EuroRAP Portugal – EN-118

Preliminary Technical Report

November - 2016

EuroRAP

About EuroRAP

The European Road Assessment Programme (EuroRAP) is an international not for profit association set up in 1999 and registered in Belgium that is dedicated to saving lives through safer roads.

EuroRAP 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.

Road Assessment Programmes (RAPs) is now active in more than 70 countries throughout Europe, Asia Pacific, North, Central and South America and Africa.

EuroRAP is financially supported by the FIA Foundation, the International Road Assessment Programme (EuroRAP) and the European vehicle manufacturers' association (ACEA).

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 EuroRAP. In addition, many individuals donate their time and expertise to support EuroRAP.

For more information

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Executive summary

Worldwide, some 1.3 million people are killed in road crashes each year. In a reflection of the significant social and economic impact of road crashes, the United Nations has declared that 2011-2020 will be the Decade of Action for Road Safety. It is expected that during the decade, significant efforts will be made to improve road infrastructure, road user behaviour and vehicle safety.

Portugal experiences approximately 122,800 road accidents in 2015 including 478 fatalities and 2,206 seriously injured [Autoridade Nacional Segurança Rodoviária (ANSR), 2015]. Hence, this situation is likely to persist unless commensurate road safety efforts are made.

In 2016, Portuguese public administrations with the support of Automóvel Club de Portugal (ACP) took the decision to undertake this evaluation in cooperation with EuroRAP. EuroRAP's vision is a "world free of high-risk roads", and this helped shape the approach taken in this project. The road network included in the evaluation consists of EN-118 road (194km).

This road inspection would serve as a pilot project to demonstrate the potential of road safety prevention. EuroRAP Road Protection Scores and Star Ratings based on detailed inspection and assessment of 50 road features at 100m intervals indicate that there are significant opportunities for improvement on the demonstration corridor. The majority of the road stretches are rated 2 or 3 stars (out of a possible of 5 stars) for vehicle occupants and motorcyclists. A programme of countermeasures has been developed to reduce deaths and serious injuries.

The overall EuroRAP Safer Roads Investment Plan identified in this project largely focus on:

- Reducing the likelihood and severity of run-off-road by installing roadside barriers, widening shoulders, removing roadside hazards and improving delineation.
- Reducing the likelihood of head-on crashes by implementing central hatching and improving sight distances.
- Signalizing intersections.

A series of investment options were generated for the EN-118 road in Portugal, and resultant reductions in deaths and serious injuries were estimated. An investment of € 8.72 million (Option A) would generate an economic benefit of € 49.6 million over 20 years, resulting in a benefit cost ratio of 6:1. This plan would result in a 26.5% reduction in deaths and serious injuries on the study road. An investment of € 4.36 million (Option B) would generate an economic benefit of € 35.6 million over 20 years, resulting in a benefit cost ratio of 8:1. This plan would result in a 19% reduction in deaths and serious injuries on the EN 118 road. Finally, an investment of € 1.51 million (Option C) would generate an economic benefit of € 21.9 million over 20 years, resulting in a benefit cost ratio of 14:1. This plan would result in a 12% reduction in deaths and serious injuries on the network.

	Option A	Option B	Option C
Minimum benefit cost ratio	3	5	8
Investment (M €)	8,731,638	4,366,898	1,508,225
Economic benefit 20 years (M €)	49,600,088	35,646,962	21,954,477
Programme benefit cost ratio	6	8	14
Deaths (per year)			
Before countermeasures	7.3	7.3	7.3
After countermeasures	5.3	5.9	6.4
Prevented	2.0	1.4	0.9
Reduction	26.5%	19%	12%
Deaths and serious injuries (20 years)			
Before countermeasures	430	430	430
After countermeasures	315	348	379
Prevented	115	82	51
Reduction	26.5%	19%	12%
Cost per death and serious injury prevented	75,927€	53,254€	29,573€

The analysis and results in this report are presented for discussion. It is anticipated that, after consultation on the report has occurred, the results will be amended based on the advice received. As part of this process, the detailed results of the project and online software that enabled the EuroRAP analyses to be undertaken will be made available to stakeholders for further exploration and use.

