SA-RAP REPORT

South African Road Assessment Programme Report

'26.5 km of the N14 - Road P158/1'

(N1/N14 to Kgosi Mampuru Correctional Service)

Gauteng Province

February 2018

Compiled by:

RTMC: Research and Development Unit

Preamble

With an investment of ZAR 20.4 million, to improve road safety on the 26.5 km of the dual carriageway of the N14(P158/1) it is estimated that fatal and serious injuries (FSIs) are likely to reduce by 53.4%, preventing an estimated 36 FSIs each year and an estimated 731 FSIs over a 20 year period.

About iRAP/SA-RAP

The International Road Assessment Programme (iRAP) is a registered charity dedicated to saving lives through safer roads.

iRAP works in partnership with government and non-government organisations to:

- inspect high-risk roads and develop Star Ratings and Safer Roads Investment Plans
- provide training, technology and support that will build and sustain national, regional and local capability
- track road safety performance so that funding agencies can assess the benefits of their investments.

The programme is the umbrella organisation for inter alia SA-RAP, EuroRAP, AusRAP, usRAP and KiwiRAP. Road Assessment Programmes (RAP) are now active in more than 80 countries throughout Europe, Asia Pacific, North, Central and South America and Africa.

SA-RAP is the South African Road Assessment Programme under the auspices of the Road Traffic Management Corporation (RTMC).

iRAP is financially supported by the FIA Foundation for the Automobile and Society and the Road Safety Fund. Projects receive support from the Global Road Safety Facility, automobile associations, regional development banks and donors.

National governments, automobile clubs and associations, charities, the motor industry and institutions such as the European Commission also support RAPs in the developed world and encourage the transfer of research and technology to iRAP. In addition, many individuals donate their time and expertise to support iRAP.

For more information

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Acronyms

AADT	Average Annual Daily Traffic
AusRap	Australian Road Assessment Programme
BCR	Benefit cost ratio
EuroRAP	Europe Road Assessment Programme
FIA	Federation Internationale de l'Automobile
FSI	Fatal And Serious Injury
GDP	Gross Domestic Product
iRAP	International Road Assessment Programme
KiwiRAP	New-Zealand Road Assessment Programme
km	Kilometre
LASA	LEA Associates South Asia Pty. Ltd.
MUARC	Monash University Accident Research Centre, Melbourne
PCU	passenger car equivalent
RTC	Road Traffic Crashes
RTMC	Road Traffic Management Corporation
SA-RAP	South African Road Assessment Programme
SRIP	Safer Roads Investment Plan
SRS	Star Rating Scores
UNDA	United Nations Decade of Action
usRAP	United States Road Assessment Programme
VIDA	Meaning 'Life' In Spanish (Refers to the online VIDA Analysis Software)
VRU	Vulnerable Road User
WHO	World Health Organisation
ZAR	South African Rand

Executive Summary

In an effort to reduce road deaths and serious injuries, the Road Traffic Management Corporation (RTMC) assessed a section of the N14 (P158/1) in the Gauteng Province, in conjunction with the Gauteng provincial road authority in August 2017 with the South African Road Assessment Programme (SA-RAP).

The ±13km section of dual carriageway (N1/N14 to Kgosi Mampuru Correctional Services) was identified by the Gauteng provincial roads authority as a priority hazardous location on their road network with an estimated 41 fatalities from 2015 to 2017. The area, which this section of road falls within, ranks high on the RTMCs Interim HazLocs 2017.

This technical report describes the N14 (P158/1) project, undertaken to identify risks and propose countermeasures through Safer Roads Investment Plan (SRIP) options in an effort to reduce road deaths and serious injuries on the section hazardous road. The report includes details on data collection, the methodology used and a summary of the results.

The infrastructure-related risk assessment involved detailed surveys and coding of 50 road attributes at 100-metre intervals along the network and creation of Star Ratings, which provide a simple and objective measure showing the level of risk on the road for each of the dual carriageway sections. The assessment was conducted on each of the carriageways in two separate parts viz.: Part A – Southbound and Part B – Northbound. The travelled ways of the ±13 km section of road is a surfaced divided dual carriage way separated with a median.

The assessment found that 71.7% of the 26.5 km surveyed is rated 1- or 2-stars (out of possible 5-stars) for vehicle occupants and 100% of the applicable 5.8 km where pedestrian activities were relevant, is rated 1- or 2-stars for pedestrians. None of the 26.5 km road assessed achieved 4- or 5-star rating for vehicle occupants with only 28.3% or 7.5 km of the road assessed achieving a 3-star rating for vehicle occupants.

Star Ratings by road user, N14 (P158/1) –Dual Carriageways (Combined)

	Vehicle Occupants		Pedestrians	
Star Ratings	Length (km)	Percent	Length (km)	Percent
5 Stars	0	0%	0	0%
4 Stars	0	0%	0	0%
3 Stars	7.5	28.30%	0	0%
2 Stars	15.9	60.00%	0.6	2.26%
1 Star	3.1	11.70%	5.2	19.62%
Not applicable	0	0%	20.7	78.11%
Totals	26.5	100%	26.5	100%

Note: the table shows 'smoothed' Star Ratings.

The road attribute data shows that the dual carriageway mostly has no physical separation between opposing flows. Roadside hazards are numerous, with 35% of the survey length having hazardous objects on the driver-side within 5m of the running lane with limited roadside protection (such as safety barriers); and 69% of the survey length having hazardous objects on the passenger-side within 5m of the running lane with limited roadside protection (such as safety barriers).

The physical median of the total surveyed section of road consists of 4.3 km (16%) metal safety barrier; 1.0km (4%) median width between 10m and 20m; 20.8km (78%) median width between 5m and 10m and 0.4 (2%) median width between 1m and 5m.

Provision for vulnerable road users is poor in the sections of road in concern (5.8km or 21.9% of the 26.5km) with no motorcycle or bicycle facilities present and insufficient footpath provision and crossing facilities where pedestrian activities are present.

The project also involved the creation of Safer Roads Investment Plans (SRIP), that consider the relative benefits of over 90 different countermeasure options, ranging from low cost road markings and pedestrian refuges to higher cost intersection upgrades and full highway duplication. Three SRIP options in this report prioritise countermeasure options that could maximise the prevention of deaths and serious injuries within the available budget. The plans largely focus on:

- reducing risk at intersections
- reducing the risk associated with run-off road crashes by improving shoulders and reducing the severity of roadsides
- reducing head-on risk by increasing the separation between opposing flows or dividing the carriageways
- providing facilities for pedestrians.

A summary of the three investment plan options is shown in the table below. Taking the most comprehensive of the plans (Plan 1) as an example, by investing ZAR 37.9 million over a 20 year period, the number of deaths and serious injuries on the road could be reduced by 54.6%, preventing more than 746 deaths and serious injuries over 20 years. The overall benefit cost ratio of this approach would be 10:1. The most viable (cost effective vs % Reduction in death and serious injury) of the plans (Plan 3) shows that by investing ZAR 20.4 million, the number of deaths and serious injuries on the road could be reduced by 53.5%, preventing more than 731 deaths and serious injuries over 20 years. The overall benefit cost ratio of this approach would be 18:1.

Safer Road Investment Plan summary (20-year analysis)

	Plan 1	Plan 2	Plan 3
Present value of investment	ZAR 37.9 million	ZAR 23.8 million	ZAR 20.4 million
Deaths and serious injuries prevented	746	727	731
Present value of safety benefits	ZAR 372.5 million	ZAR 363.1 million	ZAR 364.9 million
Cost per death and serious injury prevented	ZAR 50,856	ZAR 32,747	ZAR 27,893
Benefit cost ratio (BCR)	10:1	15:1	18:1
Reduction in death and serious injuries	54.6%	53.2%	53.5%

The selection of an appropriate level of investment is open for decision by the Gauteng provincial road authority. Final implementation of the plan will preferably include the following steps:

- local examination of proposed countermeasures (including a 'value engineering' type workshop including all relevant stakeholders)
- detailed analysis of traffic survey and crash data (if available)
- preliminary scheme investigation studies, including site surveys and preliminary design
- detailed design, star ratings of the designs, road safety audit, detailed costing and procurement, final evaluation and construction
- post-construction evaluation and road safety audit, including Star Ratings for the upgraded road and analysis of crash data (if it is available)

The detailed results of the project and online software that enabled the iRAP analyses to be undertaken are available to stakeholders for further exploration and use (http://vida.irap.org).

In order to achieve the best road safety gains on the network, efforts that go beyond the engineering improvements discussed in this report will be necessary. Significant benefits could be realised through the coordinated improvement of road user behaviour such as improving speed limit compliance, seat belt and helmet wearing rates and reducing alcohol use, improving the safety of the vehicle fleet, as well as road infrastructure. The Road Safety Toolkit (http://toolkit.irap.org) and United Nations Road Safety Collaboration Good Practice Manuals provide further information on these issues.

Further, research has demonstrated that it is crucial to ensure that local communities have the opportunity to both contribute to road designs but also understand the intended use of various road design features (see for example, BRAC, 2005). The Gauteng road authority should pursue these complementary approaches as part of the ongoing core road network development programme.

Acknowledgments

The N14 (P158/1) road assessment project would not have been possible without the support of:

- Nikola Galović; AMSS-CMV Ltd, Serbia
- James Bradfort, iRAP, UK

The project was funded and executed by the RTMC and technical input was received and collaborated with the Gauteng provincial roads authority.

Contents

1 Introduction

Around the world 1.25 million people die as a result of road traffic crashes each year, or more than 3,400 deaths per day, or one every 25 seconds.[1] Although several high-income countries are reducing the number of deaths on their roads, many low and middle-income countries are experiencing an increase in the numbers of fatal and serious injuries.

With road traffic fatalities the leading cause of death for young people aged 15 to 29 worldwide and 92% of road traffic deaths occurring in low and middle-income countries, key partners in global road safety have come together in an attempt to tackle this rapidly worsening public health crisis through accelerated investment in road safety and by fundamentally changing the way we design, build and maintain our road infrastructure networks around the world[1]. As such, the United Nations has declared 2011-2020 the Decade of Action for Road Safety. It is expected that during the decade, significant efforts will be made to stabilise and then reduce the death toll through systematic improvements in road infrastructure, road user behaviour and vehicle safety.

1.1 Road safety in South Africa

It is recognised that investment in the transport network plays an important role in a country's economic development and poverty reduction. To this end, investment in road building programmes is often focused on improving mobility and reducing journey times. However, it is of paramount importance that every opportunity be taken to ensure that these new roads and rehabilitation projects focus on the need for safe road infrastructure for all road users, particularly the young and vulnerable.

The high number of Road Traffic Crashes[2] (RTCs) and their associated consequences have a significant impact on the South African society, which continues to hamper socio-economic development and impact on the well-being of all South Africans. This impact is measured in terms of human lives lost, 'pain, grief and suffering', as well as an increasing cost to the economy. The total cost of RTCs on South Africa's road network for 2015 amounted to an estimated R142.95 billion - equating 3.4% of the South African Gross Domestic Product (GDP-2015)[3].

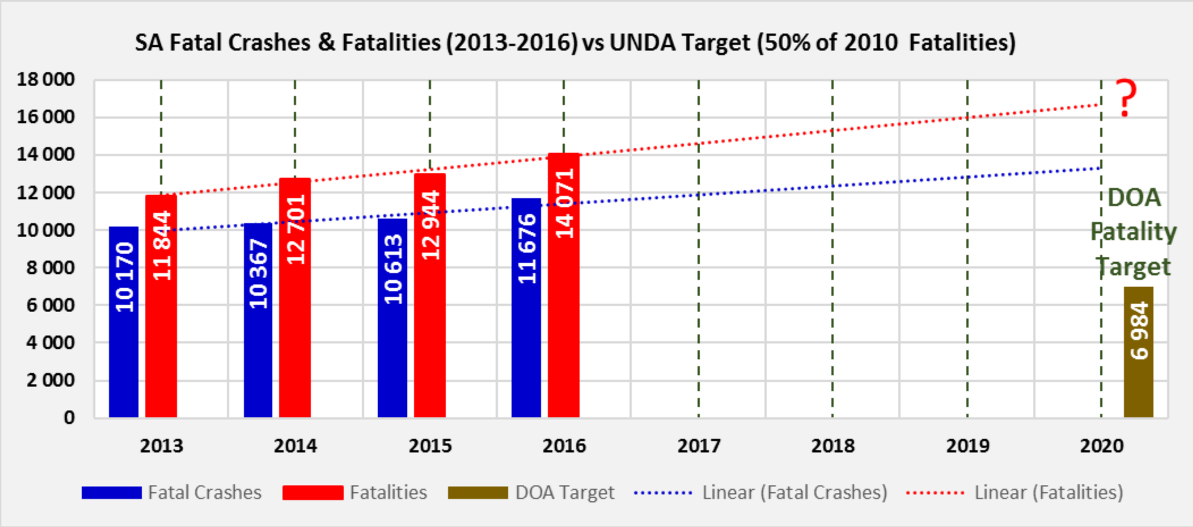
The target of the 2010 United Nations Decade of Action (UNDA) initiative of which South Africa is a signatory, to halve road fatalities by 2020, will not be reached with fatal road related crashes and fatalities in South Africa increasing drastically since 2013.

[1] WHO Global status report on road safety (2015)

[2] The term 'crash' imparts the same meaning as "accident" noted in the National Road Traffic Act, 93 of 1996.

[3] F. Labuschagne, E. de Beer, D. Roux and K. Venter, (2016). *Cost of Crashes in South Africa 2016*. Road Traffic Management Corporation (RTMC), http://www.rtmc.co.za.

