emergency Medical Services (HEMS) to other EMS transport units, the number of EMS transport units per 10 000 population and number of EMS transport units per 100 km of total road length serve as performance indicators to rate this component of EMS system. Based on these considerations, a European study reported the highest number of EMS transport units per 10 000 population in the UK (3.20), Austria (2.97) and Norway (1.47). In terms of EMS transport units per 100 km of road length, Austria was found to have the highest number of transport units on the road network (2.30), followed by Slovakia (2.11), Lithuania (1.99) then the UK (1.74) (Vis and Eksler, 2008). In South Africa the most recent data points to an average number of 3.08 EMS units per 100 km of road length (RTMC, 2020). This is however inclusive of all categories of EMS vehicles including breakdown towing vehicles and fire engines. When considering just Ambulances, this number drops to 0.99 units per 100 km.

The use of HEMS has been given credit by many EMS systems for their benefits of reducing response time and removal time to and from the crash scene. HEMS have been advocated for two main purposes: to provide EMS response at crash scene, termed '*primary scene responses*' and to provide a transport means for critically ill patients between hospitals, termed '*secondary inter-facility transfers*' (Taylor et al., 2011). The use of HEMS systems has several advantages over other transport means. These advantages include a reduction in transport time to crash scene and from scene to health facilities, provision of advanced medical care since HEMS are often staffed with ALS crews, and a provision of health service equity in isolated areas (Taylor et al., 2011).

Although several studies have produced evidences supportive of the advantages of HEMS (Andruszkow et al., 2013; Andruszkow et al., 2016; Biewener et al., 2004; Frankema et al., 2004; Ringburg et al., 2009; Thomas et al., 2002), findings from other studies are mixed (Brown et al., 2012; Thomas, 2007). In addition, the effectiveness of HEMS remains subject for debate because of the high costs involved (Chappell et al., 2002; Taylor et al., 2011). Evidences suggest that the magnitude of the advantages of HEMS are heavily dependent on local geography and the operational aspects of HEMS within specific EMS system (Taylor et al., 2011). Therefore, it is suggested that the use of HEMS should be on a regional basis when they requested in emergency critical care situations by EMS personnel at the crash scene or at a primary receiving hospital (European Transport Safety Council, 1999).

Despite the ambiguity on the effectiveness of the HEMS, patient evacuation is widely relying on HEMS systems in many developed countries. Research reported the highest proportion of HEMS in Germany and Austria; air ambulances were used to transport patients at health facilities in 41% and 30% of arrivals, in Germany and Austria, respectively (Roudsari et al., 2007). More than 52 HEMS systems cover the whole German territory (Sturm et al., 2013). In Austria, 24 physician-staffed helicopter ambulances cover mainly rural areas where ground transport is difficult or impossible and are used for critical medical conditions. All HEMS paramedics highly trained, and almost all have many years of in ground EMS. Physicians working in HEMS are required to have at least 4 years of experience in ground EMS. Other HEMS paramedics are trained nurses (Weninger et al., 2005).

Land ambulances are the most common transport mode used to transport patients to health facilities. Given the important role played by this transport mode, many countries have standards regarding the equipment, vehicle and driver safety considerations. Special laws to facilitate evacuation by ground transport units also exist in some countries. As an example, Swiss and German authorities defined a law termed in German '*Rettungsgasse*'. The law stipulates a formation of an emergency lane or emergency corridor when a road is congested as a result of a traffic crash, regardless of whether emergency vehicles are already in the vicinity or not. The emergency lane enables EMS response to get through and reach the crash scene without delays. For a two-lane road, drivers are required to steer their vehicle as far as possible to the roadside to clear a sufficient passage in the middle of the road. For a road with more than two lanes, all vehicles in the far-left lane must move as far as possible to the left and all others must move as far as possible to the right. The vehicles to the far-right lane should also use the hard shoulder in this process (ASFiNAG, n.d.; van Schagen and Machata, 2010).

The SANRAL On-road services comprise of four types of services, on the Gauteng Freeway Network, including a Medical Response Unit (MRI) with the objective of providing first responder medical services, improving the safety of motorists (particularly in the event of an incident), and reducing the impact of incidents on the flow of traffic. These services are decentralised at strategic positions across the network so as to allow for rapid response to incidents. The services are operated 24-hours per day, 7-days per week and are tracked, monitored and dispatched from SANRAL's Traffic Management Centre. The medical response units (MRUs) are intended to provide rapid medical response to incidents where injuries might have occurred and thereby act as quickly as possible in the so-called "golden hour". These units are staffed by an Intermediate Life Support (ILS) paramedic, equipped with medical kits, who will provide patient care until the arrival of an ambulance for patient transportation. that will take over the patient care and transport patients to a hospital.

6. Best practices of hospital trauma care systems

Research has shown that improvements in trauma care systems have brought significant reductions in mortality rates in many countries. A study by (Noland, 2004) reviewed several empirical studies from US, Great Britain and international studies conducted in other industrialized countries. While being not necessarily traffic-related, (Noland, 2004) used the infant mortality rates as a proxy variable to represent improvements in medical care and technology for the US data. The author found that a reduction in infant mortality rates–which was deemed in this study as a result of improved medical care and technology–resulted in a decrease in traffic fatality rates. This finding allowed the author to conclude that a reduction in the US traffic fatalities over time was partially explained by improvements in medical care and technology that took place within the same period of analysis. The author reported further evidences from his previous study that used the same dataset. In this study, he concluded that 2 047 fatalities (4.5 %) would have prevented if the technology of 1997 was available in the year 1985 for the US data.

For the British data, Noland (2004) used three proxy variables as an indication of changes in medical care and technology. These proxy variables included the average length of in-patient stay in the hospital, National Health Service (NHS) staff per capita and the number of persons waiting for hospital treatment. The study revealed that as the average length of in-patient stay in the hospital–regarded in this study as due to improvement in medical technology and care– reduced there was also a reduction in traffic fatalities over the same period. The author also found a negative correlation between the NHS staff per capita and the number of traffic fatalities. Positives associations were found between waiting times for medical treatment and total fatalities. These two last findings are clear evidences that improved medical care has resulted in a decrease in traffic fatalities. A similar conclusion emerged from another study by (Noland and Quddus, 2004) that used the same dataset. They concluded that nearly one-third of about 2100 reduction in traffic fatalities were attributed to medical and technological improvement that occurred between 1979 and 1998 across nine British regions, London and Scotland excluded.

For the international data, Noland (2004) cited his previous study in which he analysed data from several industrialized countries members of the Organization for Economic Cooperation and Development (OECD). In his study, (Noland, 2003) included three proxy variables representative of improvements in medical care and technology. These proxies were infant mortality rates, physicians per capita and average number of days in hospital for acute care patients. The analysis of correlations between these variables and traffic fatalities rates suggested that advances in medical technology and care have been one of the underlying factors behind the reduction of traffic fatalities in developed countries over the past decades. More accurately, Noland (2004) estimated that between 5% and 25% of reduction in traffic fatalities over a period of 26 years across countries member of OECD could be attributed to improvements in medical care and technology. The overall review of these studies provides enough evidences that changes in medical care and technology have played a key role in curbing traffic fatalities rates in many developed countries.

Factors such as clinical staffing, capabilities of healthcare facilities, equipment and supplies, and trauma care organization play a great impact on the overall performance of trauma care systems (European Transport Safety Council, 1999). Although there is a diversity in medical definitions, legislations and management systems within different trauma systems (Gitelman et al., 2014), evidence-based performance indicators exist in practice and research to allow national and international comparisons of healthcare systems and to develop strategic quality improvement plans. The availability of trauma beds in permanent healthcare facilities per population is one the performance indicator widely used to rate trauma systems (Vis and Eksler, 2008). Based on this indicator, the highest number of beds per 10 000 population was found in Austria (78.53), Germany (61.96) and Greece (46.19) (Vis and Eksler, 2008). In a period, interval of 2008-2009, Statistics in South Africa shows that there were 1 186 intensive care unit (ICU) beds and 3 533 ICU beds in public and private healthcare facilities, respectively (Naidoo et al., 2013). A total number of 4719 ICU beds distributed among 49.32 million population for the period 2008-2009 would mean a share of approximately 1 hospital bed per 10 000 population in South Africa (Naidoo et al., 2013). These figures for South Africa highlight an urgency to improve healthcare systems to ensure that injured patients gain access to an adequate medical care in a timely manner.

7. Best practices of rehabilitation

Rehabilitation services are an essential component of post-crash care systems. These services aim at restoring physical and mental health of road crash survivors and helping to return their places in the community. Medical rehabilitation services involved a range of professionalisms, such as physiotherapy, occupational therapy, prosthetics and orthotics, neuropsychology, psychology, speech pathology and nursing. Rehabilitation services also help survivors who are living with impairment to attain autonomy and a good quality of life (Peden et al., 2004).

The best practices of rehabilitation are rated based on the quality of the services offered to crash survivors. Several EMS systems have rehabilitation programmes developed not only for the crash survivors, but also for their supporting relatives. An example of such programmes is the project 'Road Violence Victims Care' developed in Spain (van Schagen and Machata, 2010). The project offers a psychological support to both crash victims and relatives or close friends. Evidently, research shows that early rehabilitation can play a greater role in speeding up the recovery process and in reducing permanent disability and risk of post-traumatic stress disorders (Beck and Coffey, 2007; Peden et al., 2004). Some of the European countries have established rehabilitation programmes offering more specialized care to the victims of brain injuries caused by traffic crashes (European Transport Safety Council, 1999).

8. Data and information systems

Data on road traffic crashes and on post-crash care aspects are essential for identification of priority areas, evaluation of post-crash care systems and development of future road safety strategies. The type of data that need to be collected and documented may include for instance in-depth crash data, exposure data, safety performance indicators, measurement of road crash survivor outcomes, post-crash measure of disability, and data on prehospital EMS and healthcare resources. In recognition of this, the European Union developed an initiative, named The Trauma Audit & Research Network (Euro TARN) in 14 European countries with a purpose of developing an effective system to review the standards of trauma care across Europe and developing an effective method for future data collection (European Commission Directorate General for Mobility & Transport, 2013). The evaluation of Euro TARN initiative demonstrated successful results in collecting clinical and epidemiological trauma data on a pan-European scale and recommendations were consequently made to other registries to integrate their datasets (Edwards et al., 2007).

The freeways covered by SANRAL's Freeway Management System (FMS) allows for the capture of all incidents happening on these freeways on an Advanced Traffic Management System (ATMS) at the relevant regional Traffic Management Centre (TMC) where adherence to the Road Incident Management System (RIMS) is diligently managed. Valuable insights could be gained by having access and reviewing this information that is being captured. Figure 3-6 to Figure 3-10 provides some examples taken from a Cape Town Freeway Management System Monthly Operations Report of November 2018.

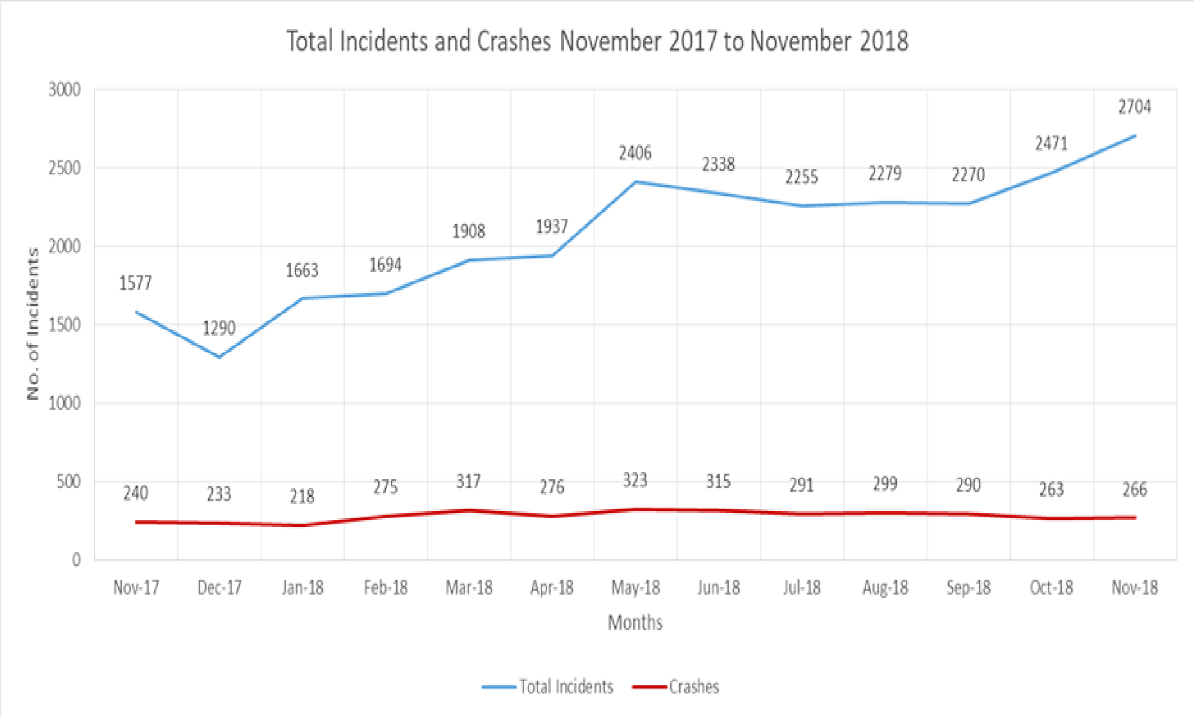


Figure 3-6: Total incidents and crashes (November 2017 to November 2018)

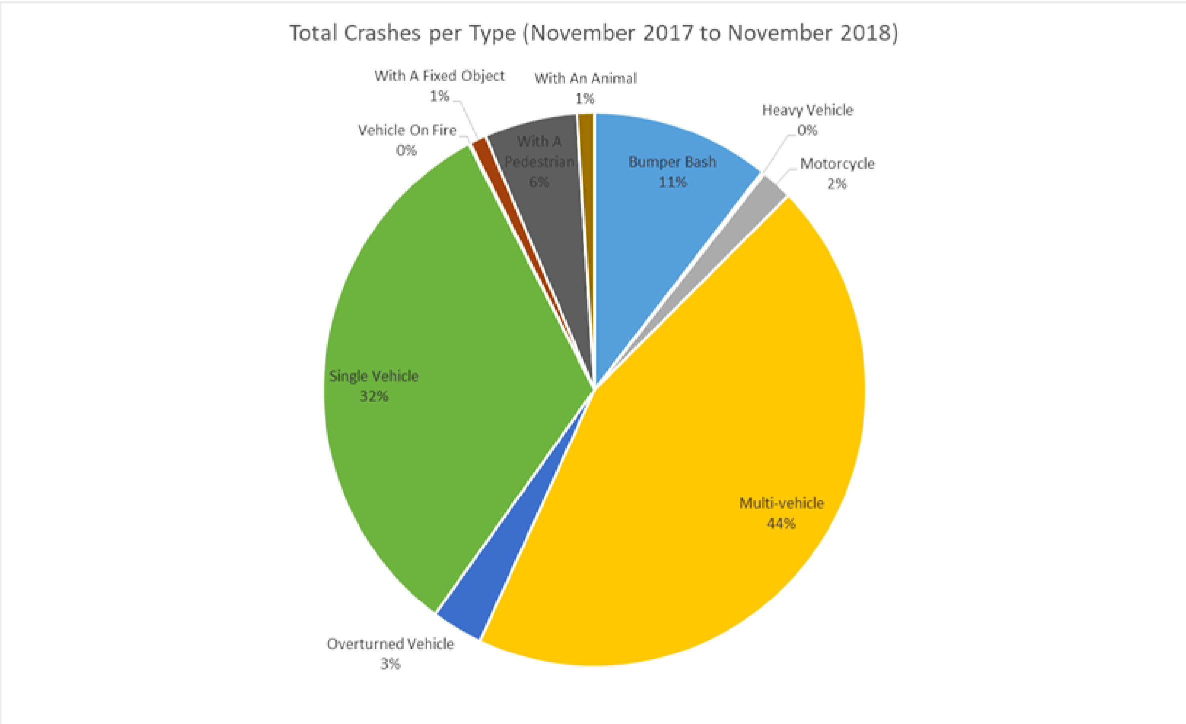


Figure 3-7: Proportion of total number of crashes per type (November 2017 – November 2018)