Apart from making recommendations about road safety countermeasures, this report also makes recommendations that relate to the implementation of EuroRAP in Portugal, including the establishment of an EuroRAP project implementation unit within the Autoridade Nacional Segurança Rodoviária (ANSR) and application of EuroRAP assessments and improvements to the study road.

Overall, this project has show how the application of EuroRAP in Portugal can assist in the prevention of deaths and serious injuries.

1 Introduction

Deaths and injuries from road traffic crashes are a major and growing public health epidemic. Each year 1.3 million people die and a further 50 million are injured or permanently disabled in road crashes throughout the world. Road crashes are now the leading cause of death for children and young people aged between 15 and 29. The burden of road crashes is comparable with malaria and tuberculosis and costs 1 to 3% of the world's GDP.

The European Road Assessment Programme (EuroRAP) has drawn upon the extensive knowledge base of established Road Assessment Programmes (AusRAP and usRAP), with the generous support of the FIA Foundation and ACEA, to target high-risk roads where large numbers of people are killed and seriously injured and inspect them to identify where affordable programmes of safety engineering can reduce death and injury. EuroRAP's vision is a "world free of high-risk roads", and this helped shape the approach taken in this project. The road network included in the evaluation consists of EN-118 road which includes about 200 km.

This report presents the study methodology, detailed condition reports, Star Ratings, and Safer Roads Investments Plans. The report also includes discussion on implementation of proposed road safety countermeasures and a series of recommendations.

1.1 Methodology

EuroRAP uses globally consistent models to produce motor vehicle occupant, motorcyclist, pedestrian and bicyclist Star Ratings and Safer Roads Investment Plans. The methodology for each of these is described in

- Star Rating Roads for Safety: The EuroRAP Methodology.
- Safer Roads Investment Plans: The EuroRAP Methodology.

Further information is available at:

http://www.eurorap.org/protocols/star-ratings

http://www.eurorap.org/protocols/safer-roads-investment-plans.

1.2 Results Online

This report provides an overview of the results produced in the project. Full results, including data tables, interactive maps and download files, as well as data underpinning the analyses, are available in the EuroRAP online software at https://vida.irap.org/en-gb/results/star_rating/map.

Stakeholders in Portugal will have access to this EuroRAP online software, which enables examination of risk factors and countermeasure triggers. Access to the EuroRAP online software is protected with password access. For further information about using the software, contact Marc Figuls at marc.figuls@racc.es.