Figure 1: SA Fatal Crashes & Fatalities (2013-2016) vs UNDA Target



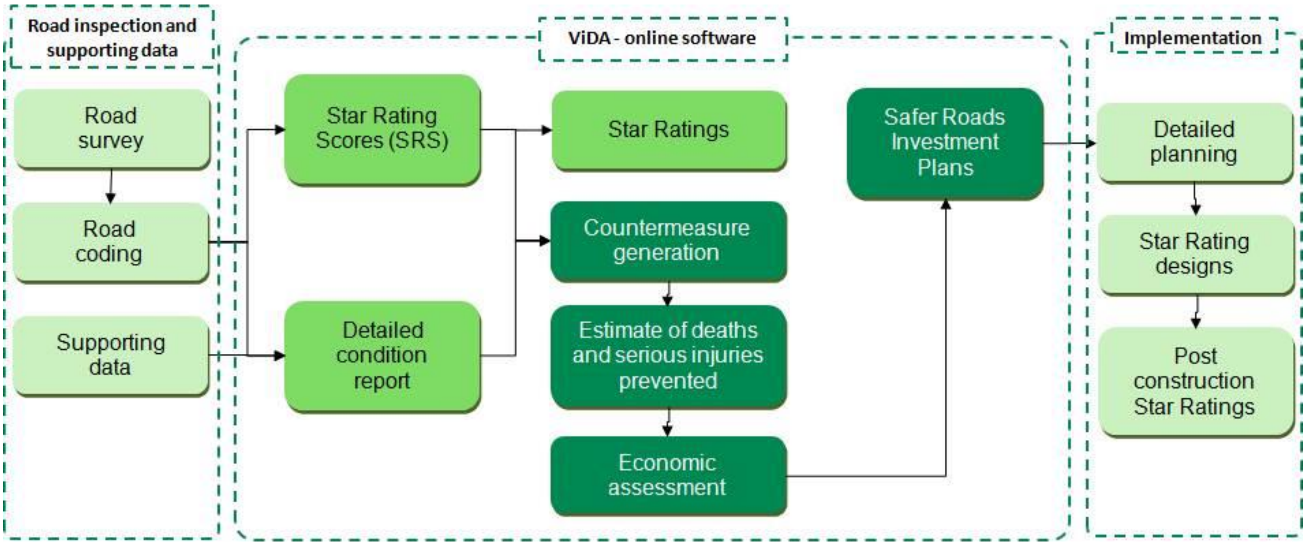
It is estimated that road related fatalities increased with 18.8% or 2,227 fatalities from 2013 to 2016 from 11,844 fatalities in 2013 to 14,071 fatalities recorded in 2016 (Chart 1). It is evident that notwithstanding considerable road safety efforts over recent years, the desired reduction in road crashes and fatalities on South African roads has not been achieved.

Urgent action is required to improve safe road design and existing road improvements in order to significantly reduce these avoidable tragedies.

1.2 Methodology

The production of Star Ratings and Safer Road Investment Plans involve a number of data collection, survey and analysis processes, as illustrated in Figure 2. The iRAP assessments make use of road attribute data for more than 50 variables at 100-metre intervals along a road. This data was compiled through road surveys that collect digital images of the road using multi-view high-resolution cameras as it is driven. After the images were collected and were viewed by coders using specialised software in the office to record the road attributes.

Figure 2: The iRAP road survey, coding, Star Rating and Safer Roads Investment Plan process



iRAP uses globally consistent models to produce vehicle occupant, motorcyclist, pedestrian and bicyclist Star Ratings and Safer Road Investment Plans. The methodology is described in the following fact sheets:

- iRAP Methodology Fact Sheet 3: Road Attributes
- iRAP Methodology Fact Sheet 4: Crash Types
- iRAP Methodology Fact Sheet 5: External Flow and Median Traversability
- iRAP Methodology Fact Sheet 6: Star Rating Score Equations
- iRAP Methodology Fact Sheet 7: Star Rating Bands
- iRAP Methodology Fact Sheet 8: Smoothed Star Ratings
- iRAP Methodology Fact Sheet 9: Star Rating Worked Example
- iRAP Methodology Fact Sheet 10: Casualty Estimation and Calibration
- iRAP Methodology Fact Sheet 11: Countermeasures
- iRAP Methodology Fact Sheet 12: Multiple Countermeasures
- iRAP Methodology Fact Sheet 13: Economic Analysis

The methodology fact sheets are available for download at: http://irap.org/about-irap-3/methodology.

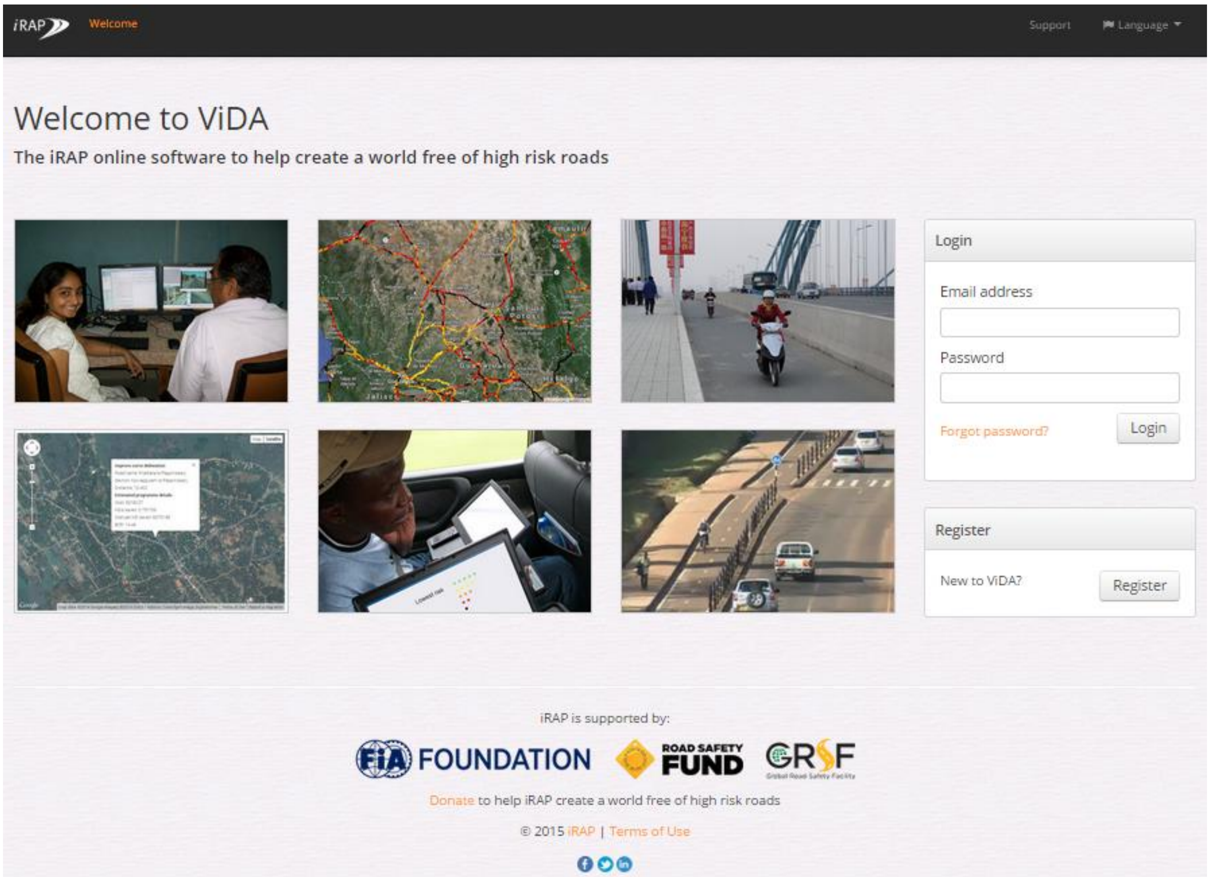
Other iRAP reference documents used in this project include:

- *The True Cost of Road Crashes – Valuing life and the cost of a serious injury*
- *Vehicle Speeds and the iRAP Protocols*
- *iRAP Star Ratings and Investment Plans: Coding Manual (August 2014)*
- *iRAP Star Ratings and Investment Plans: Quality Assurance Guide*

1.3 Online results

This report provides details of the methodology used and summarises the results produced in the *South Africa RAP > RTMC > 2017 > N14 (P158/1)* project. Full results, including data tables and charts, interactive maps and download files, as well as data underpinning the analyses, are available in the iRAP online software at http://vida.irap.org.

Figure 3: VIDA login page



The Star Ratings and Safer Road Investment Plans shown in this report can be accessed through ViDA the Road Assessment Programme's online analysis software. A guide to using ViDA to access the full results, plus details on how to register as a new user is available at http://downloads.irap.org/docs/ViDA_tour.pdf. The guidance document shows how the maps, charts, tables, economic analysis and download files can help to improve safe road design by improving understanding of the role that road infrastructure plays in influencing the likelihood and severity of common crash types and identifying countermeasures that will reduce risk.

Access to the iRAP online software can be gained by registering for an account. Following this access to the N14 (P158/1) can be requested. For further information about accessing or using the software, contact support@irap.org.

2 iRAP and the Safe System Approach

Road deaths and injuries are the result of a complex interaction between the way people behave on the roads, the types of vehicles in use and the speed they are travelling, and the design of the roads themselves. Despite this complexity, the process of creating a road system that is genuinely safe is now well understood. Experience in implementing the well-established 'safe system' approach, which recognises the mutual importance of safe road users, safe vehicles and safe roads, shows how death and serious injury can be prevented on a large scale.[4] The following principles broadly underline the safe system approach and inform the iRAP process:

- mistakes, errors of judgment and poor driving decisions are intrinsic to humans. The road safety system needs to be designed and operated to account for this
- humans are fragile. Unprotected, we cannot survive impacts that occur at even moderate speeds
- people who behave with criminal disregard for the safety of themselves and others should expect tough policing and tough penalties
- safety can be built into the road system in a comprehensive and systematic fashion, not just having the apparent problem areas patched up
- the 'engineered' elements of the system - vehicles and roads - can be designed to be compatible with the human element, perhaps taking lessons from motor racing that while crashes will occur, the total system is designed to minimise harm.

The role of iRAP is to focus specifically on the 'safe roads' element of the safety equation, in the context of safer road users, safer vehicles and safe roads. iRAP builds on the experience of developed countries that have a proven track record in infrastructure safety and, with the support of local engineers and researchers, applies knowledge and technical processes that are applicable for low and middle-income countries.

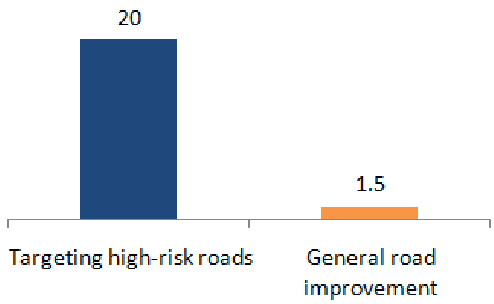
A safe road will recognise and make provision for the limitations of humans within the transport system. The network should be designed to limit the probability of crashes occurring and minimise the severity of those crashes that do occur.

Evidence shows that affordable, safe road infrastructure can cut vehicle occupant, motorcyclist, pedestrian and bicyclist deaths dramatically. Few infrastructure investments can match the economic benefits of those generated by targeted road safety measures (see Figure 4 below). Research from Australia, the United States, the United Kingdom, Norway, France, Canada, Netherlands, the Nordic Countries and New Zealand shows that targeted road safety projects generated crash cost savings of up to 60 times the cost of construction.[5] That is, for each $1 invested, there was a return of up to $60 in terms of crash costs avoided. Other research has shown that low-cost improvements at specific high-risk sites have shown first year rates of return of 300%.[6]

[4] See for example www.who.int/violence_injury_prevention/road_traffic/strategies/en/index.html and www.ors.wa.gov.au/.
[5] OECD (2008) Towards Zero – Ambitious road safety targets and the safe systems approach -- page 96, section 4.2 "The road safety management system".
[6] Road Safety Foundation (2008).

With adequate maintenance, road infrastructure investment can last decades, so the safe roads built today will continue saving lives and preventing injuries long into the future.

Figure 4: Number of lives saved for each $100m invested [7]



Engineering solutions exist for all of the primary crash types that kill road users, Table 1 below shows a summary of each of the common crash types with details of the engineering solutions that are proven to reduce risk, further information on these treatments can be found in the iRAP Road Safety Toolkit (http://toolkit.irap.org).

Table 1: Primary causes of road death and engineering solutions that save lives

Crash Type / Mechanism	Engineering Solutions	Examples
Hit Pedestrian Crash Pedestrians are killed walking along the road and in trying to cross the road.	Solutions include: Footpaths, pedestrian fencing, speed management and traffic calming, safe crossing points.	
Hit Motorcyclist Crash Motorcyclists are killed when they are hit by heavier vehicles and trucks.	Solutions include: Fully separated motorcycle lanes, on-road motorcycle lanes.	

[7] Vulcan, P. and Corben, B. (1998) Prediction of Australian Road Fatalities for the Year 2010, Monash University Accident Research Centre (MUARC), Melbourne.

Crash Type / Mechanism	Engineering Solutions	Examples
Head-on Crash Oncoming traffic collides at high speed (while overtaking or when momentarily crossing into the opposing lane).	Solutions include: Provision of overtaking lanes, median barriers or separation, flexible posts, central hatching.	
Run-off Road Crash Vehicle leaves the road and strikes a fixed object (tree, pole, structure) or steep embankment.	Solutions include: Protection of the hazard with barriers, remove hazard, provide safe run-off area.	
Intersection Crash High speed frontal or side impact, rear-end crash with non compatible vehicles.	Solutions include: Grade separation, speed management, roundabouts, signalisation, turning lanes.	
Hit Bicyclist Crash Bicyclists are killed cycling along the road and in trying to cross the road.	Solutions include: On-road and off-road, cycle paths, speed management and traffic calming, safe crossing points.	