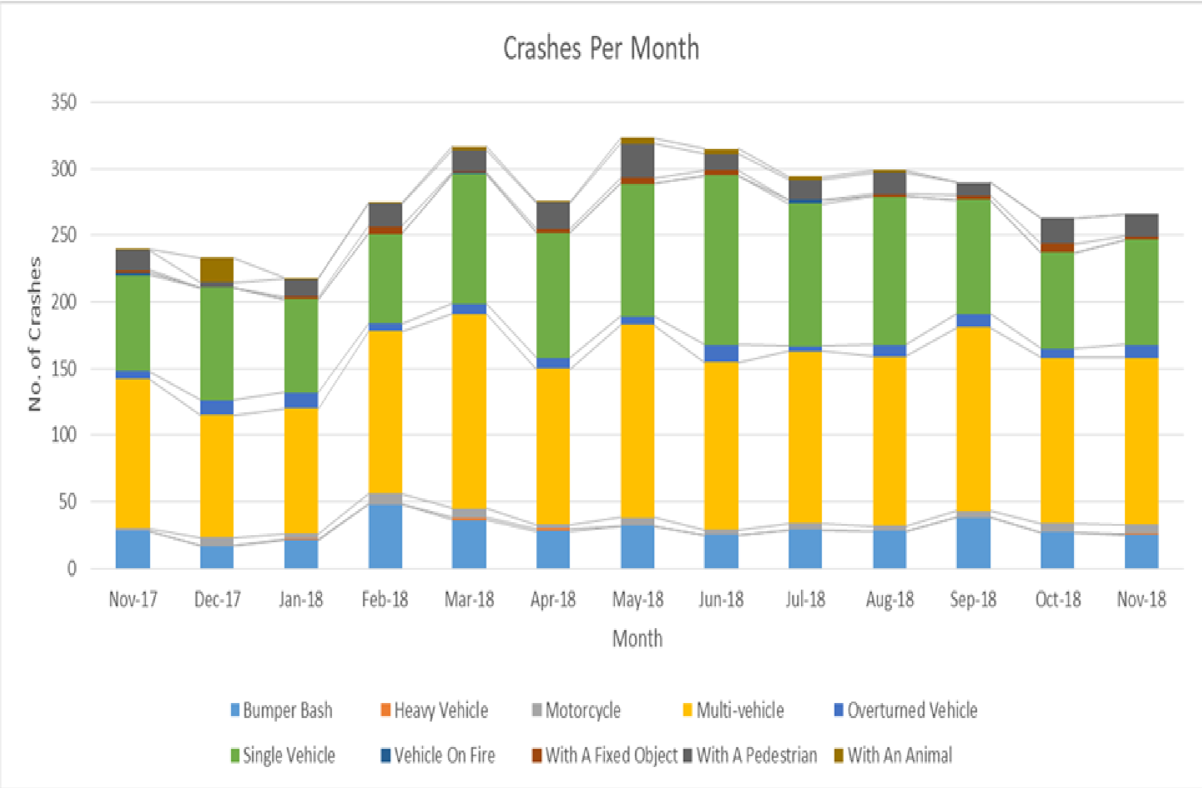


Figure 3-8: Crash types per month (November 2017 – November 2018)

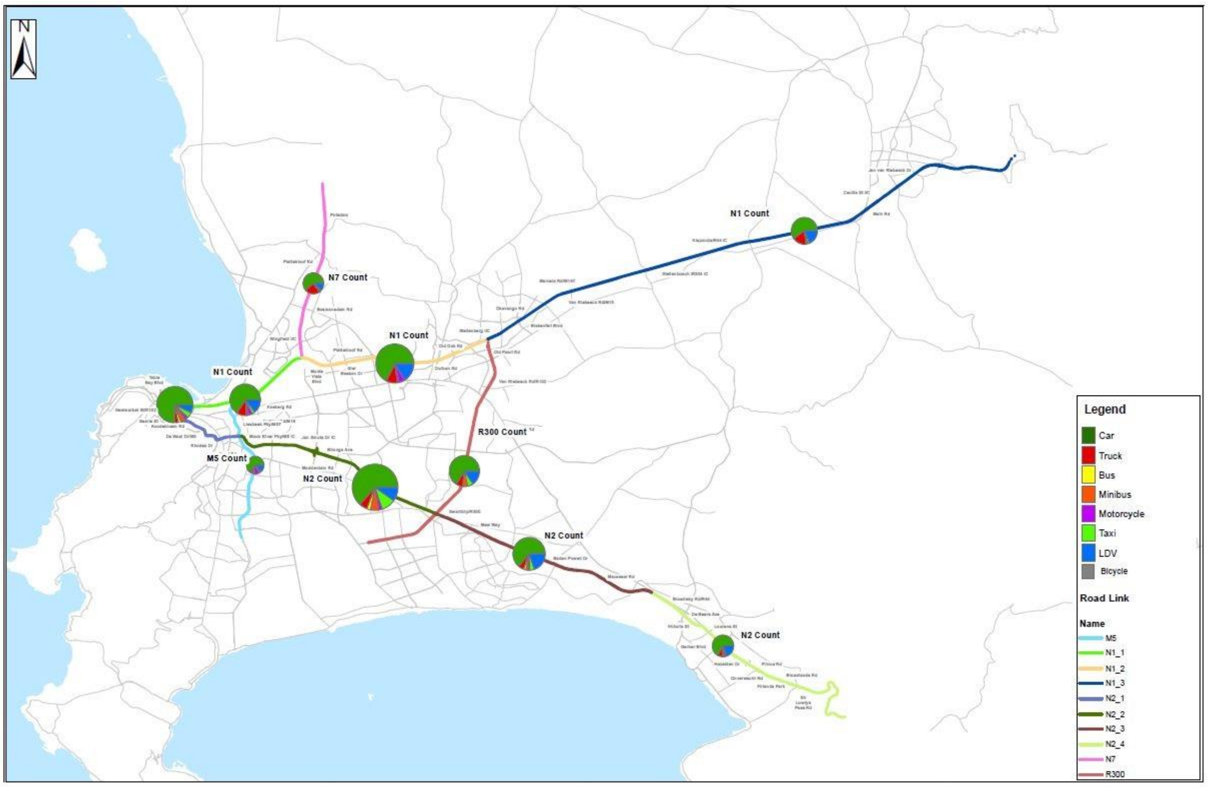


Figure 3-9: Location of crashes by type of vehicle (June 2018 – November 2018)

Figure 3-10: Crashes with pedestrians – southbound and westbound (June 2018 to November 2018)

Another example from where value insights could be obtained, is from the N3 Toll Concession (N3TC) operator who also diligently manage their Road Incident Management System (RIMS). Their database is a powerful tool which enables N3TC to identify hotspots along the N3 Toll Route and to achieve better understanding of the type of incidents along the Route, as well as how to manage and mitigate these to ensure overall improved road safety.

3.2. International review of safety performance indicators

Having discussed generally the best practices in road safety for various countries in the preceding section, it is important to gain an in-depth understanding into the performance measurement of safety initiatives and programmes. This is important in order to ensure the appropriate implementation and longevity of such safety strategies and principles as discussed in section 3.1. Of importance for this study is the need to successfully identify performance indicators to be measured in the TOSs.

Two initial questions need to be answered as relating to the successful measuring and analysing of safety performance initiatives are:

- What needs to be measured? i.e. The specific indicators.
- What is the change that needs to be observed? i.e. The relevant target setting for these indicators.

Once the above two questions are addressed, the "how" regarding data collection and analysis is discussed.

3.2.1. Prominent international guidelines on safety performance indicators

The following guidelines prominently recognised in the road safety environment were taken into account during the literature analysis into road safety performance indicators. Some of these documents where previously taken into account during the South African TOS development in 2013 (Road Traffic Management Corporation, 2013). They form the basis of discussion, with additional recent documentation reviewed thereafter. The emphasis here is to identify newer versions of the documents reviewed in 2013, or newer documents by the same organisations, and to identify whether the basic concepts and performance indicators remain unchanged or whether the emphasis has shifted.

3.2.1.1. European Transport Safety Council (ETSC)

The European Transport Safety Council (ETSC) is an international non-government organisation formed in 1993 in response to road safety issues in Europe. Their publication *Transport Safety Performance Indicators* (ETSC, 2001) aimed to highlight the importance of using performance indicators in the road safety field to assist policymakers in taking actions that are as effective as possible. This document formed the basis for many further developments concerning the issues of road safety and still to date encapsulates some important concepts.

The ETSC defines safety performance indicators as a "*any measurement that is causally related to crashes or injuries, used in addition to a count of crashes or injuries, in order to indicate safety performance or understand the process that leads to accidents. Such indicators can give a more complete picture of the level of transport safety and can point to the emergence of new problems at an early stage, before these problems show up in the form of accidents. A regular monitoring of safety performance indicators improves the understanding of road accident trends. Since these monitoring results can become available far more quickly than registered accidents, they are particularly useful for policymakers."* (ETSC, 2001).

Figure 3-11 below indicates the role of performance indicators in safety programmes.

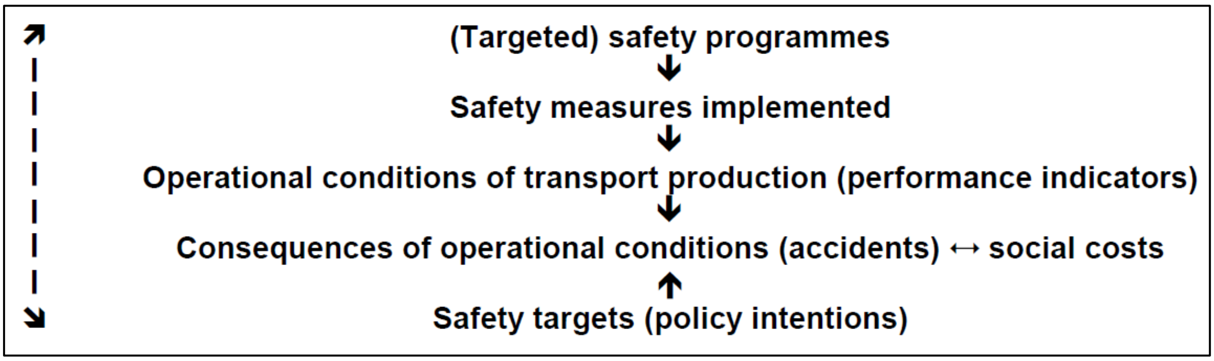


Figure 3-11: The place of performance indicators in safety programmes (ETSC, 2001)

The ETSC categorises road safety indicators according to behavioural indicators and quality indicators. Mostly of importance for the survey of traffic offences is the measurement of *behavioural indicators* (as has been the focus of South African road safety performance monitoring). The importance of a broader approach to road safety performance monitoring is, however, also noted and would include other indicators as well. The following indicators were listed as the main behavioural indicators to be considered:

- Speed levels
- Drink driving rates

- Seat belt use
- Helmet use

Excessive speeding and the impact thereof on increased serious injuries during related crashes was identified as a crucial element of road user behaviour to be addressed. The ETSC evaluated several speed monitoring systems in Europe, identifying a number of elements to speeding that have can be measured, additionally categorised according to road type, vehicle type and weather condition, such as:

- Mean speed
- 15th and 85th percentile speeds
- Speed variance
- Proportion of speeding vehicles

More recently, the ETSC published its 14th Road Safety Performance Index Report (ETSC, 2020), ranking the EU progress on Road safety. The general finding was that the observed decrease in the number of road deaths was very low, at only 3% on average in the countries participating in the PIN programme.

Concerning the performance measurement that is utilised in the EU, the following Key Performance Indicators (KPIs) are currently used:

1. Speed compliance
2. The use of safety belts and child restraint systems
3. The use of protective equipment
4. Driving under the influence of alcohol
5. Driver distraction by handheld devices
6. Safety of new cars
7. Infrastructure safety
8. Post-crash care

Once again, the behavioural indicators (numbers 1 to 5) are of most concern for Traffic Offence Surveys since these surveys aim to analyse road safety factors in control of the road users themselves. Driver distraction by handheld devices seems to be an increasingly important issue to consider since the 2013 review. Other very important road safety indicators are the physical infrastructure and the trauma management.

3.2.1.2. Organisation for Economic Co-operation and Development (OECD)

The Organisation for Economic Co-operation and Development and the International Transport Forum established a joint Transport Research Centre in 2004. The Centre conducted co-operative research programmes addressing all modes of transport to support policy making in member countries (Transport Research Centre, 2008).

To improve road safety performance over the longer term, the International Transport Forum of the OECD recommended the following actions (Transport Research Centre, 2008):

- Improved data collection and analysis to support longer term targets and interventions.
- Setting robust interim targets, based on an agreed strategy.
- Ambitious long-term vision, building on the agreed strategy with innovation.

- Adopting a Safe System approach.
- Improving key institutional management functions.
- Supporting research and development through knowledge transfer.
- Establishing adequate funding for effective safety programmes.
- Meeting management challenges, especially building political support.

According to the Transport Research Centre (2008), *"safety performance indicators help illustrate how well road safety programmes are doing in meeting their objectives or achieving the desired outcomes. They are a means of monitoring, assessing and evaluating the processes and operations of road safety systems. They use qualitative and quantitative information to help to determine a programme's success in achieving its objectives. They can be used to track progress and can provide a basis to evaluate and improve performance."*

The type of data that needs to be collected is largely influenced by the type of performance indicator that needs to be monitored. The *Towards Zero* publication (Transport Research Centre, 2008) makes reference to a number of important typical road safety behavioural indicators that can and should be measured. These include **rates of seat belt and helmet use**, **speeding**, **red light running** and **blood alcohol limits**.

Other factors of importance when considering road safety are the infrastructure factors, for example road length by crash risk, physical condition of the road network and the standard of the vehicle fleet.

More recently, the Road Safety Annual Report of 2019 by the International Traffic Safety Data and Analysis Group (International Transport Forum, 2019) highlights the following performance indicator statements:

- *"Speed management is a critical element of any road safety strategy."*
- *"Setting and enforcing limits for drivers on blood alcohol content (BAC) prevents drink-driving crashes."*
- *"Seat belts are among the most effective tools to save the lives of vehicle occupants."*
- *"Helmets protect a particularly fragile and critical body part of users of two-wheelers."*

From reviewing the Road Safety Annual Report, it seems that most of the safety performance measures mentioned in the 2013 review are still relevant.

3.2.1.3. World Health Organisation (WHO)

The latest *Global Status Report on Road Safety (GSRRS)* (World Health Organisation, 2018) published by the WHO in 2018 paints a picture of continued slow progress in reducing road deaths, although the rate of deaths relative to the world's population has stabilised in recent years.

Considering legislation and road user behaviour specifically, the report highlights the identification of five risk factors that *at minimum* need to be addressed in legislation. The five identified risk factors are:

1. Speeding
2. Drink-driving
3. Use of motorcycle helmets
4. Use of seat belts
5. Use of child restraints

At present, 123 countries have laws that meet best practice for at least one of the five key risk factors. Despite the progress made in improving legislation across the five key risk factors, enforcement remains a major challenge in most countries.

One challenge highlighted by the GSRRS is that of inadequate data collection. Robust data are a critical component for the attainment of any future target. "*Without the ability to assess progress and the effectiveness of efforts to reduce fatalities and injuries, countries will not be able to identify gaps in the system and deliver tailored improvements."* Appropriate and well-structured surveys, measuring the right performance measures are therefore an imperative and the potential use of technology driven application in such surveys is discussed in section 3.8.

3.2.1.4. European (E-) Survey of Road users' safety Attitudes (ESRA)

The European (later E-) Survey of Road users' safety Attitudes (ESRA) (Torfs *et al.*, 2016) conducted by the Belgian Road Safety Institute provides a synthesis of the main findings from the ESRA survey in 17 countries. The project was aimed at collecting comparable (inter)national data on road users' opinions, attitudes and behaviour with respect to road traffic risks.

An interesting approach to consider is the measurement of the subjective opinions of the road users themselves, rather than measuring objectively the immediate traffic offences done by them. The recorded change in trends over time in road users' **perceptions** of the road safety issues can give very important insights into the impact of a certain road safety initiative.

The themes covered are

1. the use of different transport modes,
2. involvement in road crashes,
3. safety feeling,
4. concerns about road safety,
5. self-declared behaviour,
6. attitudes towards road safety,
7. acceptability of unsafe traffic behaviour,
8. behaviour of other road users,
9. enforcement, and
10. support for policy measures.

The main focus of the survey was on the overall European results with an emphasis on the comparison between different road safety topics: **speeding**, driving under influence of **alcohol** or **drugs/medication**, **distraction** and **fatigue**, and **seat belt use**.

As a second phase of the ESRA surveys (now referred to as "E-survey of road users' Attitudes") (Torfs, Meesmann and Van den Berghe, 2019) is currently being evaluated, new insights might be gained from that survey methodology regarding self-declared driver behaviour and road safety attitudes. As part of the ESRA2 methodology, the same performance measures were focused on, indicating that these remain relevant and are seen as the most impactful measures to monitor.

Importantly, as part of the ESRA2 survey a number of African countries also participated, including South Africa, Kenya and Nigeria. This is important in gaining some insight into the African context and specifically to understand how individuals in South Africa perceive road safety issues. This could lead to formulating more targeted traffic offence surveys.

Some of the main findings of the ESRA2 survey in South Africa (accessible at: https://www.esranet.eu/en/publications/) were:

- 32.4% of respondents admitted to having driven at least once in the last 30 days when over the legal blood alcohol limit (compared to 18.7% African mean).
- People feel most safe on the roads in South Africa when using public transport and most unsafe when using powered two wheelers.
- 42.5%% of respondents admitted to texting, emailing or checking social media at least once during the last 30 days while driving (compared to 46.9% African mean).
- 61.8% of respondents admit to driving faster than the speed limit on the freeways (compared to 51.2% African mean).
- 37.6% admit to driving without a seatbelt at least once over the last 30 days (compared to 53.9% African mean).
- 76.2% of pedestrians admitted to not using pedestrian specific crossing when those are available nearby (compared to 73.3% African mean).
- 45.1% of cyclists cycled without a helmet at least once during the last 30 days (compared to 57.7% African mean).

Based on these finding of the ESRA2 survey, it would seem relevant to touch on some of the above concerns, such as **driving under the influence**, **distractive behaviour** while driving, **unsafe pedestrian behaviour** and use of **protective equipment** (seatbelt, helmets etc).

In addition to the Africa-specific survey results Pires *et al.* (2020), analysing the ESRA2 results, revealed that risky behaviour in traffic is high despite low acceptability and high risk perception; speeding and the use of mobile phones while driving are the most frequently declared risky behaviours; and there is a strong support for policy measures restricting risky behaviours in traffic. The following figures show some interesting comparisons between different regions of the world, including Africa.

Figure 3-12 shows the relative road users' *perception* of causes of a road car crash. In general, driving under the influence and speeding are the highest perceived issues.