Results Online

Web address: https://vida.irap.org/en-gb/results/star_rating/map

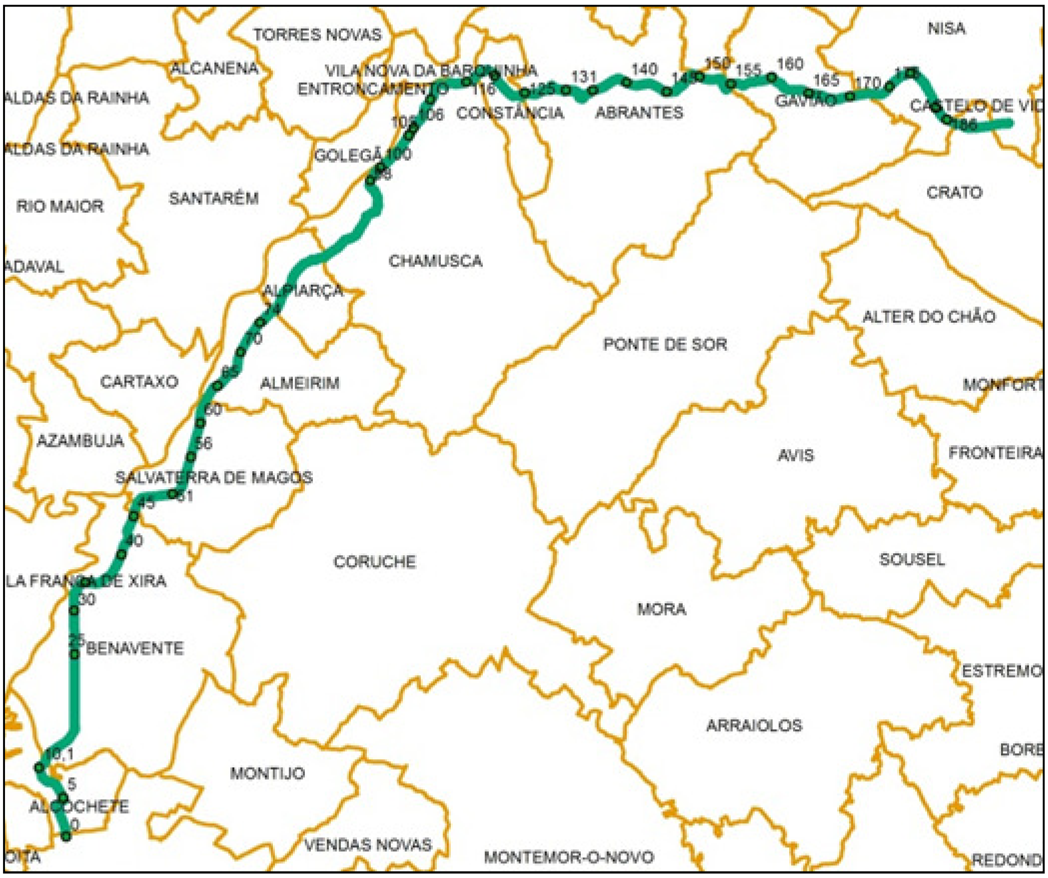
Username: To be provided

Password: To be provided

2 Pilot project and data

The EuroRAP project focused on a pilot project of 194 km of EN-118 from Montijo to Alpalhao, which were selected by the Autoridade Nacional Segurança Rodoviária (ANSR) for inclusion in the study. The study network includes 7.30km of divided carriageway and 187.10km of undivided single-carriageway road. Figure 2.1 shows the location and extent of the EuroRAP network.