An important principle for iRAP is the application of countermeasures on a large scale. Experience from the health sector has taught us that large-scale application of proven treatments is essential in eradicating wide-spread epidemics. Operation Smallpox Zero for example, was responsible for eradicating this deadly disease in just ten years. The programme of Smallpox vaccinations was described as a triumph of World Health Organization management, not of medicine. Likewise the systematic safety upgrading of the South African road network over the Decade of Action can make a significant contribution to the eradication of road traffic death and injury.

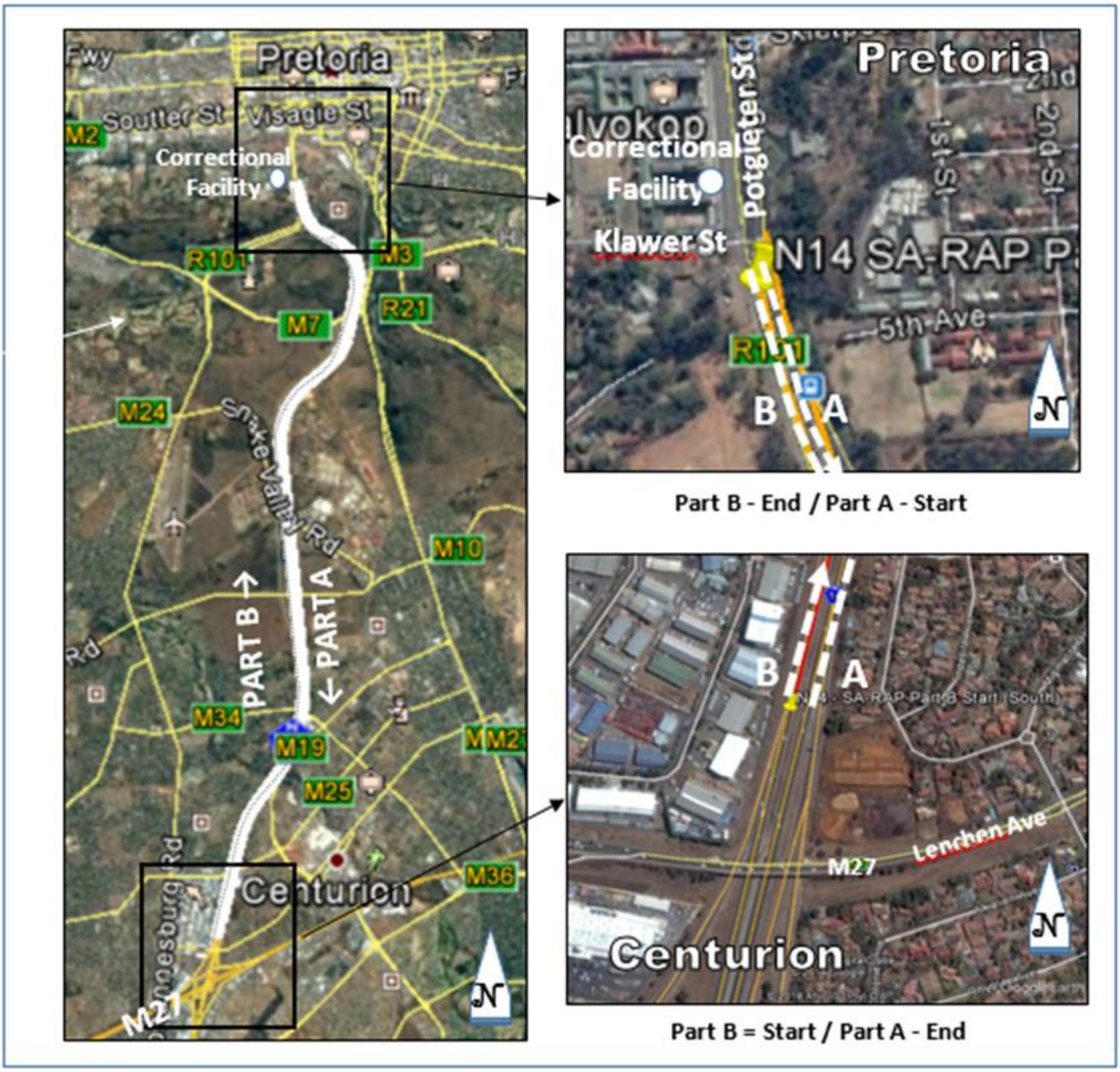
3 Road Survey and Coding

Using a specially equipped RTMC SA-RAP vehicle, the road section was surveyed, recording continuous digital images and geo-reference data to enable the coding of more than 50 road attributes relating to the likelihood and severity of a crash.

3.1 Location (N14 – P158/1)

The ±13km section of dual carriageway (N1/N14 to Kgosi Mampuru Correctional Services) is situated in the Gauteng province in the Tshwane Metropolitan area. The assessment was conducted on each of the carriageways in two separate parts viz.: Part A – Southbound and Part B – Northbound.

Image 1: Location of N14 (P158/1



Part B - End / Part A - Start

Part B = Start / Part A - End

3.2 Road surveys

The surveys were undertaken by RTMC in August 2017 using a Greenwood Engineering road inspection system. The features of the inspection system are:

- Dual roof mounted high-resolution digital cameras. Enabling wide field of view images to be taken every 20m
- Geo-reference data linked to the images.

Figure 4: The road survey vehicle

3.3 iRAP coding

Upon completion of the surveys, the RTMC coding team recorded road attributes in accordance with the iRAP Star Ratings and Investment Plans: Coding Manual. The coded data was subject to quality assurance checks in accordance with the iRAP Star Ratings and Investment Plans: Quality Assurance Guide, to ensure the highest standards of quality and consistency during the road coding process and subsequent quality reviews prior to data processing.

3.4 Road attributes

The following tables summarises the road attributes recorded and helps to illustrate the relationship between road infrastructure attributes and road user risk. A full data set of the coded attributes is available as a downloadable file from http://vida.irap.org.

3.4.1 Detailed Road Conditions (survey length: 13.20 km) – Part A

The Detailed Road Condition tables within ViDA provide the length and percentage for each category of recorded road attribute. The tables can be used to compare the infrastructure attributes of different roads or road sections and can help to provide an understanding of the Star Ratings of a given road section and the proposed countermeasures that will potentially alter the road attributes and reduce risk.

For example the data shows that for part A (Southbound) 98% of the road length is divided with a physical median separating opposing traffic flows (median width >=5.0m <=10.0m), 70% of the road length have three lanes, 25% two lanes and 5% have four or more lanes.

Table 4a-1: Roadside – Part A (Southbound)

Roadside severity - driver-side distance	km	%
0 to <1m	0.30	2
1 to <5m	3.90	30
>= 10m	9.00	68

Roadside severity - driver-side object	km	%
Safety barrier - metal	1.20	9
Safety barrier - concrete	0.10	1
Tree >=10cm dia.	1.10	8
Sign, post or pole >= 10cm dia.	0.10	1
Rigid structure/bridge or building	0.40	3
Unprotected safety barrier end	0.80	6
None	9.50	72

Roadside severity - passenger-side distance	km	%
0 to <1m	0.60	5
1 to <5m	8.40	64
5 to <10m	2.40	18
>=10m	1.80	14

Roadside severity - passenger-side object	km	%
Safety barrier - metal	2.40	18
Safety barrier - concrete	0.20	2
Upwards slope - rollover gradient	4.60	35
Upwards slope - no rollover gradient	0.20	2
Tree >= 10cm dia.	2.00	15
Sign, post or pole >=10cm dia.	0.60	5
Rigid structure/bridge or building	0.20	2
Semi-rigid structure or building	0.60	5
Unprotected safety barrier end	1.00	8
None	1.40	11

Shoulder rumble strips	km	%
Not present	13.20	100

Paved shoulder - driver-side	km	%
None	13.20	100

Paved shoulder - passenger-side	km	%
Medium (>= 1.0m to < 2.4m)	4.20	32
Narrow (>= 0m to < 1.0m)	9.00	68

Table 4a-2: Midblock – Part A (Southbound)

Carriageway label	km	%
Carriageway A of a divided carriageway road	13.20	100

Upgrade cost	km	%
Low	12.00	91
High	1.20	9

Median type	km	%
Safety barrier - metal	1.00	8
Physical median width >= 10.0m to < 20.0m	1.00	8
Physical median width >= 5.0m to < 10.0m	10.80	82
Physical median width >= 1.0m to < 5.0m	0.40	3

Centreline rumble strips	km	%
Not present	13.20	100

Number of lanes	km	%
Two	3.30	25
Three	9.20	70
Four or more	0.70	5

Lane width	km	%
Wide (>= 3.25m)	8.80	67
Medium (>= 2.75m to < 3.25m)	4.40	33

Curvature	km	%
Straight or gently curving	10.10	77
Moderate	3.10	23

Quality of curve	km	%
Adequate	3.10	23
Not applicable	10.10	77

Grade	km	%
>= 0% to <7.5%	13.20	100

Road condition	km	%
Good	13.20	100

Skid resistance / grip	km	%
Sealed - adequate	13.20	100

Delineation	km	%
Adequate	13.20	100

Street lighting	km	%
Not present	12.10	92
Present	1.10	8

Vehicle parking	km	%
None	13.20	100

Service road	km	%
Not present	13.20	100

Roadworks	km	%
No road works	13.20	100

Sight distance	km	%
Adequate	13.20	100

Table 4a-3: Intersections – Part A (Southbound)

Intersection type	km	%
Merge lane	0.30	2
3-leg (signalised) with protected turn lane	0.10	1
None	12.80	97

Intersection channelisation	km	%
Not present	13.20	100

Intersecting road volume	km	%
5,000 to 10,000 vehicles	0.10	1
1,000 to 5,000 vehicles	0.20	2
100 to 1,000 vehicles	0.10	1
None	12.80	97

Intersection quality	km	%
Adequate	0.40	3
Not applicable	12.80	97

Property access points	km	%
None	13.20	100

Table 4a-4: VRUs and Land Use – Part A (Southbound)

Land use - driver-side	km	%
Undeveloped areas	13.20	100

Land use - passenger-side	km	%
Undeveloped areas	13.20	100

Area type	km	%
Rural / open area	13.20	100

Pedestrian crossing facilities - inspected road	km	%
Grade separated facility	0.10	1
No facility	13.10	99

Pedestrian crossing quality	km	%
Adequate	0.10	1
Not applicable	13.10	99

Pedestrian crossing facilities - intersecting road	km	%
No facility	13.20	100

Pedestrian fencing	km	%
Not present	13.20	100

Sidewalk - driver-side	km	%
None	13.20	100

Sidewalk - passenger-side	km	%
Non-physical separation 0m to <1.0m	0.20	2
None	13.00	98

Facilities for motorised two wheelers	km	%
None	13.20	100

Facilities for bicycles	km	%
None	13.20	100

School zone warning	km	%
Not applicable (no school at the location)	13.20	100

School zone crossing supervisor	km	%
Not applicable (no school at the location)	13.20	100

3.4.2 Detailed Road Conditions (survey length: 13.26 km) – Part B

Table 4b-1: Roadside – Part B (Northbound)

Roadside severity - driver-side distance	km	%
1 to <5m	5.20	39
>= 10m	8.10	61

Roadside severity - driver-side object	km	%
Safety barrier - metal	3.10	23
Safety barrier - concrete	0.10	1
Tree >= 10cm dia.	0.30	2
Sign, post or pole >= 10cm dia.	0.30	2
Rigid structure/bridge or building	0.60	5
Unprotected safety barrier end	0.50	4
None	8.40	63

Roadside severity - passenger-side distance	km	%
0 to <1m	2.50	19
1 to <5m	6.60	50
5 to <10m	2.30	17
>=10m	1.90	14

Roadside severity - passenger-side object	km	%
Safety barrier - metal	2.80	21
Safety barrier - concrete	0.30	2
Upwards slope - rollover gradient	3.40	26
Deep drainage ditch	0.30	2
Downwards slope	0.10	1
Tree >= 10cm dia.	0.80	6
Sign, post or pole >= 10cm dia.	0.10	1
Rigid structure/bridge or building	0.40	3
Semi-rigid structure or building	1.60	12
Unprotected safety barrier end	1.50	11
None	2.00	15

Shoulder rumble strips	km	%
Not present	13.30	100

Paved shoulder - driver-side	km	%
Narrow (>= 0m to < 1.0m)	0.10	1
None	13.20	99

Paved shoulder - passenger-side	km	%
Wide (>= 2.4m)	0.50	4
Medium (>= 1.0m to < 2.4m)	1.60	12
Narrow (>= 0m to < 1.0m)	11.20	84

Table 4b-2: Midblock – Part B (Northbound)

Carriageway label	km	%
Carriageway B of a divided carriageway road	13.30	100

Upgrade cost	km	%
Low	7.90	59
Medium	1.90	14
High	3.50	26

Median type	km	%
Safety barrier - metal	3.30	25
Physical median width >= 5.0m to < 10.0m	10.00	75

Centreline rumble strips	km	%
Not present	13.30	100

Number of lanes	km	%
One	0.10	1
Two	1.60	12
Three	10.10	76
Four or more	1.50	11

Lane width	km	%
Wide (>= 3.25m)	12.10	91
Medium (>= 2.75m to < 3.25m)	1.20	9

Curvature	km	%
Straight or gently curving	12.40	93
Moderate	0.90	7

Quality of curve	km	%
Adequate	0.90	7
Not applicable	12.40	93

Grade	km	%
>= 0% to <7.5%	13.30	100

Road condition	km	%
Good	13.30	100

Skid resistance / grip	km	%
Sealed - adequate	13.30	100

Delineation	km	%
Adequate	13.30	100

Street lighting	km	%
Not present	12.30	92
Present	1.00	8

Vehicle parking	km	%
None	13.00	98
One side	0.30	2

Service road	km	%
Not present	13.30	100

Roadworks	km	%
No road works	13.30	100

Sight distance	km	%
Adequate	13.30	100

Table 4b-3: Intersections – Part B (Northbound)