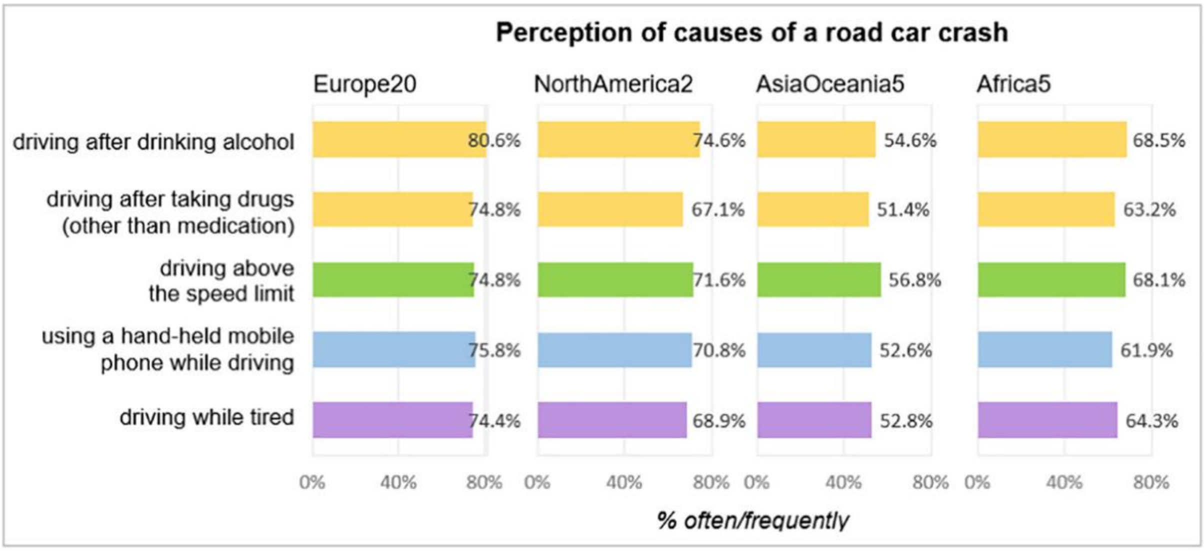


Figure 3-12: Road users' perception of what mostly causes road crashes (ESRA2 survey)

Figure 3-13 shows the perceived acceptability levels of roads users' regarding several areas of road safety. Areas of highest acceptability of unsafe behaviour are linked to speeding and the use of mobile phones. These are however at the same time also perceived as some of the most frequent causes of road car crashes as seen in the previous figure. Figure 3-14 shows the most frequent self-declared behaviour on the roads. Once again, most frequent are speeding and the use of mobile phones.

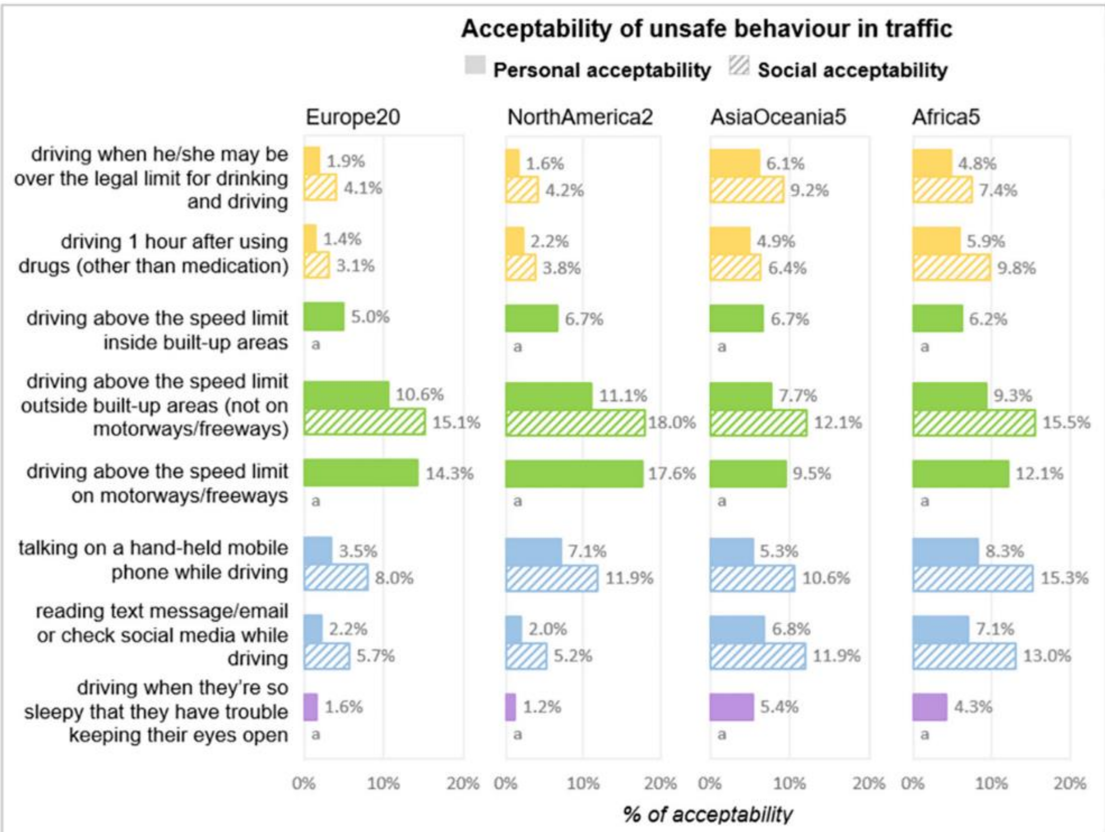


Figure 3-13: Acceptability of unsafe behaviour in traffic (ESRA2 survey)

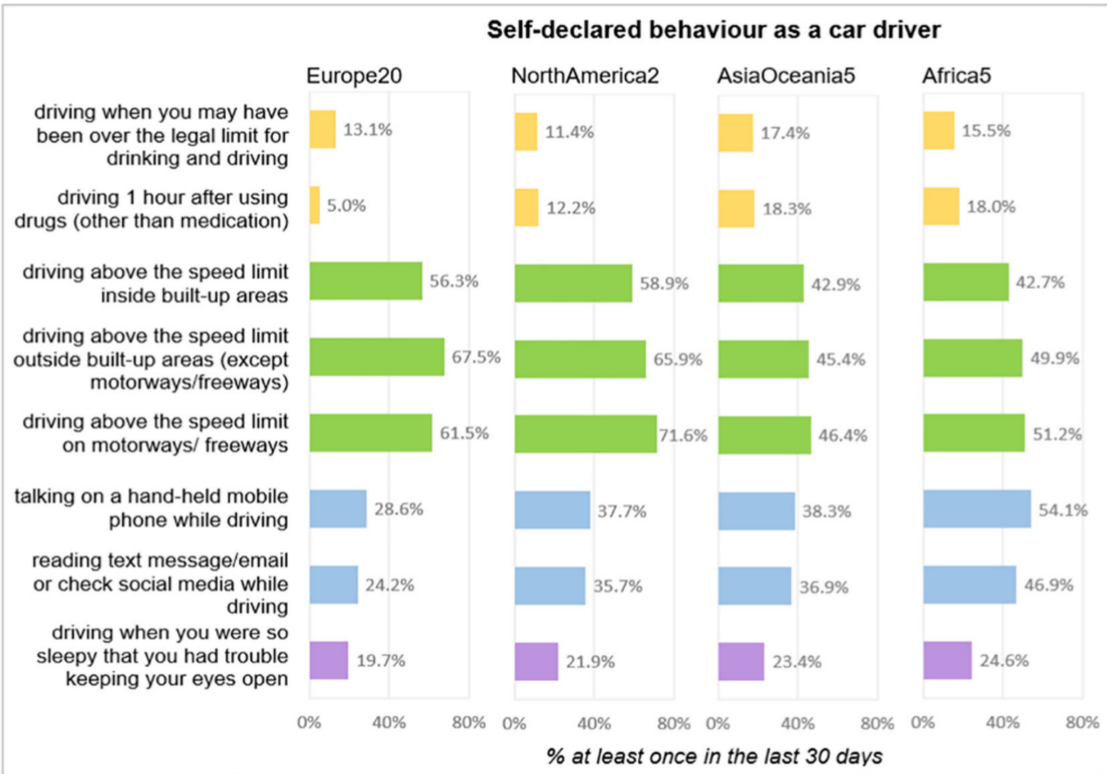


Figure 3-14: Self-declared behaviour as a car driver (ESRA2 survey)

Figure 3-15 shows that in Africa, only about 50% of respondents agreed that traffic rules should be stricter; far less than elsewhere in the world, especially considering drink driving and mobile phone usage. **This indicates that, potentially, the severe impact of not adequately enforcing in the areas of road safety is not fully understood by the average road user.** This in turn would indicate a greater need for road user education regarding road safety.

Figure 3-16, in turn, shows that there seems to be very high levels of support for implementing policy to address road safety concerns, also in Africa. The lowest support is given to the idea of zero tolerance for the use of mobile phones, although this is regarded as a very risky behaviour.

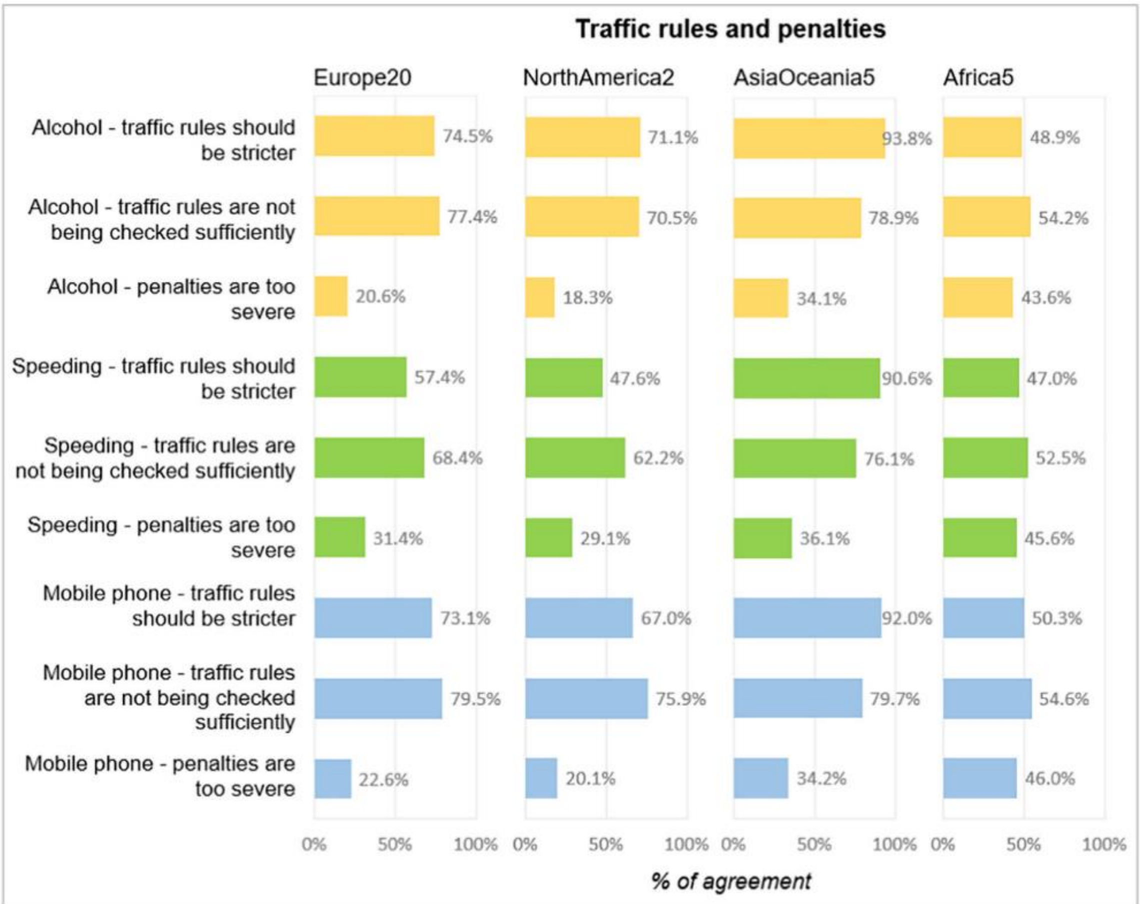


Figure 3-15: Traffic Rules and penalties (ESRA2 survey)

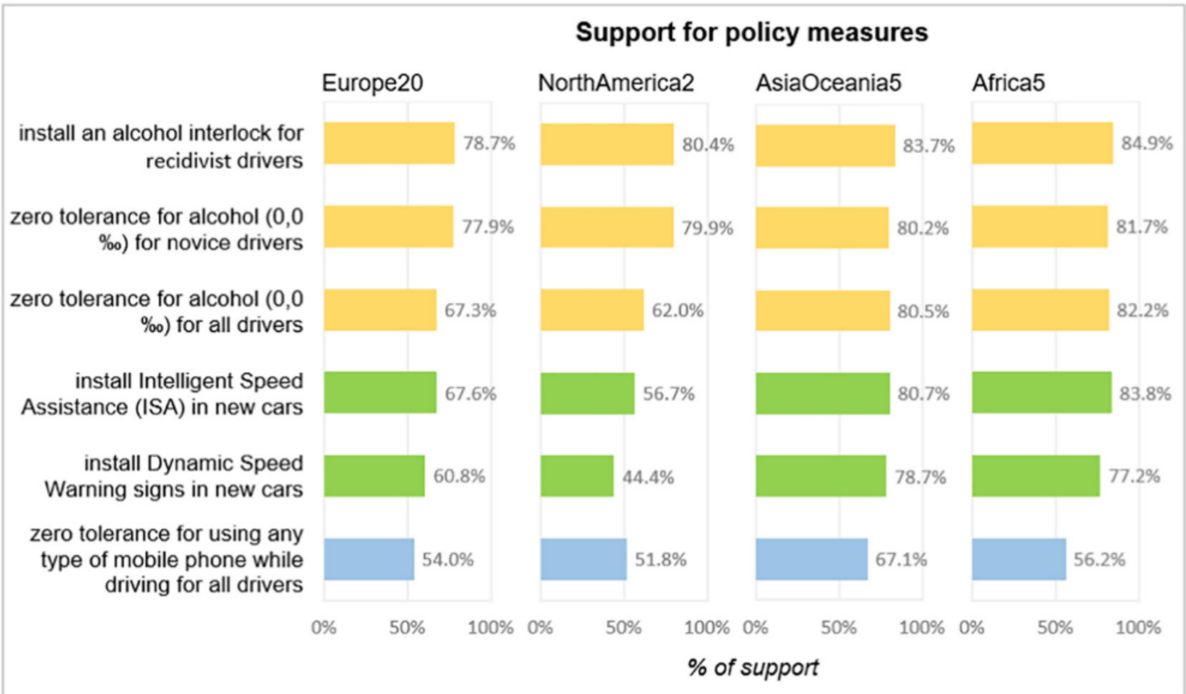


Figure 3-16: Support for policy measures (ESRA2 survey)

3.2.1.5. Road Safety Performance Indicators Manual

The Road Safety Performance Indicators (RSPI) Manual (Hakkert and Gitelman, 2007) was considered one of the most relevant documents reviewed in 2013 as part of the TOS methodology development. It is a rather dated manual, yet the foundational concepts and issues discussed are still relevant. In the manual, Safety Performance Indicators (SPIs) are classified as intermediate outcomes impacting on final outcomes which are the number of road crashes, injuries or fatalities. Safety measures and programmes are outputs impacting on SPIs.

As summarised in the TOS of 2013 (Road Traffic Management Corporation, 2013), the purpose of SPIs is threefold:

- to reflect the current safety conditions of a road traffic system (i.e. they are considered not necessarily in the context of a specific safety measure, but in the context of specific safety problems or safety gaps)
- to measure the influence of various safety interventions (but not the stage or level of application of particular measures)
- to compare between different road traffic systems (e.g. countries, regions, etc).

When developing SPIs the following steps should be taken:

1. Identify the specific domain for which the SPI is developed: road user behaviour, active vehicle safety, road infrastructure, post-crash care
2. Identify the factors contributing to accidents and injuries within the specific domain
3. Define the scope of the identified problems / contributing factors (operational conditions of the road traffic system which are unsafe and lead to accidents / injuries)
4. Convert the above into a measurable variable.

According to the Manual seven SPI domains have been identified:

- Speed
- Roads
- Protective systems
- Daytime running lights
- Vehicles
- Alcohol and drugs (substance abuse)
- Trauma management.

If emphasis was only placed on measuring Traffic Offences, factors in control of the road users themselves would need to be considered, such as Speeds, Protective systems, daytime running lights, vehicles, substance abuse. If, however, the focus shifts to the greater road safety picture, the remaining factors would have to be considered also.

3.2.2. Other literature speaking to safety performance indicators

In addition to the above-described prominent documentation relating to the performance measurement as utilised in the 2013 review, the following articles and other literature was taken into account in order to consider the newest research outputs. These documents are not necessarily international guideline manuals, but rather scholarly articles giving insight into the latest thought process around this topic.

3.2.2.1. Self-reported versus observed road safety performance indicators

As an additional thought to having analysed the ESRA survey results, which are based on self-reported behaviour, the article by Holló, Henézi and Berta (2018) discusses the comparability of self-reported and observed road safety performance indicators in Hungary specifically. The analysis was between observed and self-reported indicators obtained from the ESRA surveys.

The initial hypothesis was that self-reported behaviour generally shows a "better" picture than what reality actually presents. This was shown to not necessarily be the case, with seatbelt usage showing good uniformity between self-reported and observed. The comparison of other indicators is not necessarily as easy due to the varying time-frames within which the questions posed to road users are framed. It is however evident that self-reported behaviour and road safety attitudes can supplement observed behaviour measurements and is especially useful in monitoring change of time. Also, the comparison to other parts of the world (as is the case for the ESRA2 surveys) can highlight road safety issues in certain countries that are lacking and need to be addressed.