Figure 2.1: EN-118 road included in the EuroRAP study for Portugal

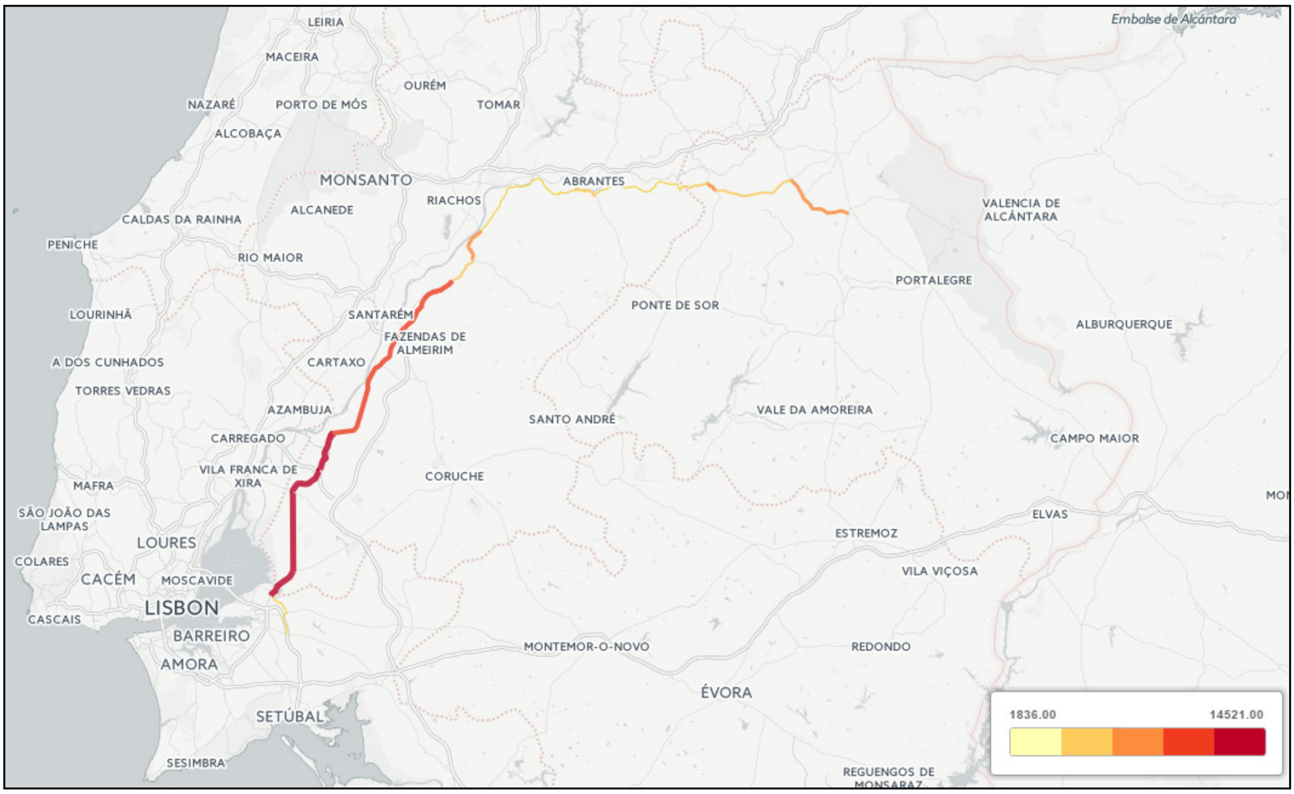


In addition, RACC has integrated external data that can provide to the project:

- Mapping of annual average daily traffic (AADT) data: using ANSR's data.

  https://martivila.carto.com/viz/ef12a908-8efd-11e6-90da-0e3ff518bd15/public_map

Figure 2.2: AADT for different segments for EN-118 road



3 Road inspections and Rating

Using a specially equipped vehicle, software, and trained coders and analysts, EuroRAP inspects and rates roads, focusing on 50 road features relating to the likelihood of a crash and its severity. These road features include, among others, intersection design, road cross-section and pavement markings, roadside hazards, average and posted speed and facilities for other user types.

3.1 Project Launch

The EuroRAP Portugal was begun with a project launch event attended by representatives of IMT, IP, ANSR and other stakeholder groups including ISCTE and ACP. The venue of the project launch was ANSR facilities in Barcarena (Tagus Park).

Name	Position	Company
Carlos Lopes	D. Serviços	ANSR
Julia Canha	C.S.O	ANSR
Rui Silva Oliveira	Assessor	ANSR
Helena Clemente	Jefe de Divisao	ANSR
Fernando P. Moutinho	Técnico Superior	ANSR
Ricardo Correia Fernandes	Técnico Superior	ANSR
Jorge Jacob	Presidente	ANSR
Joao Conte	Técnico Superior	IMT
José Lisboa Santos	Técnico Superior	IMT
Paula António	Técnica Superior	IP
Ana Tomaz	Diretora Segurança Rodoviaria	IP
Joao Queiroz		ISCTE
Mario Martins da Silva	Relaçoes Internacionais	ACP
Marc Figuls	Mobility Projects	EuroRAP - RACC
Lluis Puerto	Director Técnico	EuroRAP - RACC

3.2 Road Inspection

The inspections were undertaken by EuroRAP's certified entity RACC, in September 2016 using a "Hawkeye Scaleable Survey Solutions" digital imaging system. The features of the inspection system were:

- Use of three high-resolution digital cameras (1280 x 960 pixels).
- Digital images were collected with a 150- to 180-degree field of view (centred on the travel lane) at 10-m intervals.
- Geo-reference data was collected for each digital image, including distance along road (from an established start point for each road section) and latitude or longitude.
- The images were calibrated to enable detailed measurements of the road features.
- Capability to provide automated measurements of radius of curvature for horizontal curves and percent grade in the direction of travel.

Figure 3.1 shows a photo of the Mercedes Vito used in the road inspections. Representatives from RACC carried out the inspections.

Figure 3.1: Survey Vehicle used in the road inspection

3.3 Coding road feature data

The digital images and georeference data were reviewed by the technical team to code road features of importance to safety. The coding of road features was undertaken in accordance with the EuroRAP Rating Manual using the Hawkeye Processing Toolkit software. The road features coded are listed in Section 4 of this report.

The coded data were subject to quality assurance checks by EuroRAP team members based in UK, in accordance with *EuroRAP's Rating Quality Assurance Guide,* prior to any analysis occurring.