Intersection type	km	%
Merge lane	0.60	5
None	12.70	95

Intersection channelisation	km	%
Not present	13.30	100

Intersecting road volume	km	%
5,000 to 10,000 vehicles	0.20	2
1,000 to 5,000 vehicles	0.30	2
100 to 1,000 vehicles	0.10	1
None	12.70	95

Intersection quality	km	%
Adequate	0.60	5
Not applicable	12.70	95

Property access points	km	%
None	13.30	100

Table 4b-4: VRUs and Land Use – Part B (Northbound)

Land use - driver-side	km	%
Undeveloped areas	13.30	100

Land use - passenger-side	km	%
Undeveloped areas	13.20	99
Residential	0.10	1

Area type	km	%
Rural / open area	12.90	97
Urban / rural town or village	0.40	3

Pedestrian crossing facilities - inspected road	km	%
Grade separated facility	0.10	1
No facility	13.20	99

Pedestrian crossing quality	km	%
Adequate	0.10	1
Not applicable	13.20	99

Pedestrian crossing facilities - intersecting road	km	%
No facility	13.30	100

Pedestrian fencing	km	%
Not present	13.30	100

Sidewalk - driver-side	km	%
None	13.30	100

Sidewalk - passenger-side	km	%
None	13.30	100

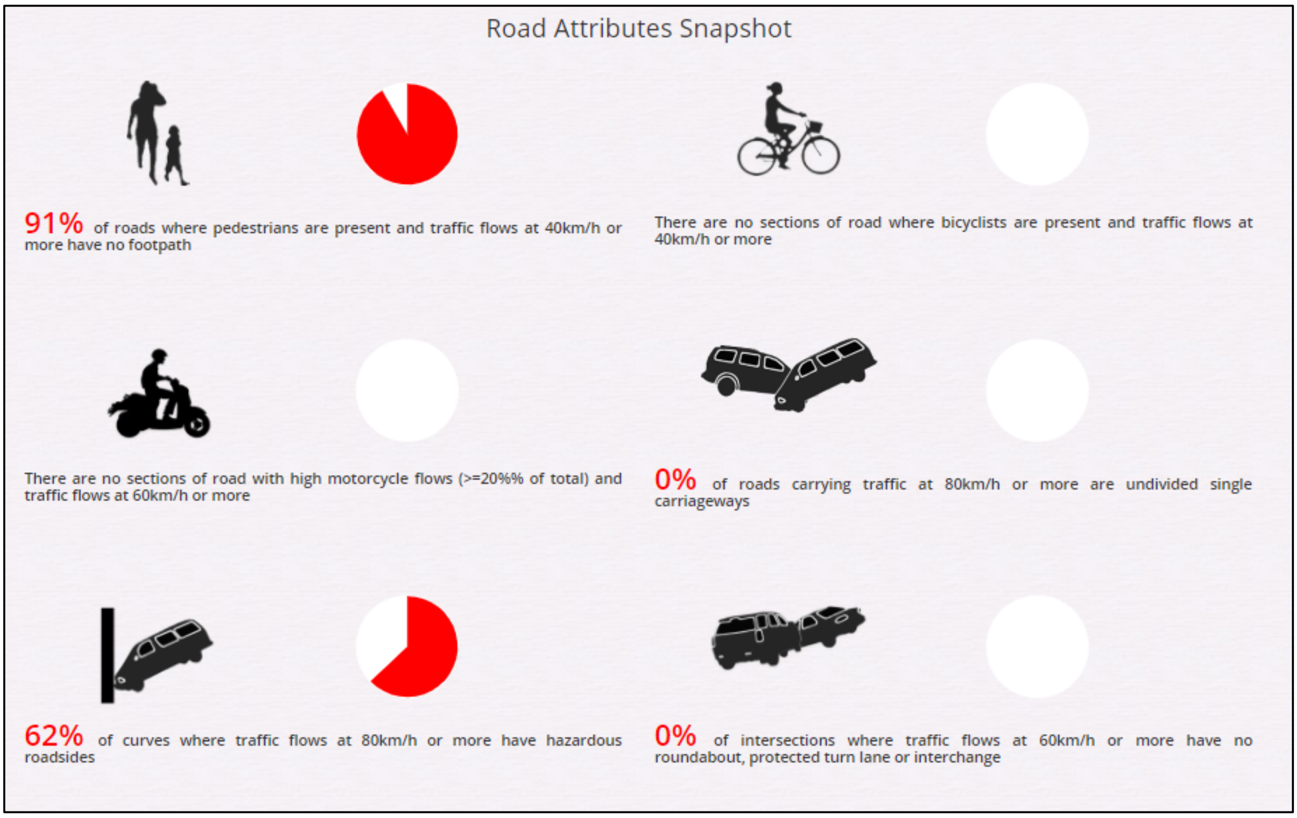
Facilities for motorised two wheelers	km	%
None	13.30	100

Facilities for bicycles	km	%
None	13.30	100

School zone warning	km	%
Not applicable (no school at the location)	13.30	100

School zone crossing supervisor	km	%
Not applicable (no school at the location)	13.30	100

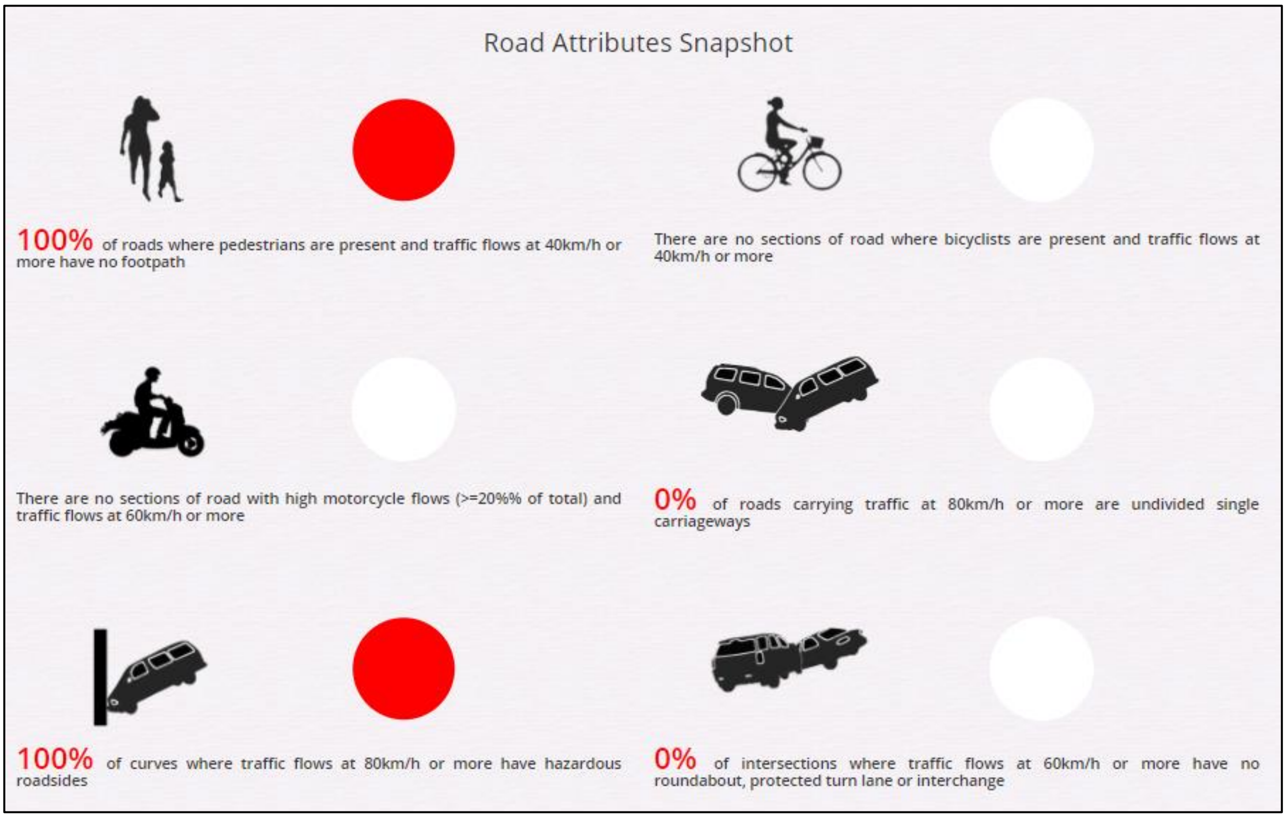
Figure 5a: Road Attribute Snapshot of high level of risk on the N14 (P158/1) – Part A



Supporting information regarding Part A (Southbound):

- Of the 2.0km where pedestrians are present and traffic flows at 40km/h or more, 2.0km have no footpath.
- There are no sections of road where cyclists are present and traffic flows at 40km/h or more.
- There are no sections of road with high motorcycle flows (>=20%% of total) and traffic flows at 60km/h or more.
- Of the 12.0km of roads carrying traffic at 80km/h or more, 0.0km are undivided single carriageways.
- Of the 3.0km of curves where traffic flows at 80km/h or more, 2.0km have hazardous roadsides.
- Of the 4 intersection(s) where traffic flows at 60km/h or more, 0 have no roundabout, protected turn lane or interchange.

Figure 5b: Road Attribute Snapshot of high level of risk on the N14 (P158/1) – Part B



Supporting information regarding Part A (Southbound):

- Of the 3.0km where pedestrians are present and traffic flows at 40km/h or more, 3.0km have no footpath.
- There are no sections of road where cyclists are present and traffic flows at 40km/h or more.
- There are no sections of road with high motorcycle flows (>=20%% of total) and traffic flows at 60km/h or more.
- Of the 12.0km of roads carrying traffic at 80km/h or more, 0.0km are undivided single carriageways.
- Of the 1.0km of curves where traffic flows at 80km/h or more, 1.0km have hazardous roadsides.
- Of the 6 intersection(s) where traffic flows at 60km/h or more, 0 have no roundabout, protected turn lane or interchange.

4 Supporting Data

Although the iRAP Star Ratings and Safer Roads Investment Plans use a standardised global methodology, the models are calibrated with local data to ensure that the results reflect local conditions. The following section outlines the supporting data and how it was used in the iRAP analysis.

4.1 The role of speed

The issue of speed management is of paramount importance in road safety and traffic speeds have a significant bearing on the iRAP Star Ratings.

The risk of death or serious injury is minimised in any crash, where:

- vulnerable road users (e.g. motorcyclists, bicyclists and pedestrians) are physically separated from cars and heavier vehicles, or where traffic speeds are 40km/h or less
- opposing traffic is physically separated and roadside hazards such as trees and other fixed objects (including concrete guard posts) are well managed
- traffic speeds are restricted to 70km/h or less on roads where opposing traffic flows are not physically separated, or where roadside hazards exist.

The safety of infrastructure is heavily influenced by the speed of traffic and without an understanding of the operating speeds it is difficult to assess the safety performance of infrastructure at a given location. All iRAP assessments are based on vehicle operating speeds to ensure that the Star Rating is based on how the road is actively functioning, which in some cases can be above the posted speed limit. For further details of the iRAP specifications in relation to vehicle speeds see *Vehicle Speeds and the iRAP Protocols*, which can be found on the iRAP website http://irap.org/about-irap-3/research-and-technical-papers.

In many countries there can be a marked difference between the posted speed limit and the actual speed of vehicles using the road. This is a function of local behaviour, local enforcement practice and whether the engineering features of the road are designed in accordance with the speed limit, for example the use of traffic calming measures to help manage speeds.

4.1.1 Speed data

For much of the N14 (P158/1) where speed limit signs were observed, vehicle operating speeds often appeared to be in excess of the posted limit.

The method adopted to estimate 85th percentile and mean operating speeds and the assumptions inter alia made are detailed below:

Table 3a: Operating speeds used – Part A (Southbound)

Speed limit	km	%
60km/h	1.30	10
100km/h	11.90	90

Motorcyclist speed limit	km	%
60km/h	1.30	10
100km/h	11.90	90

Truck speed limit	km	%
60km/h	1.30	10
100km/h	11.90	90

Differential speed limits	km	%
Not present	13.20	100

Speed management / traffic calming	km	%
Not present	13.20	100

Operating Speed (85th percentile)	km	%
65km/h	1.30	10
115km/h	11.90	90

Operating Speed (mean)	km	%
55km/h	1.30	10
100km/h	11.90	90

Table 3b: Operating speeds used – Part B (Northbound)

Speed limit	km	%
60km/h	1.00	8
80km/h	2.50	19
100km/h	9.80	74

Motorcyclist speed limit	km	%
60km/h	1.00	8
80km/h	2.50	19
100km/h	9.80	74

Truck speed limit	km	%
40km/h	0.50	4
60km/h	0.50	4
80km/h	2.50	19
100km/h	9.80	74

Differential speed limits	km	%
Not present	11.80	89
Present	1.50	11

Speed management / traffic calming	km	%
Not present	13.30	100

Operating Speed (85th percentile)	km	%
75km/h	1.00	8
95km/h	2.50	19
115km/h	9.80	74

Operating Speed (mean)	km	%
60km/h	1.00	8
80km/h	2.50	19
100km/h	9.80	74

4.2 Traffic flows

4.2.1 Vehicle traffic volumes

Total traffic flow (or volume) for all motorised vehicles is required for the road and is used in the estimation of the distribution of the numbers of deaths and serious injuries that could be prevented on the network. The data is required to be in Annual Average Daily Traffic (AADT) format and should not be adjusted to passenger car equivalent (PCU) volumes.