3.2.2.2. Other developing country perspectives

In order to gain some insight into other more developing country situations, articles relating to the current road safety performance situation and trends in the republic of Serbia (Pešić and Pešić, 2020) and the assessment of road safety performance for southeast Asian countries (Jameel and Evdorides, 2019) was considered.

The safety management system adopted by Serbia is shown in Figure 3-17 below.

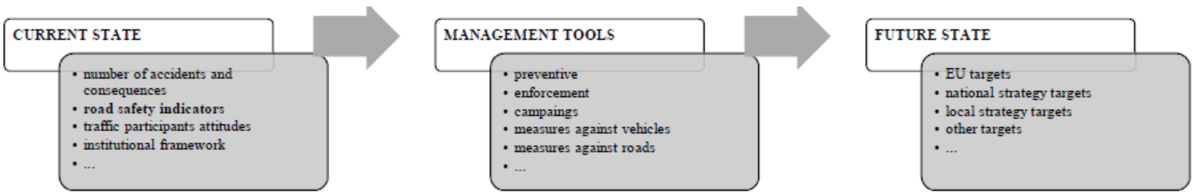


Figure 3-17: Serbia road safety management system (Pešić and Pešić, 2020)

Considering the implementation of road safety strategies and monitoring the following safety performance indicators,

- Protective systems
- Alcohol
- Daytime-running lights
- Speeding
- Mobile phone
- Vehicle health care,

Serbia has been able to observe change in trends and is able to focus attention on specific areas of intervention. They observed positive trends in front seatbelt use and helmet wearing rates.

"Road Safety Indicators unquestionably point to the emergence of road traffic vulnerabilities in a specific territory, so RSIs can be used to rank for example local communities and direct attention to the

local community where emergency measures are needed to improve the level of road safety." (Pešić and Pešić, 2020)

Jameel and Evdorides (2019) in their article compare a number of southeast Asian countries and rank them according to their uptake of the Safe System approach. To do this they analysed a number of significant and useful indicators, highlighting the necessity for such indicators.

The indicators selected for their index were: the percentage of roads awarded at least a three-star rating using the Road Assessment Programme methodology; the enforcement score on road safety laws regarding the five risk factors of **speeding**, **drink-driving**, **wearing seat belt**, **wearing helmets**, and using **child restraints**; and application of the minimum safety standards of vehicles as regulated by the UN.

One of the main critical elements of road safety that these evaluated countries have to consider is the setting of minimum vehicle safety standards, linking in to adequately road worthy and safe vehicles on the roads.

The above articles give the sense that "keeping it simple" and putting emphasis on the main road safety issues is important.

3.2.2.3. Driver fatigue as an element to consider

Driver fatigue is an element of road safety that is not easily measured. It is also not prominently featured during safety performance measures as compared to more easily measured elements such as speeding or drink-driving. Driver fatigue is however becoming more of a concern worldwide, especially for long distance and heavy vehicle drivers. It is however not per se a traffic offence such as speeding, yet is a very important point of consideration nonetheless and therefore some insights are provided here.

Davidović *et al.* (2020) delve into this topic of driver fatigue, establishing the significance of fatigue related indicators linked to professional and commercial drivers specifically. Based on an objective method of indicator selection, a narrow set of indicators were selected that were proven to have an impact on the occurrence and/or consequences of fatigue related traffic accidents. Thereafter, expert insights identified the indicators of most significant impact. Also, daily transportation company indicators were also selected.

The following four groups of indicators were selected:

- Sleep-related indicators (indicators related to the quantity and quality of sleep);
- Operation-related indicators (indicators related to working hours and time of the day);
- Rest-related indicators (indicators related to rest periods and breaks);
- Indicators of undertaken activities (indicators related to the measures for eliminating fatigue and education of drivers).

According to Davidović *et al.* (2020), the key performance indicators which affect driver fatigue are:

- % of professional drivers with good sleep quality
- % of drivers using appropriate measures for fatigue prevention (according to age groups)
- % of nights with the sufficient sleep quantity

- % of nights without sleep
- daily driving time
- weekly driving time
- fortnightly driving time
- % of daytime driving hours
- % of night-time driving hours
- daily rest

At present, the measurement of driver fatigue indicators is not an easy feat and would mostly rely on self-declared behaviour and subjective measurement of driver attitudes. Technology-aided fatigue detection mechanisms and how this could be implemented in the South African context is a possible area of further research.

3.2.3. Summarised Safety Performance Indicators

Having studied the various elements of road safety performance measurement, as well as taken into account the 2013 review findings and the comparison thereof to newer documents, the following is evident:

- The *basic* road safety issues that need to be monitored and captured in the form of performance measurement indicators still remain the same and a lot can be achieved if these are addressed.
- It is helpful to establish specific road safety domains such as *Road user behaviour* and *Trauma management* which contain specific related indicators.
- Measuring traffic offences only mostly focuses on the road user behaviour and vehicle condition. Other factors significantly impacting road safety, such as trauma management and road conditions, form part of the bigger road safety picture.
- Distracted driving by handheld devices seems to be more prominent of an issue now than what it was in 2013.
- The insight of self-declared road user behaviour and its change over time can provide awareness of certain issues and monitor the impact of certain interventions and campaigns, though subjectively only.
- Continued safety performance measurement is important in order to track changes and re-evaluate intervention strategies in order to achieve the final desired outcomes of reduced crash and fatality rates.

The below table summarises the critical indicators identified from international literature that should at minimum be tracked to evaluate monitor the change in road safety performance.

Table 3-2: Most important road safety indicators identified from international literature

Indicator number	Indicator
1	Speeding • Average travel speed on urban and rural roads • Average speed per road type and vehicle type • Percentage of surveyed car drivers exceeding the speed limit on different road types

Indicator number	Indicator
	• Subjective personal and social acceptability for driving above the speed limit (self-declared) • % speeding at least once in the last 30 days (self-declared)
2	Blood Alcohol Content (BAC) • Percentage of surveyed car drivers transgressing the alcohol limit • Percentage of road traffic deaths attributed to alcohol • Subjective personal and social acceptability for driving when under the influence of alcohol (self-declared) • % driving under the influence at least once in the last 30 days (self-declared)
3	Protective equipment (seatbelt and helmets) • Percentage of front seat belt use in cars • Percentage of rear seat belt use in cars • Percentage of child restraint use in cars • Percentage of cyclists and motorised two wheelers wearing crash helmets
4	Driver distraction (handheld mobile phones) • Use of cellular telephone while driving • % driving while using a mobile phone at least once in the last 30 days (self-declared)
5	Vehicle safety/ road worthiness • Percentage of cars in the national fleet with NCAP four-star safety ratings • Age distribution of the vehicle fleet
6	Trauma management • Ambulance response times
7	Road infrastructure • Percentage of road length with wide obstacle-free zone or roadside barrier • Percentage of road length with wide median or median barrier.

Comparing the above list to the typical indicators that have been in use in South Africa since the 1970s as summarised in Chapter 2, it is evident that most of these indicators have already been monitored to some extent. Additionally, South Africa has monitored a number of other indicators not on the above list as applicable to the South African context.

Chapter 4 makes recommendations regarding the list of indicators to be used in the new methodology, taking into account also the propositions of the 2013 methodology.

3.3. Safety performance indicator target setting

In order to address the high rates of traffic crashes and fatalities, it is important to develop, implement and monitor road safety policies. However, these road safety policies can only be successful if the extent of the problem road safety issue, its characteristics and the factors that contribute to road crashes if fully understood. Additionally, accurately recording and monitoring the trends in crashes and fatalities as well as the factors influencing these trends is also required. Collecting data on these trends regularly allows for the monitoring of Safety Performance Indicators (SPIs) for road safety, also commonly referred to as Key Performance Indicators (KPIs) (Van den Berghe, Fleiter & Cliff, 2020). These indicators are crucial as they help to assess the efficacy of policies and interventions and identify additional measures that need to be implemented.

Many countries with good road safety records use a broad set of SPIs that not only measure road safety performance but also consider the contributing factors such as quality of the road infrastructure, safety technology used in vehicles and road user behaviour (Van den Berghe, Fleiter & Cliff, 2020). In these countries, the central purpose of SPIs is to provide information on the current safety conditions of the road system, the measure and evaluate the effectiveness of interventions, to monitor trends and to enable comparisons between countries and regions.

It should be noted that merely having SPIs is not sufficient. It is equally important to determine and set goals and objectives for the reduction of traffic casualties and for improving the contributory factors to crashes (Van den Berghe, Fleiter & Cliff, 2020). These goals and objectives are referred to as targets and in order to improve road safety, it is important that these are quantitative and verifiable. In addition, it is of utmost importance to set actionable targets to be achieved as related to the level of current performance of a country. Targets need to be realistic and achievable. As a main objective of this study stands the reduction of road related fatalities with 50% by 2030 as laid out in the 2016-2030 National Road Safety Strategy (NRSS). This is the ambitious long-term vision and goal that needs to be achieved. For this to be accomplished, however, the setting of robust interim targets is needed and this is where the Safety Performance Indicators assist, indicating the desired observed change in the indicators over a certain time period.

As already summarised in the 2013 TOS literature review (Road Traffic Management Corporation, 2013) and laid out in the document *Towards Zero* (Transport Research Centre, 2008), the following is important to keep in mind regarding interim target setting:

"Ambitious, achievable and empirically-derived road safety targets should be adopted by all countries to drive improved performance and accountability. These targets should be developed by using a methodology that links interventions and institutional outputs with intermediate and final outcomes to develop achievable targets for different intervention options."

It is therefore evident from literature that the setting of intermediate targets needs to fully support the vision of the long-term road safety objective for a country. This target setting is unique for a specific environment. Important therefore is that **1)** the current situation be assessed accurately in an area so that **2)** the areas of road safety that are most critical to be addressed can be identified and **3)** the desired targets for change can be set realistically.

Chapter 4 makes recommendations regarding the revised target setting process for interim performance measures, taking into account previous targets for the South African context as well as units of measurement for these targets.

3.4. Best practice examples of safety performance monitoring

The 2013 review (Road Traffic Management Corporation, 2013) made reference to a number of monitoring examples, implemented around the world, to showcase how safety performance is monitored with the help of the previously discussed SPIs.

Most of these examples are considering the developed world context, rather than the developing country context as would be more applicable for South Africa. It is evident from literature, though, that it is important to set high desired final achievement objectives, yet being strongly supported by attainable intermittent goals. The following examples highlight some road safety performance monitoring initiatives that can be aimed towards as best practice examples. This does not mean the South African initiatives will reflect these examples exactly, but only apply the important aspects thereof. For each of the SPIs discussed, a description of the existing practices (best practice when available) used for measuring the SPI, the details and procedures that need to considered when setting up the SPI survey and collecting data (i.e., sampling procedures) and general issues related to surveying the SPI is provided.

3.4.1. Speed measurement

Speed is one of the main causes of crashes and has a direct influence on crash severity and injury outcomes. Collecting and analysing data that can indicate prevalence of unsafe vehicle speeds on the road network can be done in a variety of ways. Methods of speed data collection are summarised below (WHO, 2009).

1. **Hand-held devices**

Radar and laser guns are portable instruments that are handled by a human operator. For radar guns, a microwave beam is sent to the target vehicle, which reflects back a signal to the receiver in the radar gun. The moving vehicle affects the frequency of the returned signal. By measuring the amount of frequency shift and the duration of the time interval, the speed of the targeted vehicle can be determined. A microwave radar gun has a wide cone of detection, which is about 70 m at a range of 300 m. The laser infrared gun has a small detection cone of about 1 m in diameter at a distance of 300 m between the laser gun and the targeted vehicle. The equipment relies on the measurement of the round-trip time of the infrared light beam to reach a vehicle and be reflected back.

Radar and laser guns are flexible tools for the investigation of speeds since they do not require any permanent installation. However, the data can only be collected over relatively short periods of time due to the compulsory presence of a human operator. The use of radar and laser guns is more efficient on less-trafficked roads, as it becomes impossible for the observer to monitor the speed on highly-trafficked ones. Technical problems, due to secondary reflections from other moving vehicles can also alter the measurements. Moreover, the person responsible for the measurement must judge if the speed of a vehicle is unaffected by other vehicles and this subjectivity can introduce error in the measurement process. The overall cost of surveys with radar guns is high due to the manpower costs.

2. **Intrusive devices**

The increasing availability of electronic time and data recorders has meant that manual timing of vehicles using a stopwatch is now used only as a last resort. The passage time of a vehicle between two detectors, a measured distance apart, can easily be recorded. Detectors can include pairs of pneumatic tubes (detectors placed across the roadway on its surface), tribo- and piezo-electric cables (detectors in the form of tubes or in the form of bars in the pavement fixed by epoxy), switch tapes, inductive loops and photo-electric or electro-magnetic beams (WHO, 2009). Table below provides an overview of loop detectors used for speed measurement (Riguelle, Gitelman, Allenbach & Hollo, 2007).

Table 3-3: Intrusive vehicle technologies (loop detectors) used for speed measurement

	Description of device	Advantage of device	Disadvantage of device
Loop detectors	• Most widely used traffic surveillance system • Set of rectangular form wires embedded into roadway • Loop is traversed by an electric current creating an electromagnetic field. • Metallic content of a vehicle that passes over the loop disrupts the electromagnetic field • From the duration and nature of the disturbance, data on traffic volumes and occupancy can be derived	• Loops are cheap • Portable loops can easily be placed over road for small periods where it is not possible to install loops • Portable loops have same precision as classical loops • Maintenance costs average around 10% of original installation and capital costs	• Double –loop detectors preferred as speed data collected with single-loops have low accuracy • Classification can only be provided if the traffic is free flowing (if speed is low and headways small the loop is unable to differentiate between following vehicles) • Expensive to install • Loops can become as a result of road repairs and movement of road surface • Existing loops are often present in high-trafficked roads and freeways which may not be a representative sample of the road network

In the Netherlands, speed monitoring is conducted by means of permanent measurement devices such as loops. traffic and speed in the Netherlands are mostly recorded by (visible or invisible) measurement loops attached to a data recorder which classifies data according to a prespecified format. For example, the so-called Golden River Marksman M660 is a data recorder which is being used in the Netherlands but also in many other EU-countries (UTMC, 2000). Data recorders are read out and set up again every 4-6 weeks by a person, or are read out by transmitting the data over a phone line. New developments are that data recorders are able to send data minute by minute to a large database by GRPS wireless communication technology. For example, in the province of Zuid-Holland, 18 measurement loops send their data every minute by wireless technology to a central database. Interestingly, besides the regular speed and intensity data, car-by-car gap data can also be delivered by this large, minute-by-minute growing database.

3. Non-intrusive devices

Table below provides an overview of non-intrusive vehicle technologies used for speed measurement (Riguelle, Gitelman, Allenbach & Hollo, 2007, Adnan, Sulaiman, Zainuddin & Besar, 2013).

Table 3-4: Non-intrusive vehicle technologies used for speed measurement

	Description of device	Advantage of device	Disadvantage of device
Doppler-based microwave radars	• Preferred to other types of radar • Device send a constant wave (24.5 GHz) which is rebounded by the surface of the vehicle • Placed along the roadway (usually fixed on existing • poles). From the modified frequency, it is possible to calculate the speed	• Microwave radars are not sensitive to weather conditions • Non-intrusive, not necessary to interrupt traffic to install devices and are thus easy to place on busy roads • Several lanes can be measured with same device if traffic flow is not heavy	• Can only obtain a coarse classification of vehicles based on their dimensions
LIDAR devices (light detection and ranging)	• Works similarly to radars but on a different wavelength and a different type of wave • Use a laser wave and gather the reflected wave to get information on the encountered objects • Mainly used in enforcement because of high accuracy	• Very high accuracy	• Price is higher than classical radars
Passive acoustic devices	• Measures speed on the basis of the noise of passing vehicles • Ultrasonic devices generate a beam and measure the time taken for the reflected signal to come back •	• Inexpensive	• Must be mounted above the measured traffic lane which generates additional costs

	Description of device	Advantage of device	Disadvantage of device
Passive infrared detectors	• Detects the heat emitted from an object • Usually employed to identify vehicles or pedestrian waiting at crossings •	•	• Detection of moving objects at high and moderate speeds are not accurate
Active infrared devices	• Use the same principle as microwave radars but with infrared wavelengths • Smaller wavelengths made them more accurate than microwave (this helps to distinguish between vehicle types)	•	• More expensive • Subject to errors in bad weather conditions

4. Probe data

Probe speed data can also be used to determine vehicle speeds. Probe speed data are widely used to calculate performance measures for quantifying traffic conditions (Adu-Gyamfi, Sharma, Knickerbocker, Hawkins & Jackson, 2015). Probes are devices which are either carried by travellers or vehicles, and are able to relay their location and any available additional data in real-time at very frequent refresh rates. These devices include smartphones and in-vehicle telematics (Espada & Bennett, 2015). With the increased use of smartphones, there has been a huge growth in the volume of probe data points and probe data is an emerging source of information to assess the performance of the transport network. A unique advantage of probes over other methods to collect traffic data is that probes are nomadic devices, while existing methods are based on roadside detection. Probes are therefore not dependent on the availability of roadside units and can therefore gather data much more comprehensively and at higher resolution. Data is collected wherever and whenever a traveller with a suitable device is on the road. Probes can provide comprehensive and high-resolution data on travel speed and travel time as well as O-D, route preferences and turning ratios (Espada & Bennett, 2015).