3.4 Speed

In this project, posted speed limits were coded based on review of the digital images collected in the field. Where there was no clearly posted speed limit, the posted speed limit was estimated based on the speed limit applicable by law or the speed limit posted in adjacent road sections that were similar in character.

The observed mean speed of traffic is a better estimator of the safety performance of a roadway than the posted speed limit. Data on observed mean speeds of traffic were obtained by RACC traffic database. ANSR provided data that allowed technical team a verification of obtained data.

EuroRAP study network including roadways representing a range of conditions such as area type (rural / urban), number of through lanes, presence or absence of median, and posted speed limit. 50^{th} percentile (mean) and 85^{th} percentile traffic speeds – rather than the posted speed limits – were used in the determination of Star Ratings and the development of Safer Roads Investment Plans. In general, the use of those traffic speeds had the following effects on the data used in the analyses:

- 119 km of roads (61.4% of the network) had observed mean speeds of traffic that were approximately the same as the posted speed limit.
- 63 km of roads (32.5% of the network) had observed mean speeds of traffic that were approximately 10 km/h higher than the posted speed limit
- 12 km of roads (6.1% of the network) had observed mean speeds of traffic that were approximately 20 km/h higher than the posted speed limit

Average speed extracted (85^{th} percentile) from RACC traffic database for each 100m. A