The AADT for this assessment was provided by the Gauteng provincial roads authority in August 2017 and is shown in Table 4.

Table 4a-1: Vehicle Flow – Part A (Southbound)

Road Section Start	GPS		AADT (vehicles per day)	Distance (km)	%
Part A - 1	-25.76226793	28.18240832	27 000	0,18	1,4%
Part A - 2	-25.76381608	28.18286795	20 000	3,42	25,9%
Part A - 3	-25.78957033	28.18773012	38 299	2,70	20,5%
Part A - 4	-25.81113079	28.18150702	37 293	2,86	21,7%
Part A - 5	-25.8365543	28.18412776	34 952	4,04	30,6%

Note: AADT supplied by Gauteng Provincial Roads Authority.

Table 4a-2: Flow – Part A (Southbound)

Vehicle flow (AADT)	km	%
20000 - 40000	13.20	100

Motorcyclist observed flow	km	%
None	13.20	100

Bicyclist observed flow	km	%
None	13.20	100

Pedestrian observed flow across the road	km	%
None	13.20	100

Pedestrian observed flow along the road driver-side	km	%
None	13.20	100

Pedestrian observed flow along the road passenger-side	km	%
None	12.90	98
1 pedestrian along passenger-side observed	0.30	2

Motorcyclist %	km	%
0	0.20	2
1% - 5%	13.00	98

Pedestrian peak hour flow across the road	km	%
0	11.00	83
1 to 5	1.20	9
6 to 25	1.00	8

Pedestrian peak hour flow along the road driver-side	km	%
0	11.00	83
1 to 5	1.40	11
6 to 25	0.80	6

Pedestrian peak hour flow along the road passenger-side	km	%
0	10.80	82
1 to 5	0.40	3
6 to 25	2.00	15

Bicyclist peak hour flow	km	%
None	13.20	100

Table 4b-1: Vehicle Flow – Part B (Northbound)

Road Section Start	GPS		AADT (vehicles per day)	Distance (km)	%
Part B - 1	-25,8716903	28,17023368	33569	0,32	2,4%
Part B - 2	-25,86906062	28,17090568	32493	5,82	43,9%
Part B - 3	-25,8193341	28,18224217	37727	3,84	29,0%
Part B - 4	-25,78791814	28,1892009	18000	3,06	23,1%
Part B - 5	-25,76425576	28,18279647	27000	0,22	1,7%

Note: AADT supplied by Gauteng Provincial Roads Authority.

Table 4b-2: Flow – Part B (Northbound)

Vehicle flow (AADT)	km	%
15000 - 20000	3.10	23
20000 - 40000	10.20	77

Motorcyclist observed flow	km	%
None	13.20	99
1 motorcycle observed	0.10	1

Bicyclist observed flow	km	%
None	13.30	100

Pedestrian observed flow across the road	km	%
None	13.30	100

Pedestrian observed flow along the road driver-side	km	%
None	13.30	100

Pedestrian observed flow along the road passenger-side	km	%
None	13.20	99
2 to 3 pedestrians along passenger-side observed	0.10	1

Motorcyclist %	km	%
1% - 5%	13.30	100

Pedestrian peak hour flow across the road	km	%
0	9.90	74
1 to 5	3.20	24
6 to 25	0.20	2

Pedestrian peak hour flow along the road driver-side	km	%
0	9.90	74
1 to 5	3.00	23
6 to 25	0.40	3

Pedestrian peak hour flow along the road passenger-side	km	%
0	9.90	74
1 to 5	3.00	23
6 to 25	0.40	3

Bicyclist peak hour flow	km	%
None	13.30	100

4.2.2 Motorcycle volumes

Motorcycle volume data was unavailable for the N14 (P158/1) project and was thus not analysed.

4.2.3 Pedestrian and bicycle flows

Pedestrian and bicycle flows were recorded during the coding process. It is possible to rely solely on this data for processing, though it is not recommended. This is because pedestrian and bicycle flows can be transitory and a one-off visual inspection is unlikely to provide a strong basis for determining overall flows. In this project, pedestrian and bicyclist flows were estimated based on observed flows and the surrounding land use and road attributes in conjunction with the Gauteng Provincial Roads Authority. The approach used for estimating pedestrian along and crossing flows was as follows:

- An estimate was made for each 100 metre segment of road based on adjacent land use and road attributes. See *iRAP 310: A Guide to Producing iRAP Star Ratings and Safer Roads Investment Plans* for further information on estimating flows based on adjacent land use.
- If the estimate was less than the observed flow, then the observed flow was selected. It is noted that from time to time, this step could cause create an artificially high number if an unusually large number of people happened to be observed. However, in the case of South Africa, very high pedestrian movements are not unusual and it is also common that pedestrians walk along rural sections of road.
- The pedestrian flows along the road were 'smoothed' across 500 metre lengths for pedestrians by taking the highest value in that length (pedestrian crossing volumes were not smoothed).

Provision for vulnerable road users (pedestrians) is poor in the sections of road in concern (5.8km or 21.9% of the 26.5km) with no motorcycle or bicycle facilities present and insufficient footpath provision and crossing facilities where pedestrian activities are present.

4.3 Number of deaths

As part of the iRAP model calibration, an estimate of the number of deaths that occur on the road was required. In order to allocate deaths and serious injuries to the network, the iRAP model also requires an estimate of the distribution of deaths by road user type and the ratio of deaths to serious injuries.

The total number of deaths for a three-year period (2015-2017) was 41. The distribution of deaths by road user type are based on the recorded road death data provided and is shown in Table 5 for both Part and B combined. The data in Table 5 is for the study area i.e. for the 26.5 km of the N14 (P158/1).

Table 5: Road deaths by user type (2015-2017)

Year	Vehicle occupant	Motorcyclist	Pedestrian
2015 (Recorded)	10	0	5
2016 (Recorded)	6	0	6
2017 (Estimated)	8	0	6

An estimated ratio for Fatal vs Serious Injury in South Africa of 1:4[3] was used in the analysis

4.4 The economic cost of a death and serious injury

Safer Roads Investment Plans: The iRAP Methodology describes the process used to estimate the economic cost of a road death and a serious injury for iRAP projects. This approach is applied globally by iRAP and is based on research undertaken by McMahon and Dahdah (2008).

The key equations used are:

- the economic cost of a death is estimated to be: 70 x Gross Domestic Product (GDP) per capita (current prices)
- the economic cost of a serious injury is estimated to be: 0.25 x economic cost of a death.

The global iRAP estimates were however not used in the analysis due to RTMC having calculated the economic cost of crashes in South Africa published in September 2016[3]. The following estimated economic costs of fatalities and serious injuries were used in the analysis (adjusted with +6% per year):

- the economic cost of a death is estimated to be ZAR 4,664,241.
- the economic cost of a serious injury is estimated to be ZAR 504,821.

To calculate present value costs and benefits, a discount rate of 12% was used.

4.5 Countermeasure costs

The iRAP model requires the input of local construction and maintenance costs for each of the 93 countermeasures that are considered in the development of the Safer Roads Investment Plans. The estimated costs are categorised by area type (urban and rural) and upper and lower costs (low, medium and high), based on the extent to which the surrounding land use and physical environment impacts upon the construction cost of major works. This means that up to six different costs can be assigned to the same countermeasure treatment, although for some countermeasures the costs may be the same regardless of area type and environment.

The countermeasure costs used in this study were based on estimates calculated by engineering staff from LEA Associates South Asia Pvt. Ltd. (LASA) who are currently working as consulting engineers with the Roads & Buildings Department, Government of Gujarat and converted into ZAR. Indian countermeasures costs were used in this project due to similarities in the economies between India and South Africa. The full data set for the study is available in the iRAP online software http://vida.irap.org/.

5 Star Ratings

iRAP Star Ratings are based on road infrastructure features and the degree to which they impact the likelihood and severity of road crashes. The focus is on the features which influence the most common and severe types of crash on roads for motor vehicles, motorcyclists, pedestrians and bicyclists. They provide a simple and objective measure of the relative level of risk associated with road infrastructure for an individual road user. 5-star (green) roads are the safest, while 1-star (black) roads are the least safe. Star Ratings were not assigned to roads where there was very low use by that type of road user. For example, if no bicyclists use a section of road, then a bicyclist Star Rating is not assigned to it.

The Star Ratings are based on Star Rating Scores (SRS). The iRAP models are used to calculate an SRS at 100 metre intervals for each of the four road user types, based on relative risk factors for each of the road attributes. The scores are developed by combining relative risk factors using a multiplicative model. More information on the risk factors used within the model can be found within the Methodology Documents at www.irap.org.

5.1 Smoothed Star Ratings

A Star Rating Score (SRS) is calculated for each 100 metre segment of road for vehicles occupants, motorcyclists, pedestrians and bicyclists. These scores are then allocated to Star Rating bands to determine the Star Rating for each 100 metre of road. However, for the purposes of producing a network level map showing Star Ratings, 100 metres is too much detail. Hence, Star Ratings are smoothed (or averaged) over longer lengths in order to produce more meaningful results. The effect of smoothing is illustrated in the charts below, which shows unsmoothed (raw) Star Rating Scores (SRS) in blue and smoothed SRS in white.

Figure 6a: Raw Star Rating Scores (blue) and smoothed SRS (white) – Part A

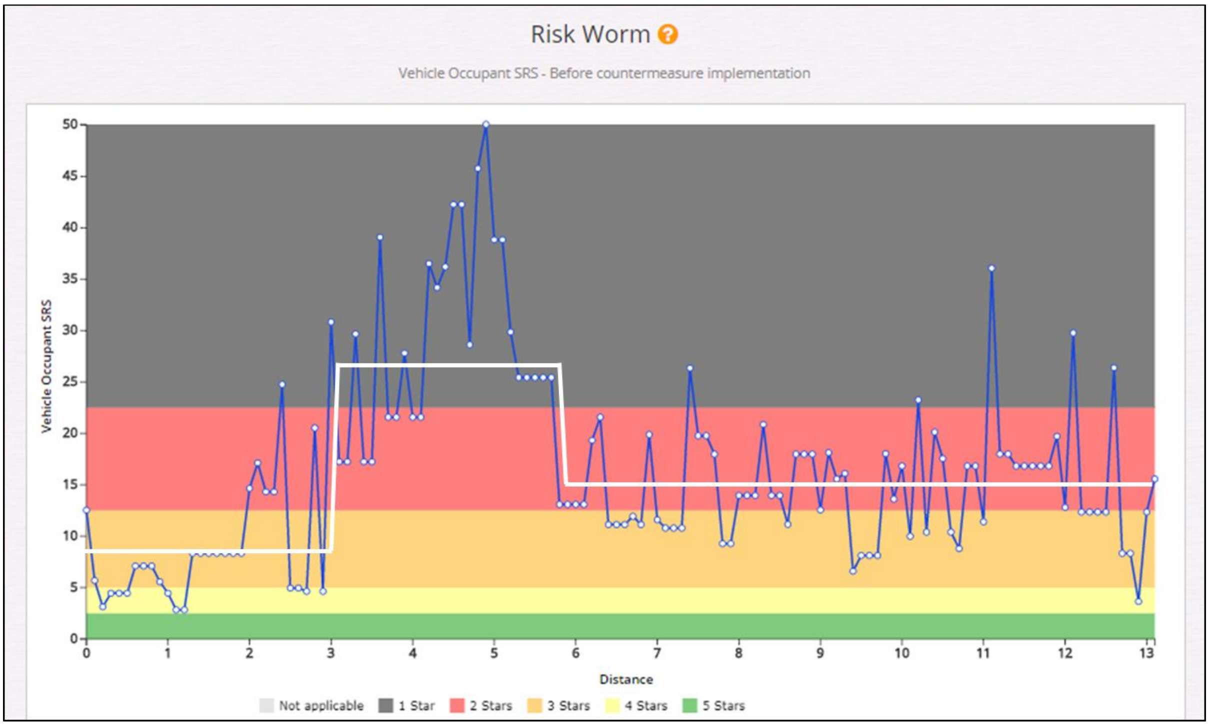
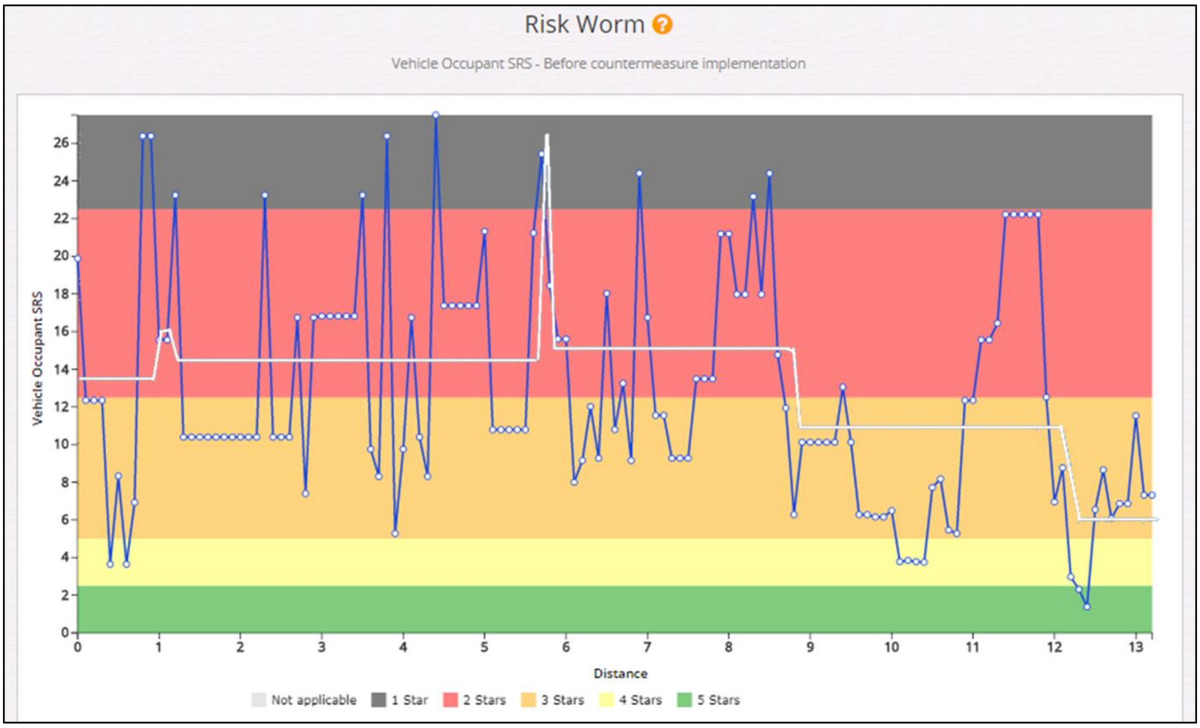


Figure 6b: Raw Star Rating Scores (blue) and smoothed SRS (white) – Part B



5.2 Star Rating results

The Star Rating results for the N14 (P158/1) project demonstrate that there is potential to improve the safety of road infrastructure for all users. High-risk road sections feature significantly in the results with the majority of the surveyed road rated 2-stars or less (out of a possible of 5-stars) for all road user types.