5. Police reports

Data on speeding can also be obtained from law enforcement. Information on the number of police checks (e.g. for speed), number of violations (e.g. number of vehicles speeding) and number of drivers punished (e.g. fines, penalties, imprisonment) are also useful measures to assess the prevalence of speeding.

6. Insurance companies

Another source of speed data can be vehicle tracking data obtained from insurance companies. However, not all vehicles are fitted with telematics devices that record this data which can skews results obtained. An example of this in the South African context is Discovery Insure's innovative vitality drive sensor which uses vehicle telematic technology to track driving behaviour. The device measures harsh braking, harsh cornering, harsh acceleration, speeding and cellphone use. The application provides real time trip updates and post-trip analysis so drivers can assess how well they have driven and make the necessary changes, accordingly.

Issues to consider

- Regardless of speed measurement type, it is vital to consider the different types of vehicles using the roads (heavy vehicles typically move more slowly than cars), the traffic volume (higher volumes result in lower speeds) and variables such as time of day, day of week, holidays and weather conditions.
- Surveys must be conducted under similar conditions each time (same location, same recording equipment and preferably same equipment operator) as any variation in collection procedures may result in differences in the speeds recorded.
- Recording equipment such as radar should be hidden, if possible, as road users who spot the equipment may change their speed and might even brake in fear of getting a fine.
- Automatic methods of data collection are recommended for larger samples
- Speed survey results are highly dependent on the way the survey is conducted

3.4.2. Use of protective systems (seatbelt and helmet use)

1. **Direct observation**

Direct roadside observation has predominately been used to provide statistically reliable data on vehicle occupant seatbelt use and helmet use in road safety surveys. Traditional observational studies on these protective systems have been based on a random sample of vehicles observed by an individual or individuals assigned to various locations such as intersections, highway exit ramps and other sites (Lofgren, 2009). Seat belt data is collected by looking into vehicles when stopped at traffic control devices, looking into vehicles as they travel along a traffic corridor or stopping them for inspection. Helmet use is surveyed in a similar manner. One drawback of this method is that when traffic becomes heavy and there are too many vehicles to count, direct observation becomes problematic as vehicles must be skipped under these circumstances.

In terms of locations a variety of sites are used. A national study assessing seatbelt wearing rates in Ghana conducted observations at fuel stations as this allowed the researchers to obtain an accurate representation of seatbelt usage (WHO, 2014). It is believed that observations conducted near roadblocks can skew results as drivers can put their seatbelt on as they approach the roadblock. A similar line of thinking is adopted in seatbelt wearing survey procedures in the UK (WHO, 2014). In this context, observations are conducted at intersections and junctions with automatic traffic signals where vehicles are stationary. A difficulty of this approach, however, is that it is impossible to make observations on motorways, and there are few suitable sites on rural roads.

2. Survey data

Driver behaviour and attitude surveys are also used to collect information on the frequency of and attitudes toward seatbelt and helmet use. This information is essential for providing insight into compliance with seatbelt laws. However, self-report surveys generally have lower validity compared to the aforementioned methods of assessing seatbelt wearing as surveys suffers from a variety of biases some of which include inaccuracies of recall (in terms of behaviour) or reporting (in terms of attitudes and beliefs), sensitivity to self-presentational issues (such as social desirability bias, acquiescence, extreme and moderacy responding and impression management biases).

3. Enforcement data

In addition to the sources of data mentioned above, data on seatbelt wearing rates can also be obtained from law enforcement. Information on the number of police checks (e.g. for seatbelt use), number of violations (e.g. vehicle occupants not wearing seatbelt) and number of drivers punished (e.g. fines issues for not wearing a seatbelt) are also useful measures to assess seatbelt usage.

Issues to consider

- With direct observations, there are many independent variables that researchers cannot control when performing an observational study (e.g. sampling diversity)
- Video data can eliminate the potential bias of self-reported seat belt use
- With video data, human error while observing vehicles is a problem. For example, it may be difficult to estimate the driver or other occupants' age.
- Roadside observations can only be used to collect information on daytime seatbelt use as daylight ensures visibility
- Need to consider privacy laws that protect citizens from unconsented surveillance
- Additional funds may be needed for surveillance equipment
- Location of survey sites with traffic officer/police roadblocks can be problematic as compliance is generally higher at permanent roadblocks since drivers know law enforcement observes motor vehicles and occupants at these locations. Thus, an accurate representation of safety habits is not provided.
- Survey sites that are chosen need to be representative of all types of road and traffic. Observation sites need to cover regions with varying populations and road environments (e.g. rural and urban areas).
- Need to ensure that a statistically significant number of vehicles pass the selected location
- Need to ensure that the chosen site does not skew the sample population based on demographic trends

3.4.3. Drink-driving

Alcohol and drug use by road users, especially drivers of motor vehicles, increases the road crash risk considerably. The SPIs for drink-driving are presented below.

1. Random breath testing

Random breath testing is defined as a test administered by police that tests the driver's breath in order to measure the level of alcohol consumption (Riguelle, Gitelman, Allenbach & Hollo, 2007). A weakness of this method is that large sample are required to obtain reliable results as the prevalence of drink driving in the general population is likely to be low in statistical terms. In addition, random breath testing as a SPI poses difficulties in establishing a representative sample of the road user or driver population. It is worth noting that several countries with good road safety records such as the UK and Germany do not allow the random breath testing of drivers. Instead, data on the prevalence of drink-driving among the driving population is obtained via traffic crash data and this is the recommended method to collect data for this SPI (Riguelle, Gitelman, Allenbach & Hollo, 2007).

2. **Traffic crash data**

The road safety situation of a country with respect to the use of alcohol can be monitored very well directly from road crash data, since the size of this problem is clearly demonstrated by testing the BAC levels of road users involved in crashes. This is a preferred method since this SPI is a direct indicator and can therefore be preferred above a general-population indicator. This SPI can be limited to severe or fatal injury crashes which make up a smaller number of crashes than road users in general. It is recommended that all drivers involved in fatal crashes are tested for alcohol (as is the case in the Czech Republic). To this end, the police should police should ensure that blood, breath and/or saliva samples are taken from all drivers involved in on-the-scene fatal accidents.

Issues to consider

- Privacy and ethical concerns related to collection of body fluids from active road users
- Taking a breath test may not always be possible from all active road users involved in crashes as some road users not be physically able to undergo a breath test
- If breath tests are used, it is recommended that alcohol testing be done by police as drivers have a right to refuse being surveyed (which is likely if they are intoxicated).
- Preferably the SPIs should be reported for provinces within the country and for day and night time, day of the week and month. Time series/trends should be established when the SPIs have been reported for several years.

3.4.4. Driver distraction surveys

Driver distraction is a major contributing factor to crashes and a precursor to degraded driving performance. Monitoring driver distraction is therefore regarded as a possible way to improve traffic safety. Driver distraction can be monitored in a variety of ways. This includes direct observation, survey data and enforcement data. The procedures of obtaining data through these various measures are similar as outlined above for helmet use, seatbelt use, and speed measurement.

3.4.5. Non-motorised transport safety in African context

The variation in fatality rates across regions and countries also translates into differences in the types of road users most affected. Vulnerable road users which compromise pedestrians, cyclists and motorcyclists make up more than half of all traffic fatalities globally. Almost half of all deaths (54%) on the world's roads are among those with the least protection- motorcyclists (28%), cyclists (3%) and pedestrians (23%). In terms of non-motorised road users, pedestrian and cyclists are disproportionately impacted and it is reported that the African region has the highest proportion of pedestrian (40%) and cyclist (4%) fatalities. This is in stark contrast to the developed world which has fewer deaths among NMT users. For example, in the Americas pedestrian fatalities account for 22%

of traffic deaths and cyclist fatalities account for 3%. Similarly, in Europe pedestrian fatalities account for 27% of traffic deaths and cyclist fatalities account for 5%.

The higher fatality rates among NMT users in African cities is hardly a surprise considering that NMT is a marginalised mode of transport in the developing world. This is in large part due to the fact that NMT is a neglected mode of transport, past South Africa transport policies prioritised the extension of the road network which favoured private transport use in cities, the rapid rate of motorisation, most safety interventions improving the safety of drivers rather than pedestrians and the prioritisation of other basic infrastructural needs over NMT (Mokitimi & Vanderschuren, 2017, Segni Tulu, Washington, King & Haque, 2013).

3.4.6. Vehicle safety

The crash protection performance of a vehicle is very important. Properly maintained and fully functioning vehicles that meet all safety requirements is less likely to be involved in a traffic crash. Many countries with good safety records have EU and national legislation setting out safety standards for motor vehicles. Regular vehicle inspections are set up to check compliance with some of these standards helping to prevent a substantial number of vehicle defects.

An important element of common action on vehicle safety is the EuroNCAP crash test programme, in which the crashworthiness of cars is tested (Duboka, 2011). This programme is financially supported by the European Commission, some Member States and international consumer and motoring organisations. Based on research it is claimed that if all cars in a country earned, on average, one star more, this would lead to 12% less casualties (Lie and Tingvall, 2000, Duboka, 2011). An indicator that can be measured in all countries in a comparable way, is the frequency of number of stars for the vehicle fleet in each country. The Swedish National Road Safety Programme already explicitly mentions the crashworthiness of cars as an indicator with a quantitative target.

An alternative method of vehicle fleet measurement is to develop and maintain a database of vehicle registrations. The minimum information which is required to produce some calculations of vehicle age (as a proxy for vehicle crashworthiness) and fleet composition (as a measure of compatibility), are total number of vehicles listed by:

- Year of manufacture (or year of first registration)
- Vehicle type

3.5. Pedestrian Safety

Walking is a prevalent mode of transport both globally and in South Africa. According to the 2018 Global Status Report on Road Safety (World Health Organisation, 2018), 40% of traffic deaths in Africa occur among pedestrians. This is a significant number of fatalities compared to other regions such as Europe (27%), the Americas (22%) and South-East Asia (14%). In South Africa, pedestrian fatalities contributed to 41% of traffic fatalities in 2019 (Road Traffic Management Corporation, 2019). In contrast, car occupants and drivers accounted for 31% and 27% of traffic deaths, respectively. Pedestrians are the most vulnerable road users and this is attributed to increased traffic exposure. In addition to increased traffic exposure, the difference in the distribution of road user mortality can be attributed to the fact that pedestrians are traffic participants that have the least protection in the event of a crash and are therefore more likely to sustain severe injuries or fatalities. They lack the physical protection of an external hard shell and vehicle safety features such as airbags and seatbelts that are awarded to motorists and passengers (Segni Tulu, Washington, King & Haque, 2013).

There are a number of risk behaviours that pedestrians engage in that heightens their crash risk. Among these factors are illegal crossing behaviour, walking while intoxicated and walking at night. Pedestrian conspicuity is a major contributor to the high rates of pedestrian crashes. Despite the lower exposure of pedestrians at night, most pedestrian crashes occur during hours of darkness (from dusk to dawn) compared to daylight (Goodwin and Hutchinson, 1977 cited in Shinar, 2007). Fatal pedestrian crashes are overrepresented at night with more than half of all pedestrian fatalities occurring during darkness. Pedestrians have a higher risk of being involved in a crash at night time and it has been reported that pedestrians are up to seven times more vulnerable during the hours of darkness (Langham & Moberly, 2003). This increased vulnerability can be attributed to driver factors such as excessive vehicle speed, driving while intoxicated and inadequate visual search. However, besides these factors the late detection of pedestrians is also owing to poor pedestrian conspicuity (Schneider, Grembek & Braughton, 2013). Poor pedestrian conspicuity can also be used to explain the higher rate of crashes and fatalities in the developed vs developing world. Though drivers' ability to recognise pedestrians in both of these contexts is degraded, most pedestrians in developed countries can afford to buy retroreflective clothing which is both available and has shown to enhance pedestrian visibility at night (Segni Tulu, Washington, King & Haque, 2013). However, in developing countries, retroreflective clothing is neither commonly available nor affordable. In addition, most locations in developed countries with high pedestrian traffic have sufficient street lighting to facilitate visibility of pedestrians at night and thereby reduce road crashes, whereas the same does not apply widely in developing countries (Segni Tulu, Washington, King & Haque, 2013).

In contrast to the victims of traffic casualties in developed countries, the victims of traffic crashes and fatalities in developing contexts such as the African continent are primarily vulnerable road users (Mackenzie, Seedat, Swart & Mabunda, 2008). A review of the African literature reveals that there are few pedestrian safety efforts and countermeasures in Africa. The limited research and pedestrian safety interventions is attributed to a lack of resources and the fact that NMT infrastructure is highly cost-effective (Mackenzie, Seedat, Swart & Mabunda, 2008, Segni Tulu, Washington, King & Haque, 2013). Existing interventions that are frequently used to address this problem, improve pedestrian safety include engineering, education and enforcement.

In terms of education, in 2006, a survey of African organisations who hosted pedestrian safety programmes in African countries (South Africa, Uganda, Kenya) were examined and it was reported that educational and training programmes were the most popular intervention programme among these countries. Moreover, the intervention programmes primarily targeted school-going children and adult pedestrians were targeted in educational interventions to a lesser degree. The adult pedestrians in this context also included parents, community leaders and law enforcement officers. Information regarding pedestrian safety was mainly disseminated via community workshops and at a broader national level, media campaigns were also used. The themes of the educational workshops were road crossing, visibility and the effects of alcohol and drugs on crossing safety. In Uganda, a focus on injury prevention was also included, in addition to a first aid component (Mackenzie, Seedat, Swart & Mabunda, 2008).

Apart from education, pedestrian safety programmes also include engineering-environmental interventions such as constructing pedestrian crossings, pedestrian walkways, pedestrian bridges, traffic calming and pedestrian road signs. According to a report by Ribbens (1996), two main approaches are used in South Africa: integration and segregation. Integration involves integrating pedestrians with the road traffic and managing their movement through "temporal separation" such as pedestrian crossings, traffic lights and "soft separation" such as traffic calming measures (e.g., roundabouts, rumble strips, speed bumps and road narrowing). These measures help to prevent motorised traffic from travelling at high speeds and has been noted to be less developed in the South African context (Mackenzie, Seedat, Swart & Mabunda, 2008). Segregation approaches separate pedestrians from the road either horizontally (e.g. pedestrian malls, sidewalks, separate walkways systems) or vertically (e.g. foot bridges and subways). As a result of cost constraints, these approaches are typically absent in Africa and South Africa compared to developed countries (Mackenzie, Seedat, Swart & Mabunda, 2008). However, some examples of engineering-design initiative to improve NMT facilities has been reported in the African context. For example, a pilot project in Nairobi and Kenya used three distinct menus to enhance NMT safety on problematic locations on existing roads (Setty Pendakur, 2005). These were building special infrastructure for pedestrians and cyclists (introducing walkways that are separated from motor transport, dedicated to walking and paved without obstructions), introducing traffic calming measures to reduce speed and thus increase speed for NMT users (raised and painted zebra crossings, speed bumps, islands for pedestrians and cyclists) and including interventions to increase the ownership and use of bicycles (construction of missing cycling and walking links, dedicated bicycle tracks/lanes). Following the implementation of these interventions, performance monitoring measures show that the interventions generally contributed positively to achieving the specified performance indicators. It was noted that certain performance indicators were unachievable and this was attributed to small interventions samples and that some performance indicators were impossible to measure (Setty Pendakur, 2005).

Besides traffic calming schemes, the integrated approach to land use planning and pedestrian safety is a promising avenue to improving pedestrian facilities because these two areas are closely related. In South Africa, improper land use planning and the lack of an integrated walking network plays a major role in the pedestrian safety problem. This lack of integration results in the provision of pedestrian facilities during planning and construction of road projects not being prioritised and ultimately deficits in NMT infrastructure (Mokitimi & Vanderschuren, 2017). These deficits take the form of a lack of or poor maintenance of footpaths and crossings and explains the lack of compliance among pedestrians in the road environment (Vanderschuren, 2012). Because of this poor planning, pedestrians often tend to walk along roads due to the absence of sidewalks. The lack of separation between vulnerable road users and motorised traffic leads to a considerably larger set of potential crash risk opportunities for pedestrians compared to separated facilities encountered in developed countries (Schneider, Grembek & Braughton, 2013). Another example of the effect of a lack of land use planning and coordination with road safety is pedestrians use of the freeway in South Africa. In South Africa, pedestrian crashes on the freeway are commonplace. The high number of pedestrians on South African freeways has roots in apartheid spatial and urban planning where black South Africans were prohibited from living in the inner cities and were forced to the periphery to reside in townships. As a result of this, many of the townships are located alongside the freeway and cause pedestrians to endure long distances to the city centres (Sinclair & Zuidgeest, 2016). Because the residential areas are located on one side of the freeway and major places of work on the other side of the freeway and are not connected physically or with transport services, pedestrians' resort to walking alongside or crossing busy urban freeways as this is the shortest route to their destinations.

3.6. Survey sampling methods

Since it is impossible to collect data for the entire population of road users, using the correct sampling technique is important. The quality of a sample statistic (i.e., accuracy, precision, representativeness) is strongly affected by the way that sample observations are chosen; that is, by the sampling method.

According to Stat Trek (2020), two overall categories of sampling methods exist, **probability samples** and **non-probability samples**. With probability sampling methods, each population element has a known (non-zero) chance of being chosen for the sample, such as road side surveys. With non-probability sampling methods, we do not know the probability that each population element will be chosen, and/or we cannot be sure that each population element has a non-zero chance of being chosen. This would be the case for example with voluntary online surveys.

Within probability sampling, a number of sampling methods are available, such as simple random sampling, stratified sampling, cluster sampling, multistage sampling and systematic random sampling. As previously discussed in the 2013 TOS literature study, the RSPI manual makes reference to the fact that **stratified sampling** is the most common probability sampling method linked to road safety surveys. With stratified sampling, the population is divided into groups, based on some characteristic. Then, within each group, a probability sample (often a simple random sample) is selected. In stratified sampling, the groups are called strata.

To calculate sample size the following variables are required:

- Confidence level (e.g. 95%)
- Z Score (e.g. at 95% confidence - Z Score = 1.96)
- Population size (if small and known)
- Margin of error (e.g. 5%)
- Standard deviation or sample proportion

For a large or unknown population size the following formula can be used to calculate the sample size:

$$Necessary\ sample\ size = \frac{(Z\ score)^2 \times StdDev \times (1 - StdDev)}{(margin\ of\ error)^2}$$

Sample size also depends on the aim of the research. When comparing strata, an equal number of sampling units per strata is required. When, however, desiring to obtain a truly representative sample, then the proportion of sampling units in the different strata as compared to the actual population should be the same.

In real world circumstances it is impossible to obtain a statistically 100% correct random sample since the different road conditions and external factors influence the sampling procedure. The practically of sampling locations and timelines also impacts the actual sample that is collected. This needs to be taken into account when defining the sampling size and strategy for different indicators and when analysing the resultant data.

Chapter 4 makes recommendation regarding revised sample sizes to be used for the individual indicators, or at least the process to be followed for the determination of new sample sizes.

3.7. Standard data collection, processing and analysis methods

As has become evident from the literature review, collection of data can no longer purely be focused on primary observed data collection such as measuring speeds with a radar gun. Secondary data sources are available and should in this age of shared data be utilised to obtain a better picture of road safety conditions, whilst reducing redundant and expensive primary surveys.

It is however noted that, especially in the context of South Africa, these secondary data sources are not necessarily as readily available as in developed countries. It is therefore necessary to include the use of conventional primary surveying methods, either to collect data exclusively for a specific SPI or to complement the data available via other sources. This section expands on the primary data collection methods as well as processing and analysing the data. Section 3.7 delves into the use of alternative and advances data collection mechanisms.

3.7.1. Data collection

Based on previous research by the University of Stellenbosch (Road Traffic Management Corporation, 2013), as well as insight gained from the preceding sections in this literature review, the following are some important points to make regarding data collection:

- The purpose of the specific survey as well as the sample that is required impacts and defines the data collection procedure. For example, if the purpose of a survey is to measure statistically relevant speed data at a location, the use of radar guns would be an option. If, however, the subjective road user attitude towards speeding is important to measure the impact of road safety education, then something like an e-survey or questionnaire is more appropriate.
- It is also important that data collection is done in a consistent manner to obtain comparable result over time. This would mean that surveys should be done during the same period of the year on a rolling basis.
- Survey site selection should be statistically relevant, yet also practical and feasible. It is impossible to obtain a truly random sample of survey sites and emphasis should be placed on the local knowledge of the area and other practical constraints. The same is also applicable for vehicle selection during the surveys.
- Comprehensive training for the surveyors is an imperative in order to maximise the usefulness of the survey results. This goes hand-in-hand with involving the police force in aiding road-side surveys.
- There is a need to move from paper-based surveys to mobile phone- or tablet-based surveying methods that can automatically sync data and provide a more user-friendly experience.
- In a developing country context, using manual primary surveying methods contributes to job creation which could potentially be lost when utilising only secondary and technology driven data collection methods. This needs to be considered also.

The below table provides some examples of conventional data collection mechanisms for some specific SPIs as summarised in the 2013 TOS methodology (Road Traffic Management Corporation, 2013):

Table 3-5: Data collection methods 2013

Safety Performance Indicator	Data collection method
Speed	Data collected from road authorities Automatic vehicle counting stations Ad hoc road-side surveys
Alcohol	Data collected by screening devices at roadblocks
Seatbelt use	Data collected manually during roadside surveys
Barrier line compliance	Data collected manually during roadside surveys
Traffic signal compliance	Data collected manually during roadside surveys
Vehicle condition	Data collected during roadblock surveys Heavy vehicle data acquired from SA freight industry
Emergency response times	Data obtained from provincial health authorities and Private and public emergency services

3.7.2. Processing and analysis

3.7.2.1. Survey software and data management

Previously when Traffic Offense surveys were conducted, the service provider responsible would utilise their own software package and data management platform to process and analyse the survey results. In the 2013 methodology it was emphasised that a standard data management solution needs to be researched that is able to handle this task continuously and pull in data from various sources. Section 3.8 explores the concept of a central traffic data platform that will make this feasible and practical.

Several survey software options are available when considering the paperless manual survey environment. The following software packages were recommended options in the South African context as part of the previous methodology:

- FluidSurveys
- DeviceMagic
- Datafield
- SurveyToGo
- iSurvey

Upon reviewing these software packages again, the following can be concluded:

- FluidSurveys (as the recommended number one choice previously) is no longer available and has been replaced by **SurveyMonkey**. This platform provides the same advanced and user-friendly survey package that can be used to digitally create surveys and questionnaires and collect the data.

- Another options that is still relevant is **SurveyToGo**. This tool allows the creation of complex surveys for multiple use cases and scenarios.
- An alternative to SurveyMonkey and SurveyToGo is the **SmartSurvey** option. Equally powerful and applicable to also conduct offline surveys.
- For all these survey software options the need to analyse the data after collection needs to be met with a different software package. This could be handled in a similar manner as for paper-based surveys after the data has been recorded digitally.

If paper-based surveys are required, then this data would have to be manually read into a data program that can be utilised to analyse the data. The 2013 methodology recommended the use of Microsoft Excel in conjunction with an Access database to handle this task. In conjunction with more technology driven data collection, manually collected data would still have to be accommodated.

3.7.2.2. Calculation of a comprehensive Index

Combining separate road safety performance indicator results into one composite index has the value of presenting an overall comparative picture and being able to compare year-on-year. In the SUNflowerNext project (Wegman *et al.*, 2008) the following steps were suggested to calculate a composite index:

1. Theoretical framework: identification of domains and best indicators in each domain
2. Indicator data: collection of reliable data of the indicators
3. Normalisation: standardisation of data so that data from various indicators becomes comparable
4. Weighting: allocation of weights to each indicator based on its relative importance
5. Aggregation: application of the mathematical operation to combine the normalised indicator data into an index (arithmetic or multiplicative averaging)
6. Presenting the result: presentation of the index scores by means of graphs, etc.

This same process was also recommended in the 2013 methodology, differing from the previous calculations by taking into account compliance rates, rather than defect rates. It was also proposed that the process of calculating this index per region or country should be an automated process after all the data has been recorded properly. This approach is coherent with international standards and should be utilised.

3.8. Technological advancements and possibilities

Today, technology is already being used to monitor and manage Bus Rapid Transit systems, Freeway Management Systems, etc. that could be potentially leveraged off to assist in compiling Traffic Offence Surveys. However, recent technological advancement such as 5G, AI, machine learning, Big Data, IoT, cloud computing and fatigue detection technology holds further promising benefits in compiling future Traffic Offence Surveys.

3.8.1. Existing systems and technology

In various fields systems and technology have already been deployed to assist in the management thereof. The table below list some of these fields, where if access to their data can be obtained, it could provide valuable insights and contribute in compiling Traffic Offence Surveys (TOS) in South Africa.

Table 3-6: Existing systems and technology for potential TOS application

No.	Field	Description	Traffic Offence Relating To	Potential SPI to measure
1	Bus Rapid Transit (BRT)	BRT uses an Advanced Public Transport Management System (APTMS) on which Operators log incidents.	Urban areas: • BRT vehicles • Other vehicles • Cyclists • Pedestrians	• No. of cyclists and pedestrians in BRT lanes • No. of cyclist and pedestrian fatalities involving BRT • No. of vehicles using the BRT lanes illegally • No. of speeding BRT vehicles
2	Freeway Management System (FMS)	SANRAL's FMS uses an Advance Traffic Management System (ATMS) on which Operators log incidents.	Urban and rural areas: • Vehicles • Pedestrians • Animals • Infrastructure issues	• No. of speeding vehicles • No. of crashes • No. of fatalities • Dangerous zones (crime hotspots, animals, infrastructure issues) • No. of Jaywalkers
3	Open Road Tolling (ORT)	Readers on the ORT gantries record a vehicle's tag information, thus back office systems can also calculate the speed of a vehicle.	Gauteng: • Speed violation	• No. of speeding vehicles
4	Law Enforcement	Metro Police uses CCTV cameras to assist them in crime prevention and law enforcement.	Metropolitan areas: • CCTV footage can be reviewed to determine offences pertaining to driver, passenger, cyclist and pedestrian behaviour.	• No. of drivers allowing passengers to disembark while stopped in lane • No. of vehicle occupants not wearing seatbelts • No. of jaywalkers • No. of vehicles not adhering to traffic signal compliance
5	Average Speed Over Distance (ASOD) deployments	ASOD uses Automatic Number Plate Recognition (ANPR) cameras to allow backend systems to determine the average speed that a vehicle has travelled between two points.	Various areas: • Speed violation	• No. of speed violations

No.	Field	Description	Traffic Offence Relating To	Potential SPI to measure
6	Insurance companies	Discovery, for example, offers their clients a smartphone application which provides real-time feedback on how one is driving, as well as other features like "ImpactAlert" and a vehicle panic button.	Nationally: • Driver behaviour • Speed violation	• No. of crashes • No. of unsafe driver behaviours • No. of speed violations
7	Navigation Apps	Navigation applications like TomTom uses probe data to provide a driver with information and the optimum route to reach a destination.	Nationally: • Infrastructure and capacity issues • Prioritising areas to focus enforcement in areas with a high percentage of non-adherence to speed limits	• No. of infrastructure and capacity issues • No. of areas where speeds are consistently not adhered to.
8	Vehicle load	Weighbridges and weigh-in-motion are used to determine if a vehicle is overloaded.	Nationally: • Overloaded vehicle	• No. of overloaded vehicles
9	NaTIS	National Traffic Information System	Nationally: • Motor vehicle crashes	• No. of crashes
10	AARTO	Administrative Adjudication of Road Traffic Offences	Nationally: • Traffic fines	• No. of traffic fines
11	Cross border road transport	Various technologies could be deployed at road cross border control gates like ANPR for vehicle classification, weigh-in-motion, automatic vehicle and/or container recognition systems, video surveillance system, automatic health-check equipment (inclusive of breathalyser testing), passport and driver's license control systems, etc.	Road border control gates: • Vehicle classification • Roadworthiness of vehicles • Valid driver's licenses • Driving under the influence • Overloaded vehicles	• No. of trucks • No of busses and taxis • No. of cars and other vehicles • No. of invalid licenses • No. of un-roadworthy vehicles • No. of drivers under the influence • No. of overloaded vehicles • No. of vehicles over height

3.8.2. Other technology options

Other technologies such as smartphone sensors, GSM data and Artificial Intelligence (AI) could potentially in future also be considered as input sources into compiling Traffic Offence Surveys.

3.8.2.1. Smartphone sensors

The increasing number of smartphones being used by the South African public brings further possibilities which could be useful in a transportation context. For example, by deploying sensors to detect the smartphones' Wi-Fi and Bluetooth signals that could then be processed to determine Origin-Destination (OD) information which could in turn be used to, for example, prioritise areas where to focus on speed violations and unsafe driver behaviour. The Figure 3-18 below provides a conceptual illustration of traffic monitoring by using a Bluetooth sensor network.

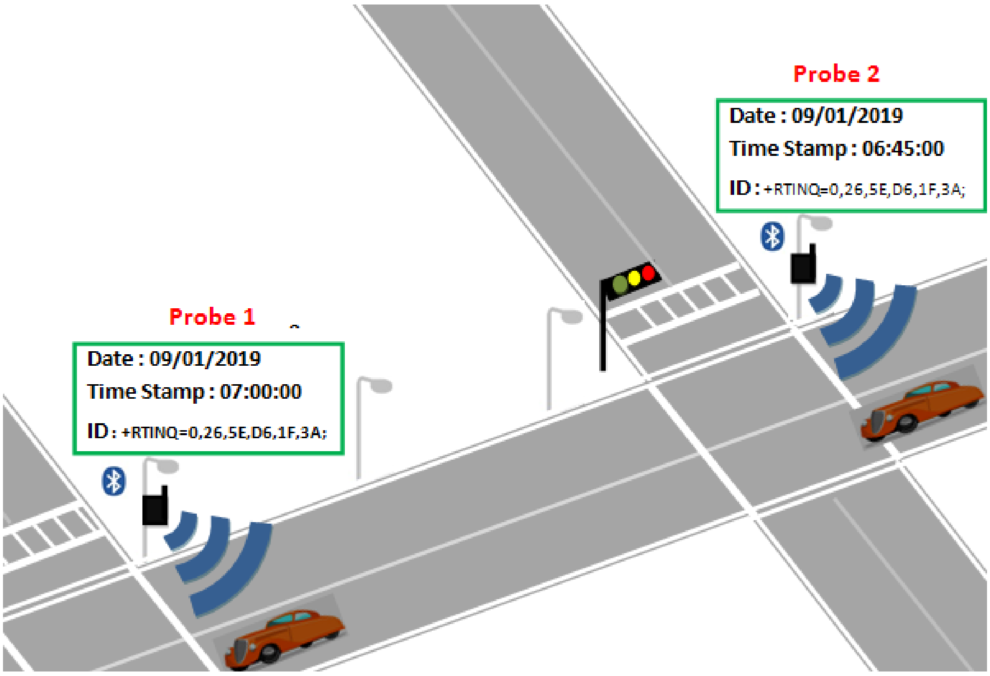


Figure 3-18: Traffic monitoring by using a Bluetooth sensor network

3.8.2.2. Mobile phone data

Within the realm of the Big Data environment, mobile phone data could potentially be a major contributor in determining OD information that would assist in ensuring TOSs are conducted in the optimum areas for such surveys to gauge compliance to speed limits and safe driver behaviour. It could also facilitate a near real-time overview of traffic flows and conditions.

Cellular network-based data is collected by telecommunication companies. Two types of network-based data could typically be used in the transportation context, namely call data record (CDR) and global system for mobile communication (GSM).

CDR data comprises a set of phone activity records (e.g. phone calls, text messages or Internet access) along with the time and location information of cell towers channelling the calls. CDR data is routinely saved by mobile phone companies for billing purposes and involves no additional effort from their side in data provision.

On the other hand, GSM data are generated from an interaction between a device and the mobile network as long as the device is powered on. GSM data has a higher occurrence as compared to CDR data and would therefor provide the best input in the context of transportation. However, GSM data is normally more difficult to get access to and might require some additional effort by the mobile network operator (MNO) companies in providing it. It is further important to note be that as the right to privacy is recognised and protected in South Africa, only anonymised GSM data should be considered.

For a single mobile phone, CDR or GSM data is dispersed and provides very little information. However, the aggregation of thousands of mobile phones' data overcomes this limitation.

The general approach to estimate origin-destination data from mobile phone data is illustrated in the Figure 3-19 below and consist of five important steps namely:

(i) Pre-process and data cleaning
(ii) Sample selection
(iii) Trip/Activity identification
(iv) Sample expansion
(v) Post-processing

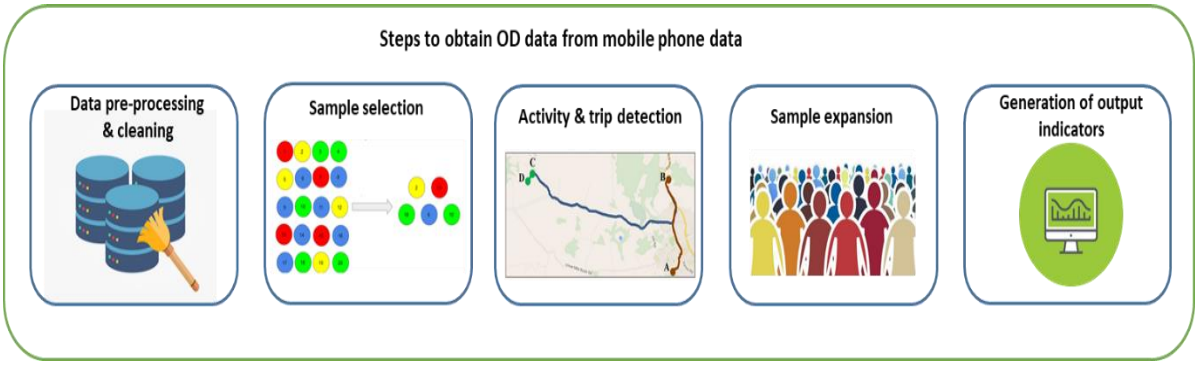


Figure 3-19: Steps to obtain OD data from mobile phone data

However, as the right to privacy is recognised and protected in South Africa, only anonymised GSM data should be considered.

3.8.2.3. *Artificial Intelligence*

With the vast computational and software algorithm capabilities in present times, a system using cameras and making use of Artificial Intelligence (AI) could for example be considered to detect driving violations like using a cell phone while driving or not wearing a seatbelt as illustrated in Figure 3-20 below (Wijers, 2020). The vast amount of data that is generated by the CCTV cameras and the various scenarios that need to be taken into consideration and analysed in near real time for detecting infringements such as this, makes it ideally suited for AI (i.e. software programmes and algorithms running on high-end processers) to perform such tasks.

Figure 3-20: Real-time detection of distracted driving using artificial intelligence

3.9. Central traffic data platform

As currently traffic related data is fairly dispersed, it would be good to create a central data platform that could be used as input to Traffic Offence Surveys in South Africa. Figure 3-21 below serves to illustrate the variety of current data sources and how a central data warehouse and data analysis functionality could be established as a platform that would assist the RTMC.