The star ratings show that:

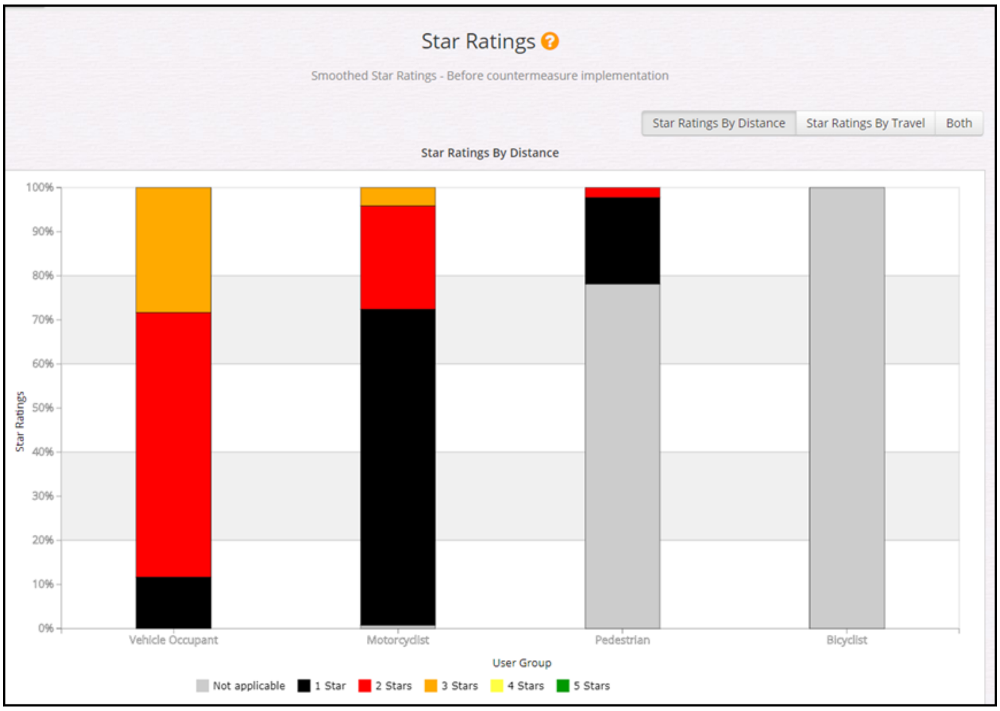
- For vehicle occupants, 0% of road length is rated as 4- or 5-star, 28.3% of road length is rated as 3-star, and remaining is rated as 2-star and below.
- For pedestrians 0% of the road length is rated as 3-star or above, 2.26% of road length is rated as 2-star and 19.62% of the 5.8 km road length where pedestrians are active is rated 1-star. Provision for pedestrians are poor in the sections of road in concern and insufficient footpath provision and crossing facilities where pedestrians are activitie.

Table 6 : Star Ratings Table, N14 (P158/1) – Dual Carriageways (Part A and B Combined)

	Vehicle Occupants		Pedestrians	
Star Ratings	Length (km)	Percent	Length (km)	Percent
5 Stars	0	0%	0	0%
4 Stars	0	0%	0	0%
3 Stars	7.5	28.30%	0	0%
2 Stars	15.9	60.00%	0.6	2.26%
1 Star	3.1	11.70%	5.2	19.62%
Not applicable	0	0%	20.7	78.11%
Totals	26.5	100%	26.5	100%

Note: the table shows 'smoothed' Star Ratings.

Figure 7: Star Ratings Graph, N14 (P158/1) – Part A and B Combined



5.3 Star Rating maps

The following images show the Star Rating maps for vehicle occupants and pedestrians. The maps show how road user risk can change along a route based on the safety aspects provided by the road infrastructure and can be used to identify the high-risk areas for priority treatment.

Figure 8a: Vehicle occupant Star Ratings (Part A)

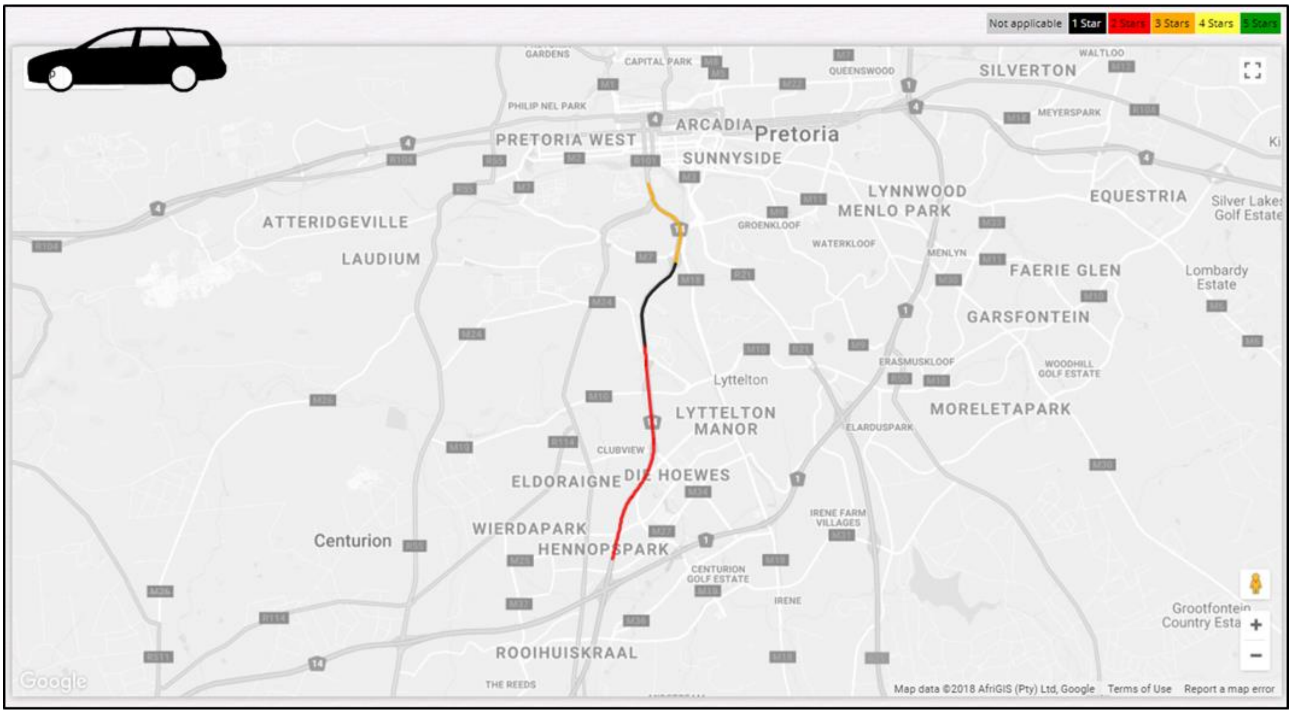


Figure 8b: Pedestrian Star Ratings (Part A)

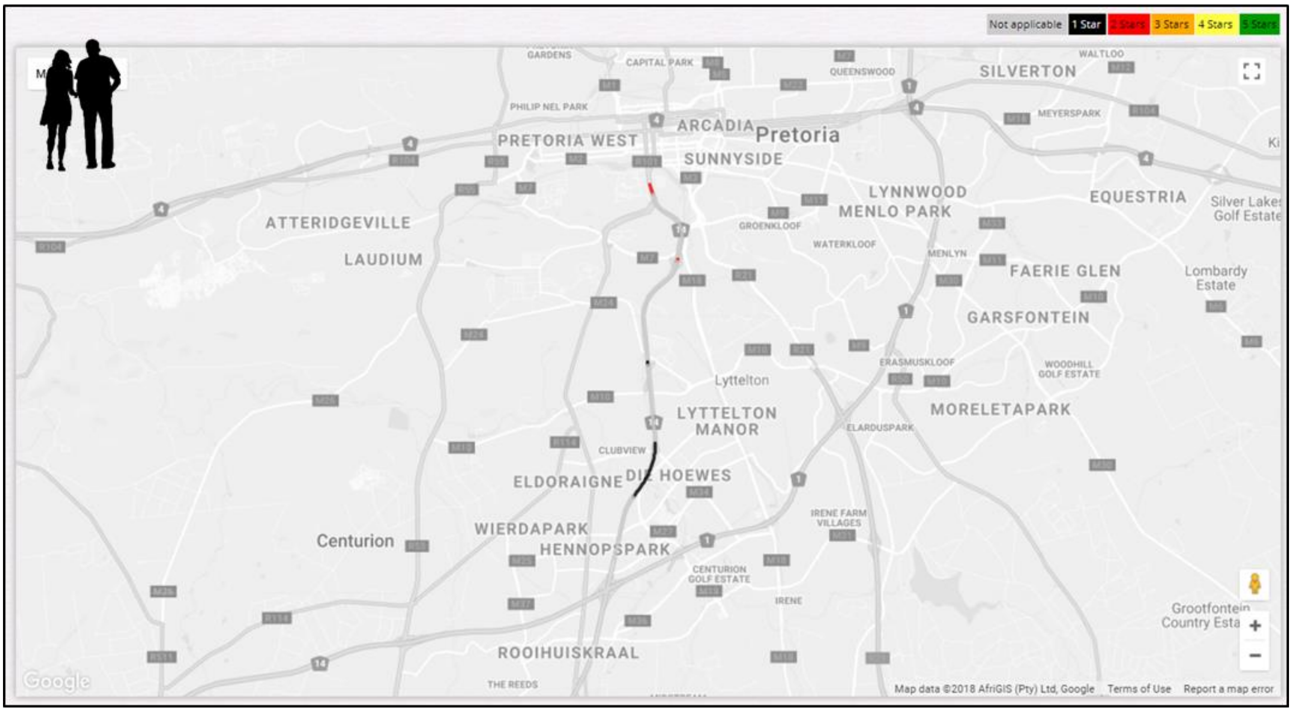


Figure 9a: Vehicle occupant Star Ratings (Part B)