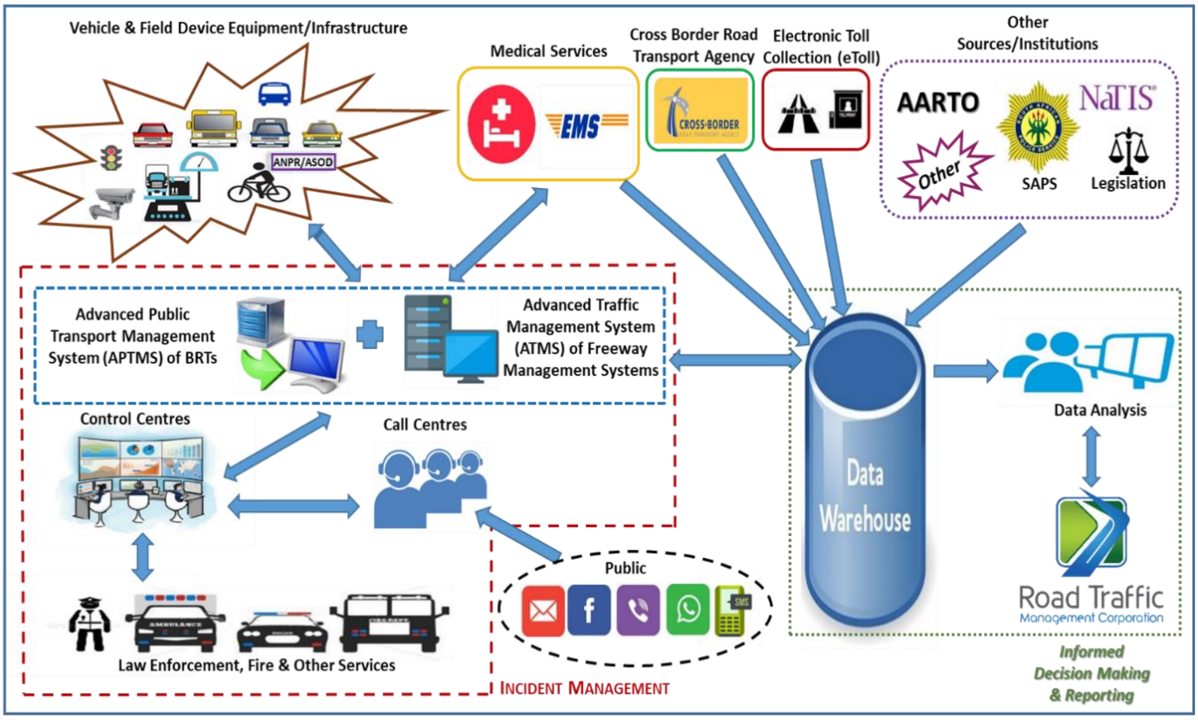


Figure 3-21: Central Traffic Data Warehouse

From Figure 3-21 above, it follows that first of all the RTMC will have to establish agreements with the various other entities (e.g. SANRAL, AARTO, SAPS, Rea Vaya, MyCiti, etc.). E-toll and cross border have been included as potential sources for Road Safety data (Cross Border Road Transport Agency, 2016; UNESCAP, 2020), but other sources can also be considered such as airports and harbours (ports of entry). Thereafter electronic interfaces should be established to download and import data to the central data warehouse from the various Advanced Public Transport Management Systems (APTMSs) of the BRTs, the Advanced Traffic Management Systems (ATMSs) of the Freeway Management Systems, medical services, eToll, AARTO, NaTis, etc. These data downloads could for example be done on a monthly basis.

The RTMC could either outsource the data warehousing and data analysis functionality, or cater for it internally themselves. Either way it will greatly assist the RTMC with the Traffic Offence Surveys as it would allow for informed decisions making and reporting.

4. SUMMARY AND INPUT TO THE TRAFFIC OFFENCE SURVEY METHODOLOGY

This chapter summarises the findings of the literature review that was conducted into various aspects of road safety internationally and locally, establishing the context for the TOS methodology development. Together with this, recommendations are made specifically for the South African context.

4.1. Purpose of Traffic Offence Surveys

As a part of the greater road safety initiatives, Traffic Offence Surveys (TOSs) are an important element. However, upon reviewing how the purpose of TOSs has changed over the years it is evident that only monitoring "offences" does not do justice to a holistic approach to road safety monitoring. Doing this puts the focus on lawless behaviour only, which is important to consider, yet neglects elements such as road infrastructure and post-crash care. Additionally, the use of compliance rates rather than offence rates is an internationally accepted practice and should be applied in South Africa.

Considering this then, it is recommended that *Traffic Offense Surveys* should be rebranded as *Road Safety Performance Monitoring* (RSPM) as a step to address road safety more holistically. The purpose of Road Safety Performance Monitoring then is:

1. To collect data periodically (or continuously where available) that is linked to specific road safety performance indicators (SPIs), not only using manual surveys but also making use of available technology options to enhance data quality.
2. To utilise non-typical data sources such as self-declared road user behaviour to enhance road safety insights and provide a wider spectrum of data.
3. To follow an outcomes-based philosophy that focuses on compliance rates linked to these SPIs rather than defect/offence rates.
4. To allow the observed SPI trends to guide policymakers in addressing the pertinent issues of road safety far earlier than pure crash data would allow.
5. To follow a 'Safe System' approach that shifts emphasis towards improving vehicles and the road environment, in addition to improving road user behaviour.
6. To ultimately lead to a reduction in road related incidents, fatalities and the severity of injuries.

Following this, including in the Part B methodology development document, the term *Traffic Offence Surveys* is replaced and exclusive use is made of ***Road Safety Performance Monitoring (RSPM)***. The core focus of RSPM still remains the monitoring of road user behaviour, yet room is given for the inclusion of other factors that influence road safety. The 80/20 principle is applied in identifying SPIs relating to road user behaviour as compared to other factors. This has a particular impact on proposed survey strategies for different indicators, which will be detailed per SPI.

4.2. Important Road Safety Performance Monitoring aspects to consider

Having conducted the literature study, a number of elements are important in defining the methodology development. Putting the findings of the literature review into the context of the South African environment and circumstances is the most important step in defining a practical RSPM methodology.

The following important aspects of the RSPM framework are discussed, forming part of the overall survey strategy:

- Road Safety Domains
- Road Safety Performance Indicators (SPIs)
- Sampling for SPIs
- Data Collection
- Data Quality
- Data Processing and Reporting
- Utilising Technology
- Institutional Collaboration and Partnerships
- Monitoring and Interventions

4.2.1. Road Safety Domains

4.2.1.1. Literature insights

An important aspect is to make use of Road Safety Domains. These domains group a number of SPIs according to similar characteristics. These can be either overarching domains such as *Road User Behaviour*, *Vehicle Safety*, *Road Environment* and *Trauma Management*, or they can be more specific such as *Speed*, with subsequently a number of SPIs that speak to speed.

Literature uses a number of different terms to speak of these overarching categories. Domains, themes, risk categories etc. The most prominent of these is the use of "Domains". These domains enable shifted focused to the important parts of road safety and also give insights ultimately into the main problem areas.

4.2.1.2. South African context

In order to make the RSPM process most practical, it is recommended that the following overarching domains are utilised as shown in Table 4-1. Since it was identified that *Road User Behaviour* will continue to be the area of road safety in which the most positive impact can be achieved through targeted interventions, it is recommended that 80% of monitored Safety Performance Indicators are allocated to that domain. As such, it is seen fit to sub-divide the *Road User Behaviour* Domain into four sub-domains, namely NMT, Light Vehicles, Public Transport and Logistics. It is important to note that international literature does not put a lot of emphasis on NMT road users as a risk category, yet in South Africa it is known that about 40% of all road related fatalities are involving pedestrians. It is therefore of utmost importance that specific SPIs are created to incorporate and address this issue.

Table 4-1: Recommended Road Safety Domains for Road Safety Performance Monitoring

No	1				2	3	4
Domains	**Road User Behaviour**				**Vehicle Safety**	**Road Environment**	**Post-Crash Care**
Sub-domains	NMT	Light Vehicles	Public Transport	Heavy Vehicles (Logistics)			

4.2.2. Road Safety Performance Indicators

4.2.2.1. Literature insights

In order to make use of an outcomes-based approach to road safety management, international literature shows that it is most helpful to make use of intermediate targets which can be measured with performance indicators. Thus, the Safety Performance Indicators (SPIs) are very helpful.

There is a distinction between observed and self-declared indicators, both having their use-case. Self-declared indicators will never have the same level of accuracy but do still provide a helpful comparative insight. This is an emerging and alternative type of gathering data on road safety and can potentially provide important and helpful insights.

During the literature review it became evident that additional indicators need to be defined that do not purely relate to road user offences but also road conditions and post-crash care. This aligns with international approach perspectives. Section 3.2.3 summarises the internationally accepted and utilised SPIs as intermediate outcomes. Importantly, pedestrian-related indicators are omitted and this has to be accounted for in the South African context.

4.2.2.2. South African context

Of importance is to place these indicators into the South African context and to align them with the needs that are present here. The following table provides the recommended SPIs for the RSPM.

Table 4-2: Recommended Safety Performance Indicators for Road Safety Performance Monitoring

<table>
<tr><th>No</th><th colspan="2">Domain</th><th>Safety Performance Indicators (observed/self-declared)</th></tr>
<tr><td rowspan="17">1</td><td rowspan="17">Road User Behaviour</td><td rowspan="4">NMT</td><td>• Compliance rate to pedestrian crossing facilities</td></tr>
<tr><td>• Number of cyclists and pedestrians in BRT lanes</td></tr>
<tr><td>• Non-use of intoxicating substances by pedestrians</td></tr>
<tr><td>• Helmet wearing compliance rates for cyclists</td></tr>
<tr><td rowspan="7">Private Vehicles</td><td>• Driver compliance to speed limits</td></tr>
<tr><td>• Driver compliance to non-use of intoxicating substances</td></tr>
<tr><td>• Driver compliance to wearing of seatbelts</td></tr>
<tr><td>• % not speeding at least once in the last 30 days (self-declared)</td></tr>
<tr><td>• Non-use of cellular telephone while driving</td></tr>
<tr><td>• % not driving while using a mobile phone at least once in the last 30 days (self-declared)</td></tr>
<tr><td>• Helmet wearing compliance rates for motorcycles</td></tr>
<tr><td rowspan="4">Public Transport</td><td>• Public transport vehicle compliance to speed limits</td></tr>
<tr><td>• Number of cyclist and pedestrian fatalities involving BRT</td></tr>
<tr><td>• Non-use of intoxicating substances by public transport drivers</td></tr>
<tr><td>• Compliance to overloading restrictions for public transport vehicles</td></tr>
<tr><td rowspan="2">Heavy vehicles (Logistics)</td><td>• Compliance to overloading restrictions for freight vehicles</td></tr>
<tr><td>• Non-use of intoxicating substances by professional drivers</td></tr>
<tr><td rowspan="2">2</td><td colspan="2" rowspan="2">Vehicle Safety</td><td>• Road worthiness of all vehicle types, specifically tyre wear and vehicle lights</td></tr>
<tr><td>• Number of new cars with a minimum NCAP rating of 3.</td></tr>
</table>

No	Domain	Safety Performance Indicators (observed/self-declared)
		• Age of vehicles (In particular public transport vehicles)
3	Road Environment	• Compliant road signage at hazardous locations
		• Number of implemented road safety audits (unforgiving road infrastructure)
		• Number of road kilometres with a minimum 3-star SA-RAP rating
4	Post-Crash Care	• Emergency Medical Service response times
		• Number of EMS vehicles per 10 000 inhabitants

Taking into account the above table of recommended SPIs, the RSPM methodology will expand on why these SPIs are chosen and develop specific **units of measurement** and **targets** to be achieved. Additionally, short- medium- and long-term plans are laid out indicating which SPIs are relevant at each stage of RSPM implementation.

4.2.3. Sampling for SPIs

4.2.3.1. Literature insights

Sampling strategies revolve around manual surveys and the objective to obtain a representative sample of the actual population. This is needed since it is impossible to survey at extended periods where this is done manually. Literature shows that when a sampling strategy is required, the typical approach would be to follow a stratified sampling approach for the application of traffic surveys. This is explained in section 3.5.

With increased use of alternative options to manual data collection that often provide automated collection options, this step becomes irrelevant. A number of the SPIs recommended above can be potentially collected at a more permanent rate, which will eliminate the issue of sampling. Where data is still collected manually, sample size has to be determined.

4.2.3.2. South African context

In the South African context, a number of SPIs will still have to be collected via manual surveys, or at least only be supplemented with alternative, more constant data sources. It is however, imperative that the use of technology be expanded continuously to increase the quality of insights that are gained from the RSPM process.

Minimum sample size requirements were captured in the previous methodology to be the following:

- Provincial level: 95% level of confidence at a confidence interval of 5%
- National level: 99% level of confidence at a confidence interval of 3%

The methodology will provide calculations for the **sample sizes** for those indicators where this is relevant. This will also be compared to the previously utilised samples sizes as laid out in the 2013 methodology.

4.2.4. Data Management

Data management is a crucial element of successfully providing insights into the Road Safety condition on South African Roads. The following components will be dealt with in detail in the methodology;

- Data collection
- Data quality
- Data processing and reporting

4.2.4.1. Literature insights

Literature is adamant that big data management has become one of the fastest growing industries and brings with it many benefits. Gone are the days where manual data collection should be necessary and the present developments in this field allow vastly increased efficiency in collecting, processing and reporting on data.

Previously, the TOS methodology was focused on manual surveys, even as the emphasis was shifting to more technology driven methods. Largely this depended on the level of development in South Africa, but also on the opportunity that manual labour for such offence surveys was deemed necessary job creation. However, the developments in data management open new doors of opportunity as roles and responsibilities change and new job opportunities are created.

Overall, the quality of data is dependent on the collection, processing and reporting thereof. This quality can be enhanced with increased sampling sizes and larger data quantities that all feed into the same picture. Data however has to be comparable and combinable into index form in the context of an overall road safety perspective.

4.2.4.2. South African context

In South Africa, an aspect of data management that has been neglected is that of reporting. A part of this is the merging of various data sources into a holistic picture and being consistent about this process. The following will be defined in detail in the methodology:

<u>Data Collection</u>

- Timeframe (periodically or continuously)
- Method of collecting data (manually or automatically)
- Source of data (various institutions, organisations and systems already in place or ad-hoc road side surveys)
- Locations of various surveys (Roadblocks, hazardous locations, FMS, BRT, e-Toll, EMS, SAPS etc)

<u>Data Processing and reporting</u>

- Combination and standardisation of data from various sources
- Software utilised
- Central data storage solution
- Method and timeline of reporting on SPIs

4.2.5. Utilising Technology

4.2.5.1. Literature insights

A main focus of developing the RSPM methodology is to define the impact of recent technology developments and how these can assist in gathering data related to Road Safety more efficiently.

Developing countries utilised various data sources from numerous systems and processes to gather data and combine this into comparable road safety statistics that can be monitored over time.

4.2.5.2. South African context

A number of well-functioning traffic related systems are already in place in South Africa that gather valuable data on a continuous basis, including BRT systems, Freeway management systems and e-toll operations. Table 3-6 makes reference to the various systems already in place in South Africa that can be utilised for such purposes. It is evident that many resources are available and data is being gathered, it is just about making the necessary changes to allow such data to be manipulated for purposes of monitoring road safety.

The RSPM methodology will provide specifics regarding the various technology options that need to be explored. The following needs to be considered:

- ATMS and APTMS system data
- Vehicle and field device equipment and infrastructure
- Mobile phone and App data
- Data analysis processes and the use of a central data warehouse

4.2.6. Institutional Collaboration and Partnerships

4.2.6.1. Literature insights

The first pillar of the five pillars for the United Nations Decade of Action for Road Safety speaks about road safety management. This is only possible with combined action and effort and requires institutional collaboration and partnerships

4.2.6.2. South African context

In the South African context this concept is even more important due to the current lack of collaborated management of road safety issues. The following major issues will be addressed in the methodology document:

- Funding of road safety initiatives
- Shared data and relevant MOUs
- The legal implications of such collaborative actions
- The concept of a road safety regulator

4.2.7. Monitoring and Interventions

4.2.7.1. Literature insights

As literature has shown, continuous monitoring with the help of specific SPIs is far more impactful than exclusively using fatality and crash stats to measure the state of road safety and make the correspondingly important decisions.

It is important to set realistically achievable, yet challenging targets to be attained for each SPI. In addition, the importance of identifying the necessary interventions in order to achieve the desired changes is the very reason why Road Safety Performance Monitoring is done in the first place. Without the proper managerial and oversight structure in place, the results of all Road Safety Performance Monitoring initiatives will not bear fruit.

4.2.7.2. South African context

South Africa has dire need for more focused management and cooperation processes to be put in place, especially considering the aspect of road safety. The RSPM methodology will advise on the following:

- Collaboration structures between various institutions in terms of road safety management
- Process of identifying interventions for specific SPIs in order to attain the desired targets

4.3. Key Focus Areas for the Road Safety Performance Monitoring Methodology

Upon finalising the synthesis of the information captured during the literature review, a number of Key Focus Areas as shown in Figure 4-1 can be identified that will specifically guide the methodology document. It is evident that the purpose of Traffic Offence Surveys (TOS) has changed to more holistically be replaced by Road Safety Performance Monitoring (RSPM).