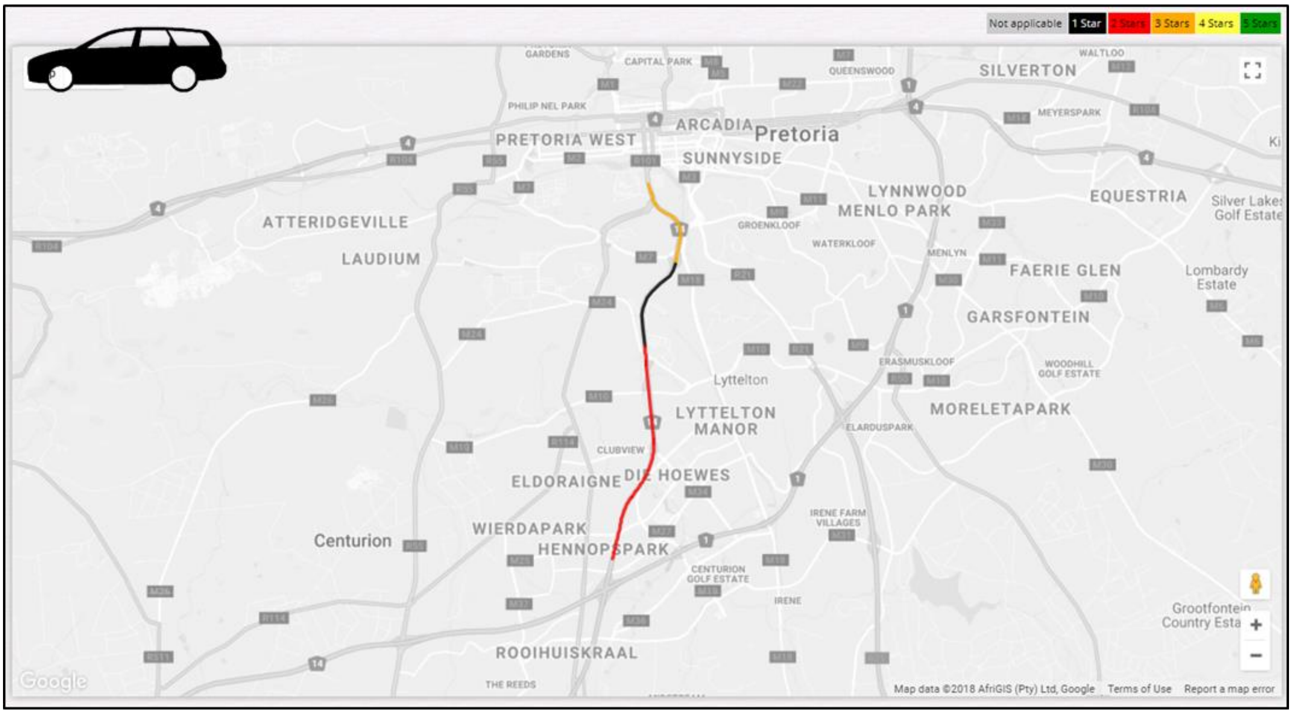
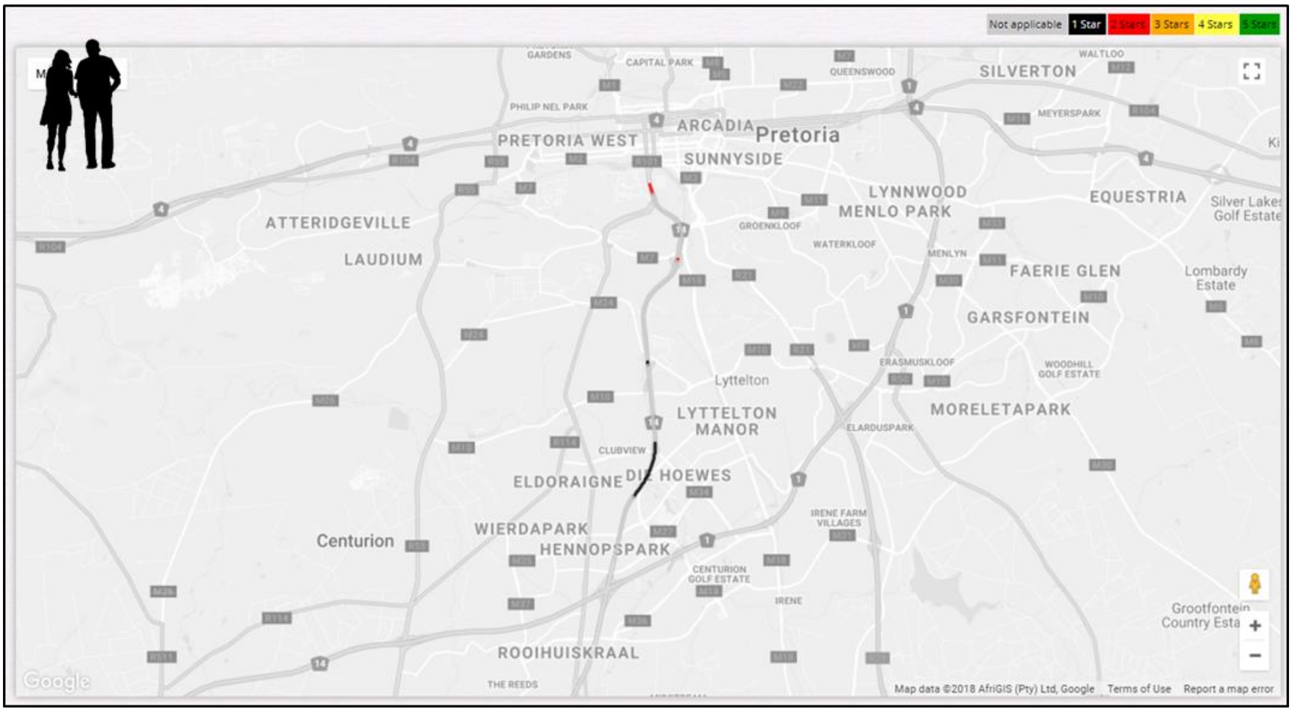


Figure 9b: Pedestrian Star Ratings (Part B)



6 Safer Roads Investment Plans

iRAP considers more than 90 proven road improvement options to generate affordable and economically sound Safer Road Investment Plans (SRIP) that will save lives. Road improvement options range from low-cost road markings and pedestrian refuges to higher-cost intersection upgrades and full highway duplication.

Plans are developed in three key steps:

1. Drawing on the Star Ratings and traffic volume data, estimated numbers of deaths and serious injuries are distributed across the road network.

2. For each 100 metre segment of road, countermeasure options are tested for their potential to reduce deaths and injuries. For example, a section of road that has a poor pedestrian Star Rating and high pedestrian activity might be a candidate for a footpath or pedestrian crossing facility.

3. Each countermeasure option is assessed against affordability and economic effectiveness criteria. The economic benefit of a countermeasure (measured in terms of the economic benefit of the deaths and serious injuries prevented) must, at a minimum, exceed the cost of its construction and maintenance (that is, it must have a benefit cost ratio (BCR) greater than one). In many circumstances, the 'threshold' BCR for a plan is lifted above one, which has the effect of reducing the overall cost of the plan. This helps to ensure that the plan is affordable while representing a positive return on investment and the responsible use of public money.

The SRIP shows a list of affordable and economically sound road safety treatments, specifically tailored to reduce risk on the N14 (P158/1). Each countermeasure proposed in the SRIPs is supported by strong evidence that, if implemented, it will prevent deaths and serious injuries in a cost-effective way). Nevertheless, each countermeasure should be subject to additional prioritisation, concept planning and detailed design before implementation.

Three SRIP options were produced to prioritise countermeasure options that could maximise the prevention of deaths and serious injuries within the available budget. The plans largely focus on:

- reducing risk at intersections
- reducing the risk associated with run-off road crashes by improving shoulders and reducing the severity of roadsides
- providing facilities for pedestrians.

Plan 1 was produced using a threshold BCR of 1 (that is, the economic benefit of each countermeasure must be at least greater than the cost), Plan 2 was produced using a threshold BCR of 3 (economic benefit of each countermeasure must exceed 3 times the cost) and Plan 3 with a threshold BCR of 5. An overview of the three plans are provided in Table 7a below.

Table 7a: Investment plan options (20 years)

	Plan 1	Plan 2	Plan 3
Present value of investment	ZAR 37.9 million	ZAR 23.8 million	ZAR 20.4 million
Deaths and serious injuries prevented	746	727	731
Present value of safety benefits	ZAR 372.5 million	ZAR 363.1 million	ZAR 364.9 million
Cost per death and serious injury prevented	ZAR 50,856	ZAR 32,747	ZAR 27,893
Benefit cost ratio (BCR)	10:1	15:1	18:1
Reduction in death and serious injuries	54.6%	53.2%	53.5%

The most comprehensive SRIP (Plan 1) shows that, by investing ZAR 37.9 million over a 20 year period, the number of deaths and serious injuries on the road could be reduced by 54.6%, preventing more than 746 deaths and serious injuries over 20 years. The overall benefit cost ratio of this approach would be 10:1. Plan 2 shows that, by investing ZAR 23.8 million, the number of deaths and serious injuries on the road could be reduced by 53.2%, preventing more than 727 deaths and serious injuries over 20 years. The overall benefit cost ratio of this approach would be 15:1.

The most viable of the plans (Plan 3) shows that by investing ZAR 20.4 million, the number of deaths and serious injuries on the road could be reduced by 53.5%, preventing more than 731 deaths and serious injuries over 20 years. The overall benefit cost ratio of this approach would be 18:1.

In total, ten investment plans were produced ranging from Plan 1 with a threshold BCR of 1 (that is, the economic benefit of each countermeasure must be at least greater than the cost) up to Plan 10 with a threshold BCR of 20 (that is, the economic benefit of each countermeasure must exceed 20 times the cost). Plan 3 provided the largest %FSI reduction in relation to the estimated cost over 20 years vs minimum present value of investment (ZAR 20.4 million); the ten plans are summarized in Table 7b below:

Table 7b: Summary - Safer Road Investment Plans1 to 10 - (Part A and B Combined)

Plan	BCR Qualification Value	Total FSIs Saved	Total PV of Safety Benefits	Estimated Cost	Cost per FSI saved	Program BCR	% Reduction FSI
Plan1	1	746	372 469 429	37 943 551	50 856	10	54,6%
Plan2	3	727	363 110 782	23 818 843	32 747	15	53,2%
Plan3	5	731	364 896 134	20 388 086	27 893	18	53,5%
Plan4	7	729	364 171 211	19 597 231	26 865	19	53,3%
Plan5	9	687	343 059 777	16 413 537	23 885	21	50,3%
Plan6	11	667	332 895 954	15 154 453	22 726	22	48,8%
Plan7	13	598	298 417 493	11 978 355	20 039	25	43,8%
Plan8	15	574	286 486 462	11 005 919	19 179	26	42,0%
Plan9	17	556	277 403 813	10 342 220	18 612	27	40,7%
Plan10	20	512	255 752 964	8 935 387	17 442	29	37,5%

The list of countermeasures shown in each of the plans suggest that significant safety improvements can be made to the N14 (P158/1) through the implementation of several key safety treatments. Countermeasure treatments such as central median barrier (some form of physical median to prevent head-on collisions). Roadside improvements such as hazard removal and the implementation of roadside safety barriers could reduce run-off the road fatal and injuries. Countermeasures focused on reducing risk for vulnerable users are also estimated and available in VIDA.

The countermeasures identified in Plan 3 are shown in Table 8; countermeasures for Plan 1 and Plan 2 are available in ViDA

Table 8: Safer Road Investment Plan 3 - (Part A and B Combined)

Total FSIs Saved	Total PV of Safety Benefits	Estimated Cost	Cost per FSI saved	Program BCR
731	364 896 134	20 388 086	27 893	18

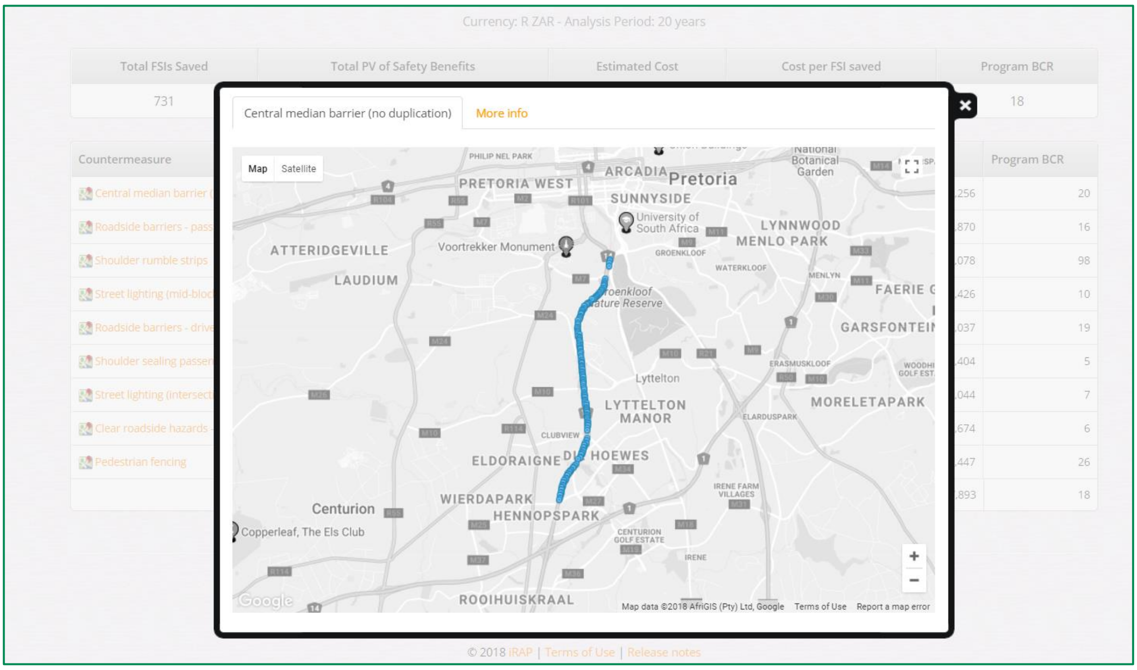
Countermeasure	Length / Sites	FSIs saved	PV of safety benefit	Estimated Cost	Cost per FSI saved	Program BCR
Central median barrier (no duplication)	16.70 km	274,0	136 991 878	6 930 592	25 256	20
Roadside barriers - passenger side	12.70 km	174,0	86 671 087	5 533 012	3 187	16
Shoulder rumble strips	25.20 km	122,0	60 972 844	620 235	5 078	98
Street lighting (mid-block)	5.00 km	111,0	55 217 373	5 466 873	49 426	10
Roadside barriers - driver side	2.20 km	42,0	20 804 303	1 085 037	26 037	19
Shoulder sealing passenger side (>1m)	0.90 km	4,0	2 243 568	482 686	107 404	5
Street lighting (intersection)	1 site	3,0	1 302 765	174 956	67 044	7
Clear roadside hazards - passenger side	0.30 km	1,0	518 346	87 918	84 674	6
Pedestrian fencing	0.20 km	0,0	173 969	6 777	19 447	26
Totals		731,0	364 896 134	20 388 086	27 893	18

FSI = fatal and seriously injured

BCR = benefit cost ratio

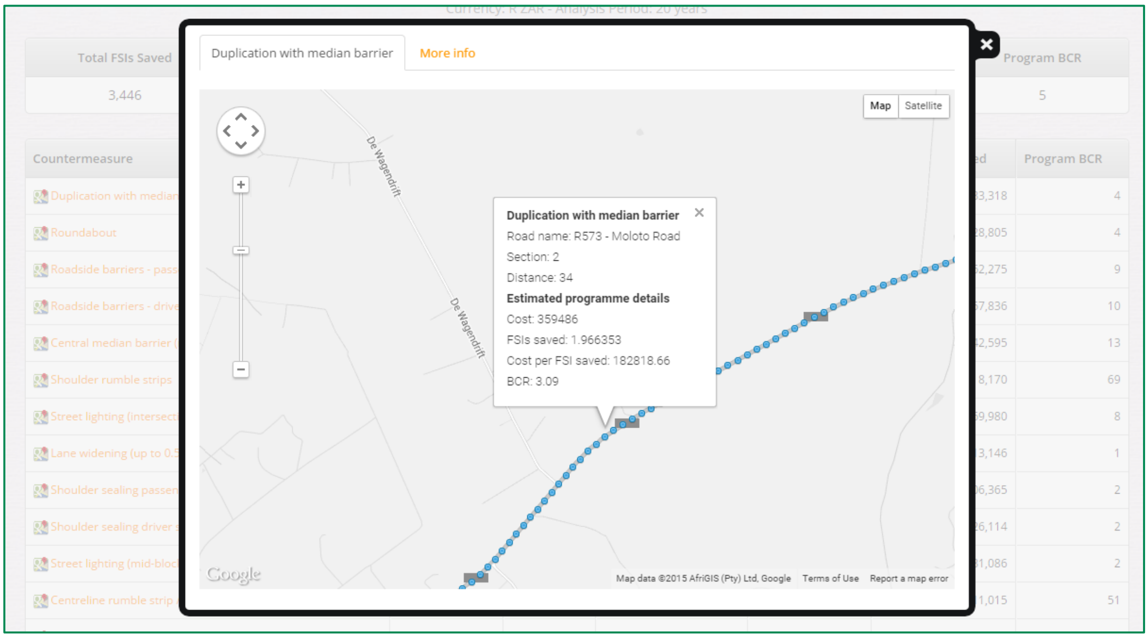
Maps showing the location of each countermeasure listed within the Safer Roads Investment Plan (Plan 3) can be accessed through the SRIP Table within ViDA as shown in Figure 21.

Figure 21: Map showing location of a treatment (Central median barrier (no duplication))



Full details of each recommended countermeasure, including location description, geo-reference data and economics is provided by clicking on an individual icon as shown in Figure 22. Strip plans showing the location, by distance, of up to five recommended countermeasures for each road section, are also available within ViDA, the iRAP online software at http://vida.irap.org/.

Figure 22: Individual countermeasure details



Descriptions of these countermeasures, and many other road safety treatments, including advice on implementation issues and crash reduction effectiveness can be found at the Road Safety Toolkit http://toolkit.irap.org.

6.1 Star Ratings after countermeasure implementation

The Star Rating (After) table provides details of the projected Star Ratings based on the countermeasures within Plan 3. The Star Rating (After) table shown below provides the percentage change for each star rating category relative to the original Star Rating.

Table 9 : Star Ratings After (smoothed) – Part A and Part B Combined

Road User	Vehicle Occupants			Pedestrians		
	Length (km)	Percent	Change	Length (km)	Percent	Change
5 Star	3,1	11,70%	11,70%	0	0,00%	0,00%
4 Star	20,3	76,60%	76,60%	0	0,00%	0,00%
3 Star	3	11,32%	-16,98%	0	0,00%	0,00%
2 Star	0,1	0,38%	-59,62%	0,6	2,26%	0,00%
1 Star	0	0,00%	-11,70%	5,2	19,62%	0,00%
Not applicable	0	0,00%	0,00%	20,7	78,11%	0,00%

Analysis of the projected Star Ratings after implementation of Plan 3 shows that it is economically viable to increase almost the entire length of road (both Part A and Part B) rated at 3-star and above for the vehicle occupants. Due to the level of the road i.e. a National dual carriageway with high traffic volumes and numerous lanes across both carriageways. Due to the low pedestrian flow, a grade-separated pedestrian crossing as countermeasure did not trigger in the VIDA analysis due to it not being economically feasible with not adequate return on investment. Pedestrian activity need to be addressed separate from this analysis by means of either education and/or law enforcement.

The Star Ratings (after – with proposed countermeasures) for Plan 1 and Plan 2 are available in ViDA.

6.2 Economic assessment

Using actual crash data, an estimate of the number of deaths and serious injuries that occur on the surveyed sections of road were made. Crash modification factors were then used to provide an estimate of the number of road deaths and serious injuries that are likely to be prevented through the infrastructure improvements that are proposed in each investment plan. More information on the crash modification factors used in the model is available in the iRAP Road Attribute Risk Factor factsheets in the Documents section of the iRAP website at: http://irap.org/about-irap-3/methodology.

It is important to ensure that improvements such as lane widening, resurfacing, additional lanes and paved shoulders do not result in excessive vehicle speeds, particularly where vulnerable road users such as pedestrians are present. In such cases vehicle speeds must be effectively managed in order to minimise risk.

Assuming that the proposed countermeasures (Plan 3) do not lead to an increase in vehicle operating speeds, it is estimated that fatal and serious injuries (FSIs) are likely to reduce by 53.4%, preventing an estimated 36 deaths and serious injuries each year and an estimated to 731 deaths and serious injuries over 20 years.

Table 10: Economic analysis

Economic Analysis: N14 (P158/1) - Plan 3 – Part A and B Combined			
Road length		26.5 km	
Investment		ZAR 20.4 million	
Economic benefit (20 years)		ZAR 364.9 million	
Benefit cost ratio (BCR)		18:1	
Deaths and serious injuries	Deaths (per year)	Deaths and serious injuries (per year)	Deaths and serious injuries (20 years)
Before countermeasures	*13*	*68*	*1,367*
After countermeasures	*8*	*32*	*636*
Prevented	*5*	*36*	*731*
Reduction		53.4%	
Cost per death and serious injury prevented		ZAR 27,893	

It is estimated that the economic benefits of a reduction in the numbers of deaths and serious injuries from 68 to 32 per year, as seen in Plan 3, would total approximately ZAR 18.2 million per year in crash costs saved.

Thus, with an investment of ZAR 20.4 million, to improve road safety on the 26.5 km of the N14(P158/1) in year 1, ZAR 18.2 million or 89.4% of the investment cost will be saved in year 2 due to the predicted saving in the economic cost of crashes.

7 Implementation and recommendations

The N14 (P158/1) survey successfully assessed 26.5 kilometres of road and generated Star Ratings for vehicle occupants and pedestrians. The Star Rating results show that road infrastructure poses a relatively high risk for all users.

The road attribute data shows that the N14 (P158/1) is a dual carriageway road with only 63% having central median barrier between opposing flows. Roadside hazards are numerous, with sections of the survey length having hazardous objects within 5m of the running lane and limited roadside protection. Provision for vulnerable road users is poor.

The available data from a road assessment such as this provides extensive planning and engineering information such as road attribute records, road user risk, countermeasure proposals and economic assessments for 100 metre sections of road network. The assessments are supported by the iRAP online software which makes this information highly accessible. Each countermeasure proposed in a SRIP is backed by strong evidence that, if implemented, it will prevent deaths and serious injuries in a cost-effective way.

Nevertheless, in interpreting the results of this report, it is important to recognise that iRAP is designed to provide a network-level assessment of risk and cost-effective countermeasures. As such, a SRIP should be considered just the first step in ensuring a safe road. For this reason, implementation of the proposals in this report will ideally include the following steps:

- local examination of proposed countermeasures (including a 'value engineering' type workshop including all relevant stakeholders)
- detailed analysis of available traffic survey and crash data
- preliminary scheme investigation studies, including site surveys and preliminary design
- detailed design, star ratings of the designs, road safety audit, detailed costing and procurement, final evaluation and construction
- post-construction evaluation and road safety audit, including Star Ratings for the upgraded road and analysis of crash data.

The detailed results of the project and access to the iRAP online software (http://vida.irap.org) have been provided to key stakeholders for further exploration and use.

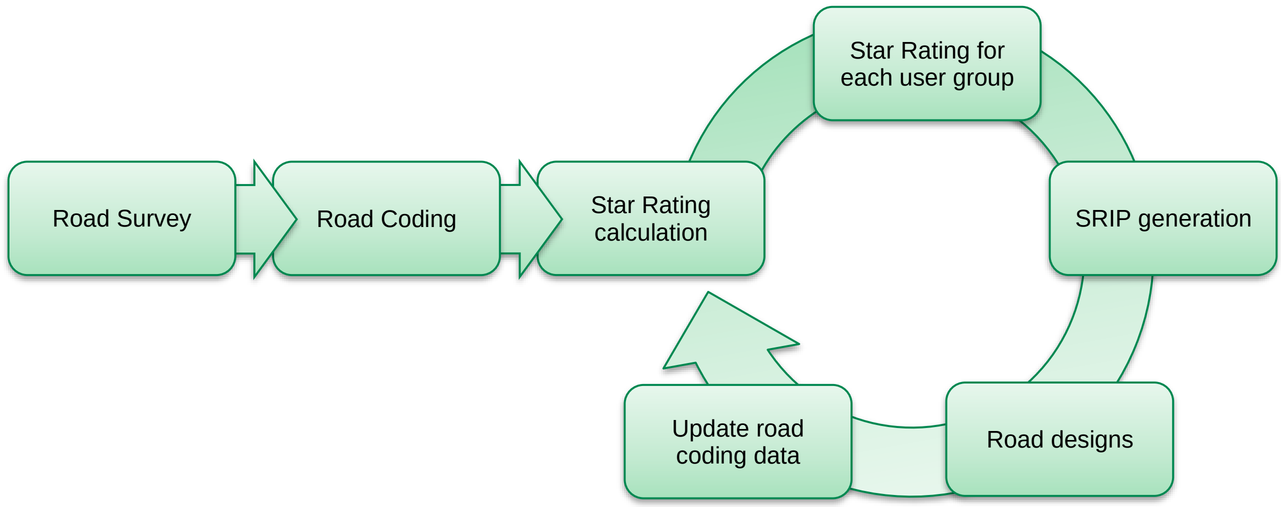
The findings and recommendations of this report was corroborated by the RTMC with the Gauteng provincial road authority and the Gauteng provincial road authority will use this report as a scientific base when designing countermeasures on the sections of road in concern.

7.1 Star Rating designs

A number of countries around the world are now using Star Ratings during the road design process to help ensure that safety of designs is optimized. Star Ratings can objectively quantify the level of risk associated with new road designs and provide a platform to make evidence-based improvements.

The iterative star rating process is shown in Figure 14 below:

Figure 14: Using Star Ratings to improve road designs - process diagram



By engaging consultants to Star Rate proposed designs, the road authorities are able to assess the potential risk to road users prior to construction and amend the designs to include recommended treatments that are proven to reduce the likelihood and severity of road crashes.

As an example of such a process, see the *Star Rating Road Designs: Performance Indicators for Roads in India* report for further information regarding the star rating of new road designs http://www.irap.net/about-irap-3/research-and-technical-papers?download=64:star-rating-road-designs-performance-indicators-roads-in-india.

7.2 Commit to a Safe System approach

The investment plans contain infrastructure improvements that can be set in place immediately. To complement those improvements, a series of additional measures need to be implemented, and a longer-term safety strategy set in place.

The Safe System approach is based on the theory that all humans make mistakes, but that a mistake made on the highway should not result in death or serious injury. It recognises that the human body is vulnerable and is unlikely to survive an un-cushioned impact at speeds of 30km/h or more.

When these occasional, but inevitable mistakes occur on our busy roads, it stands to reason that collisions or crashes will result. Currently some of these collisions have fatal consequences, and others are less severe. The Safe System provides a forgiving highway infrastructure, one which recognises that mistakes will be made and attempts to minimise their occurrence, and the forces involved in a resulting crash, to reduce its severity to survivable levels.

The Safe System approach includes engineering measures such as the removal or protection of roadside hazards, the re-design of roads, roadsides and intersections to reduce risk to a minimum and the setting of appropriate speed limits according to the existing levels of infrastructure safety. The adoption of this approach is recommended.

7.3 Engage with local communities

In order to maximise the benefits from road safety projects it is recommended that public participation is encouraged. Community engagement and cooperation between road authority and local interest groups is regarded as providing a useful two-way flow of information that will not only educate and inform local road users and communities on how they are expected to use the road network, but can also provide designers and decision makers with an understanding of the needs and requirements of affected groups. For example, research has demonstrated that it is crucial to ensure that local communities not only have the opportunity to contribute to new road designs but that they also understand the intended use of various road design features.[8]

Star Ratings can be used to effectively communicate the need for safe road design, not only within road authorises, but also to local residents and other stakeholders. Using Star Ratings will allow opportunities to celebrate success i.e. Ministers, local politicians, and/or road authorities can celebrate road safety upgrades “1-star road upgraded to 3-star standard” etc.

In addition to the road safety engineering upgrades, significant benefits could also be realised through the coordinated targeting of behavioural risk factors for road users (such as speeding, seat belt wearing, helmet use, the adherence to traffic regulations and alcohol use) and road vehicle safety (i.e. ABS brakes, side-impact bars and airbags). This would be consistent with taking a Safe System approach to the programme. The Road Safety Toolkit (toolkit.irap.org) and United Nations Road Safety Collaboration Good Practice Manuals provide further information on these issues.[9]

[8] BRAC Annual Report 2009 http://www.brac.net/

[9] UN Road Safety Collaboration manuals: http://www.who.int/roadsafety/projects/manuals/en/index.html

7.4 Set policy targets

With the increasing death toll on the South African road network it is strongly recommended that the Government set policy targets to stabilise and then reduce the forecasted level of road traffic fatalities in line with the recommendations discussed in the *Global Plan for the Decade of Action for Road Safety 2011-2020*. Recommendations include:

- Set a target to eliminate high-risk (1- and 2-star) roads by the end of the Decade of Action for Road Safety (2020).
- Set minimum Star Ratings for all new road designs to ensure that no more 'killer roads' are built. For example, adopt the policy that all new roads shall be built to a minimum 3-star standard for all road users.
- iRAP Star Rating and Investment Plans for the highest risk or highest volume 10% of roads in the state.

For further information on the setting of road safety policy targets, the development of local and national action plans and implementing sustainable road safety strategies, refer to the *Global Plan for the Decade of Action for Road Safety 2011-2020*.

8 References

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