The purpose of the RSPM Methodology guideline is as follows:

- Provide detailed Safety Performance Indicators that align according to a number of Road Safety Domains which should be monitored to assess the Road Safety situation.
- Identify all data collection processes associated with each SPI, ranging from sample size, survey locations, type of data collection and data sources.
- Identify data processing and management aspects, including potential data collaboration and data warehouse options.
- Provide specific and informed guidelines in terms of technology application in light of road safety.
- Identify the managerial and collaborative institutional aspects that need to be considered and how the formulation of specific interventions should be facilitated.

It is also recognised that the shifted emphasis from TOS to RSPM requires a phased approach of implementation, especially since the processes for alternative data collection avenues still need to be established. In order to prevent the monitoring process from coming to a standstill while these processes are established, the methodology makes provision for a short-term plan to facilitate the continuation of Road Safety monitoring, even if initially only based on manually collected data.

Any potential risk of implementation of the Road Safety Performance Monitoring methodology is captured in Chapter 9 of Part B: Methodology. In addition, remedial measures for the mitigation of the risks are provided to minimise the potential severity of their impact.

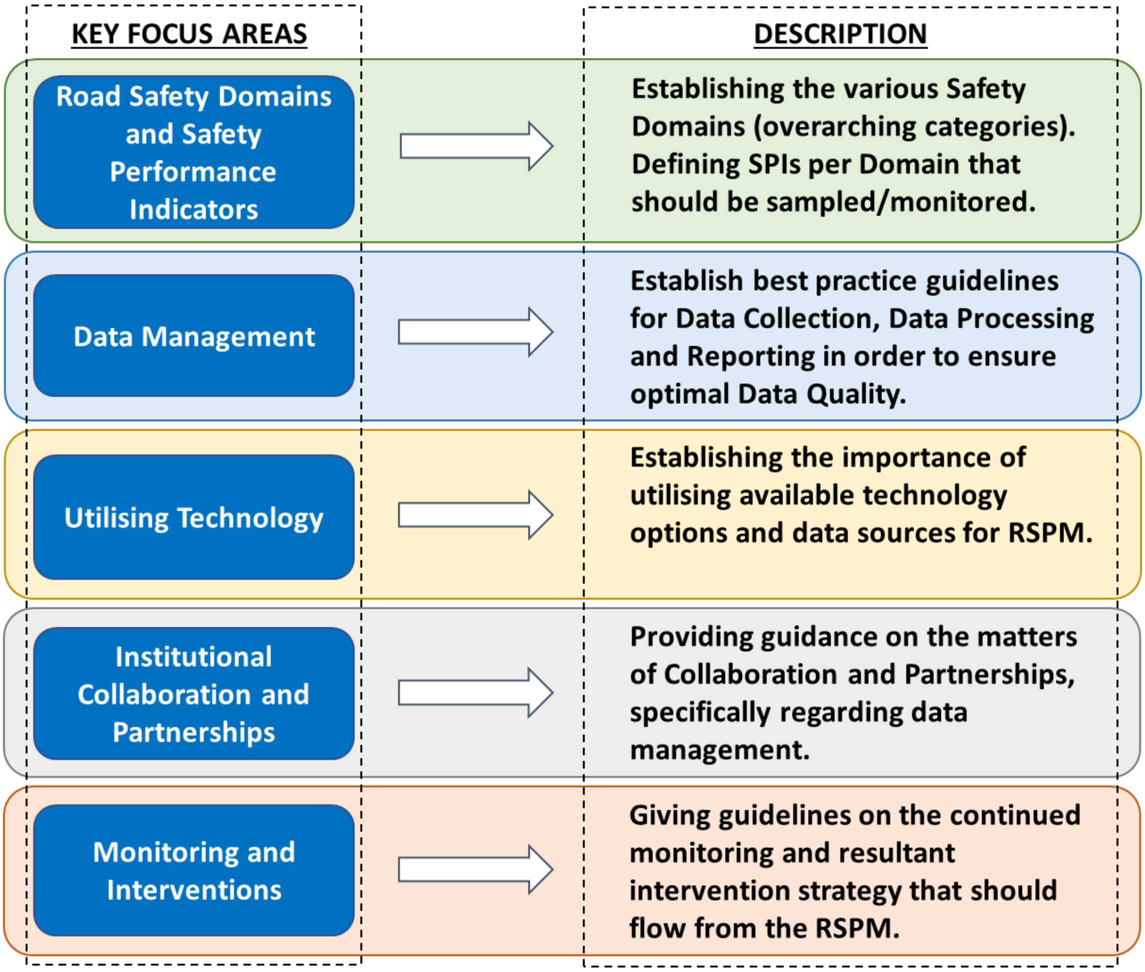


Figure 4-1: Key Focus Areas for successful Road Safety Performance Monitoring

5. FURTHER RESEARCH OPPORTUNITIES

While conducting the literature review into Road Safety Performance Monitoring, a number of factors were identified that require further research for the South African context. They include the following:

- Regarding speeding: Establishing the coherence of road design and posted speed limits as compared to the actual operating speed in order to ensure that surveyed compliance rates are realistic on specific roads. The RTMC is busy with a study regarding this topic.
- More research is needed into the importance of measuring barrier line offences and the impact this has on road safety. The manner of measuring this offence has been an issue in past surveys.
- Establishing the significance of driver fatigue and how technology can be utilised to measure compliance.
- Explore the use of Artificial Intelligence (AI) in measuring road safety issue such as driver distraction.
- Broaden the research into studying South African conditions more specifically and establishing which additional safety performance indicators should be monitored.
- Explore the compulsory use of a road user App that is linked to obtaining vehicle registration as a means to capture driver behaviour and establish a reward system for safe driving practices. The privacy issues and other possible problems should be studied.
- Define the best practices surrounding the funding of road safety initiatives, specifically when a greater stakeholder group is involved.
- Establish the relevance of a Road Safety Regulator, similar to the Rail Safety Regulator.
- Conduct specific research into how to address and redress spatial land-use planning that causes Road Safety issues due to misaligned Origin and Destination travel patterns, especially for pedestrians.
- Research the impact which mandated vehicle insurance will have on driver behaviour. This is since a large number of vehicles on South African roads are not insured.
- Explore the differential NCAP ratings of the same vehicle models in developed versus developing countries (specifically South Africa) and how this impacts Road Safety.
- Understand the impact which increased availability of emergency medical response units will have on the improvement of Road Safety.
- Consolidate the use of various emergency contact numbers nationally and provincially/per metro.
- In order to be able to incorporate a specific SPI into the RSPM monitoring process regarding the loading of passengers in the goods department of vehicles, it is necessary to conduct some specific research into this practice and its prevalence, including legal guidance on the matter.

6. REFERENCES

Adnan, M.A., Sulaiman, N., Zainuddin, N.I. & Besar, T.B.H.T. (2013). Vehicle speed measurement technique using various speed detection instrumentation. In BEIAC 2013 - 2013 IEEE Business Engineering and Industrial Applications Colloquium. 668–672.

Adu-Gyamfi, Y., Sharma, A., Knickerbocker, S., Hawkins, N. & Jackson, M. (2015). Reliability of Probe Speed Data for Detecting Congestion Trends. In Vols 2015-October. Institute of Electrical and Electronics Engineers Inc. IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC. 2243–2249.

Andruszkow H., Lefering R., Frink M., Mommsen P., Zeckey C., Rahe K. (2013). Survival benefit of helicopter emergency medical services compared to ground emergency medical services in traumatized patients. Critical Care 17(3): R124.

Beeharee A., Fremont G., Grau G., Campo R., Lovas T. and Besnard L. (2012). Enabling Next Generation Emergency Call Service. Procedia - Social and Behavioral Sciences 48: 2718-2727.

Cabo M., Fernandes F., Pereira T., Fonseca B. and Paredes H. (2014). Universal Access to eCall System. Procedia Computer Science 27: 104-112.

Castrén M., Karlsten R., Lippert F., Christensen E.F., Bovim E., Kvam A.M. (2008). Recommended guidelines for reporting on emergency medical dispatch when conducting research in emergency medicine: The Utstein style. Resuscitation 79(2): 193-197.

Colwell C.B. and Soriya G. (2012). Basic Life Support. In: Vincent J. and Hall J.B. (eds). Encyclopedia of Intensive Care Medicine.: Springer Berlin Heidelberg, 285-288.

Cross Border Road Transport Agency (2016) 'Annual State Of Cross Border Operations Report September 2016', (September), p. 78. Available at: https://www.cbrta.co.za/uploads/files/ASCBOR2March2016.pdf.

Davidović, J. et al. (2020) 'The Significance of the Development of Road Safety Performance Indicators Related to Driver Fatigue', Transportation Research Procedia, 45(2019), pp. 333–342. doi: 10.1016/j.trpro.2020.03.024.

Duboka, C.V. (2011). VEHICLE SAFETY PERFORMANCE INDICATORS & INDEXES. In 23rd JUMV International Conference "Science and Motor Vehicles 2011.

Espada, I. & Bennett, P. (2015). Probe Data and its Application in Traffic Studies. In Proceeding of Institute of Public Works Engineering Australasia (IPWEA 2015).

ETSC (2001) Transport Safety Performance Indicators. Available at: http://etsc.eu/wp-content/uploads/2003_transport_safety_stats_eu_overview.pdf.

ETSC (2020) RANKING EU PROGRESS 14 th Road Safety Performance Index Report.

European Commission Directorate General for Mobility & Transport. (2013). Post-Impact Care.: European Commission.

European Transport Safety Council. (1999). Reducing the Severity of Road Injuries through Post Impact Care. Brussels: European Transport Safety Council.

Geuens C. and Dumortier J. (2010). Mandatory implementation for in-vehicle eCall: Privacy compatible? Computer Law & Security Review 26(4): 385-390.

Hakkert, A. and Gitelman, V. (2007) 'Deliverable D3.8: Road Safety Performance Indicators Manual'.

Hendrickson, C., Biehler, A. and Mashayekh, Y. (2014) Connected and Autonomous Vehicles 2040 Vision, Commonwealth of Pennsylvania Department of Transportation.

Holló, P., Henézi, D. and Berta, T. (2018) 'Comparison of self-reported and observed road safety performance indicators', Periodica Polytechnica Transportation Engineering, 46(3), pp. 117–121. doi: 10.3311/PPtr.12127.

Hussain L.M. and Redmond A.D. (1994). Are pre-hospital deaths from accidental injury preventable? BMJ (Clinical Research Ed.) 308(6936): 1077-1080.

International Transport Forum (2019) 'Road Safety Annual Report 2019'.

Jameel, A. K. and Evdorides, H. (2019) 'Assessment of Road Safety Performance for Southeast Asian Countries', Journal of the Society of Automotive Engineers Malaysia, 3(3), pp. 246–259. Available at: www.jsaem.saemalaysia.org.my.

Kapila, K.K., Prabhakar, A. & Bhattacharjee, S. (2013). Safe road infrastructure design for highways. Transport and Communications Bulletin for Asia and the Pacific. 83. [Online], Available: http://www.irfnet.ch/index.php. [2020, December 07].

Kim, E., Muennig, P. & Rosen, Z. (2017). Vision zero: a toolkit for road safety in the modern era. Injury Epidemiology. 4(1):1–9.

Kobusingye O.C., Hyder A.A., Bishai D., Hicks E.R., Mock C. and Joshipura M. (2005). Emergency medical systems in low- and middle-income countries: recommendations for action. Bulletin of the World Health Organization 83(8): 626-631.

Langham, M.P. & Moberly, N.J. (2003). Pedestrian conspicuity research: A review. Ergonomics. 46(4):345–363

Lerner E.B. and Moscati R.M. (2001). The golden hour: scientific fact or medical "urban legend"? Academic Emergency Medicine: Official Journal of the Society for Academic Emergency Medicine 8(7): 758-760.

Lofgren, M. (2009). Measuring Seatbelt Usage Through Existing Traffic Surveillance Systems: Pilot Project. Upper Great Plains Transportation Institute, North Dakota State University.

Lungu K., Kafosa V.M., Hussein J. and Ashwood-Smith H. (2001). Are bicycles ambulances and community transport plans effective? Malawi Medical Journal 13(2): 16-18.

Mackenzie, S., Seedat, M., Swart, L.-A. & Mabunda, M. (2008). Pedestrian Injury In South Africa: Focusing Intervention Efforts On Priority Pedestrian Groups And Hazardous Places. Pretoria: Medical Research Council-Uiversity of South AFrica.

Mackenzie, S., Seedat, M., Swart, L.-A. & Mabunda, M. (2008). Pedestrian Injury In South Africa: Focusing Intervention Efforts On Priority Pedestrian Groups And Hazardous Places. Pretoria.

McKibbin, D. (2016). Examining Best Practice in Road Safety Management. Northern Ireland Assemly.

Mock C.N., Tiska M., Adu-Ampofo M. and Boakye G. (2002). Improvements in Prehospital Trauma Care in an African Country with No Formal Emergency Medical Services. The Journal of Trauma, Injury, Infection, and Critical Care 53(1): 90-97.

Mokitimi, M.M. & Vanderschuren, M. (2017). The Significance of Non-Motorised Transport Interventions in South Africa - A Rural and Local Municipality Focus. In Vol. 25. Elsevier B.V. Transportation Research Procedia. 4798–4821.

N3 Toll Concession (RF) Proprietary Limited (N3TC). (2021). About the N3 Toll Route. Available at: http://www.n3tc.co.za/about-the-n3/.

NHS (2020) 'Ambulance Quality Indicators'. Available at: https://www.england.nhs.uk/statistics/statistical-work-areas/ambulance-quality-indicators/.

Persia, L., Usami, D.S., De Simone, F., Beaumelle, V.F.D. La, Yannis, G., Laiou, A., Han, S., Machata, K. (2016). Management of Road Infrastructure Safety. Transportation Research Procedia. 14:3436–3445.

Pešić, D. and Pešić, A. (2020) 'Monitoring of Road Safety Performance Indicators-Current Situation and Trends in the Republic of Serbia', Transportation Research Procedia, 45(2019), pp. 70–77. doi: 10.1016/j.trpro.2020.02.064.

Pires, C. et al. (2020) 'Car drivers' road safety performance: A benchmark across 32 countries', 44, pp. 166–179. doi: 10.1016/j.iatssr.2020.08.002.

Riguelle, F., Gitelman, V., Allenbach, R. & Hollo, P. (2007). Road Safety Performance Indicators: Manual. [Online], Available: https://www.academia.edu/13535031/Road_Safety_Performance_Indicators_Manual_Deliverable_D3_8_of_the_EU_FP6_project_SafetyNet [2020, December 11].

Road Traffic Management Corporation (2013) 'Road Traffic Offence Survey Methodology', (November).

Road Traffic Management Corporation (2020) 'State of Road Safety Report 2020'.

SANRAL (2017) 'GUIDELINES FOR PEDESTRIAN AND PUBLIC TRANSPORT FACILITIES ON NATIONAL ROADS'.

SANRAL. (2018). Cape Town Freeway Management System Monthly Operations Report November 2018.

Schneider, R., Grembek, O. & Braughton, M. (2013). Pedestrian crash risk on boundary roadways. Transportation Research Record. 2393(1):164–173.

Segni Tulu, G., Washington, S., King, M.J. & Haque, M.M. (2013). Why are Pedestrian Crashes so Different in Developing Countries? A Review of Relevant Factors in Relation to their Impact in Ethiopia. In Australasian Transport Research Forum.

Setty Pendakur, V. (2005). Non Motorized Transport in African Cities: Lessons from Experience in Kenya and Tanzania. Sub-Saharan Africa Transport Policy Program Working Paper, 80.

Setty Pendakur, V. (2005). Non-Motorized Transport in African Cities: Lessons from Experience in Kenya and Tanzania. [Online], Available: www.worldbank.org/afr/ssatp [2021, January 21].

Sinclair, M. & Zuidgeest, M. (2016). Investigations into pedestrian crossing choices on Cape Town freeways. Transportation Research Part F: Traffic Psychology and Behaviour. 42(3):479–494.

Stat Trek (2020) Survey Sampling Methods. Available at: https://stattrek.com/survey-research/sampling-methods.aspx?tutorial=samp.

Torfs, K. et al. (2016) 'ESRA 2015 - The results - Synthesis of the main findings from the ESRA survey in 17 countries.

Torfs, K., Meesmann, U. and Van den Berghe, W. (2019) E-Survey of Road users' Attitudes 2. Brussels, Belgium.

Transport Research Centre (2008) Towards zero: Ambitious road safety targets and the safe system approach. doi: 10.1787/9789282101964-en.

UNESCAP (2020) 'Overview of the Existing New Technologies and Management At Border Crossings', pp. 3–18.

Van den Berghe, W., Fleiter, J.J. & Cliff, D. (2020) *Towards the 12 voluntary global targets for road safety.* Guidance for countries on activities and measures to achieve the voluntary global road safety performance targets. Brussels: Vias institute and Genève: Global Road Safety Partnership

van Schagen, I.N.L.G. & Machata, K. (2010). Best practices in road safety: handbook for measures at the country level.

Vanderschuren, M. (2012). Non-Motorised Transport in Africa. In 3rd ed. Rory Williams (ed.). Alive2Green The Sustainable Transport & Mobility Handbook. 19–24.

Wegman, F. et al. (2008) SUNflowerNext: Towards a composite road safety performance index. Available at: e-mail: info@swov.nl Internet: www.swov.nl.

Wijers, P. (2020) 'Automated Enforcement Systems for Distracted Driving', IRF Webinar, (December).

World Health Organisation (2018) GLOBAL STATUS REPORT ON ROAD SAFETY 2018.

World Health Organisation. (2009). Speed management: A road safety manual for decision-makers and practitioners. [Online], Available: https://www.who.int/publications/i/item/speed-management-a-road-safety-manual-for-decision-makers-and-practitioners [2020, December 09].

World Health Organisation. (2014). Seat-belts and child restraints: a road safety manual for decision-makers and practitioners.