https://martivila.carto.com/viz/9edad05a-89a8-11e6-8233-0e3a376473ab/embed_map

Figure 3.2: Traffic speed (85th percentile) for EN-118 road

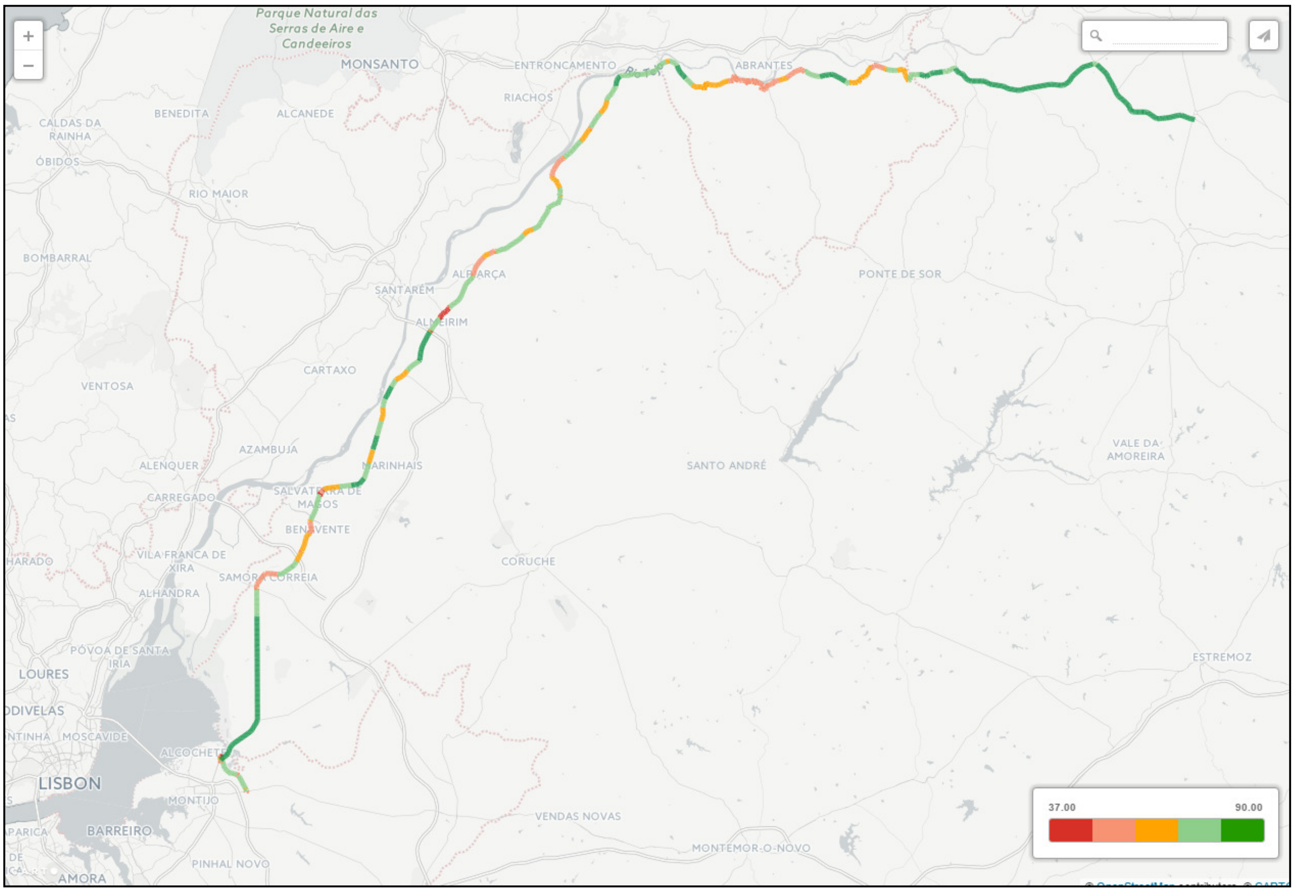
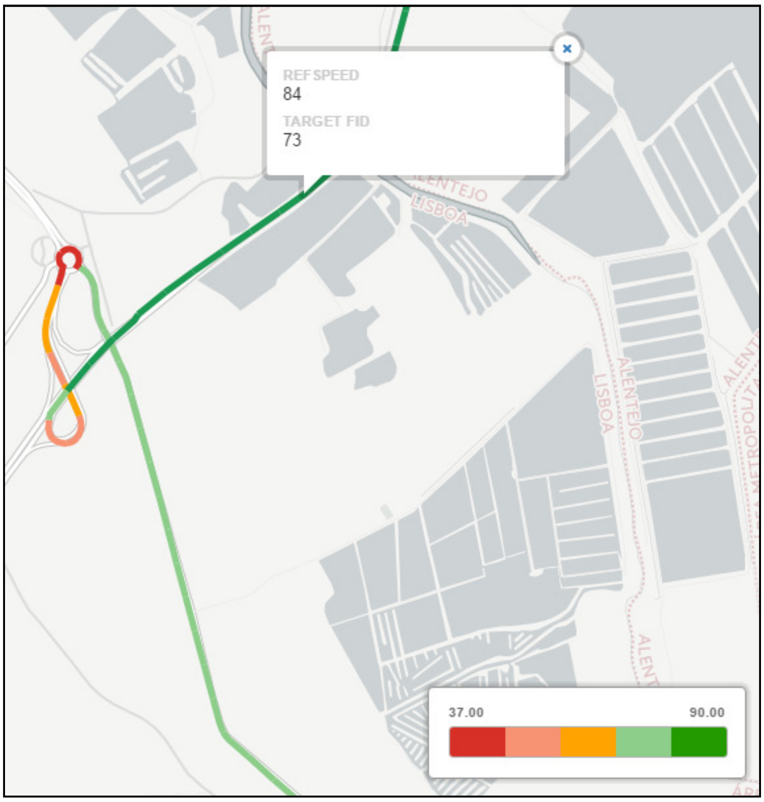


Figure 3.3: Detailed information of Traffic speed (85th percentile) for a road segment.



4 Road conditions

The following is a summary of the condition of the inspected roads for each of the road features included in the EuroRAP models. More detailed reports on the road condition are available in the EuroRAP online software (https://vida.EuroRAP.org/es/results/star_rating/map).

Roadside features

Roadside severity - driver-side distance	km	%
0 to <1m	59.80	31
1 to <5m	121.70	63
5 to <10m	7.30	4
>= 10m	5.60	3

Roadside severity - driver-side object	km	%
Safety barrier - metal	40.80	21
Safety barrier - concrete	0.40	0
Safety barrier - motorcycle friendly	9.30	5
Safety barrier - wire rope	13.20	7
Aggressive vertical face	1.20	1
Upwards slope - rollover gradient	9.30	5
Upwards slope - no rollover gradient	3.60	2
Deep drainage ditch	0.60	0
Downwards slope	1.10	1
Tree >=10cm dia.	46.50	24
Sign, post or pole >= 10cm dia.	41.00	21
Rigid structure/bridge or building	2.10	1
Semi-rigid structure or building	18.30	9
Unprotected safety barrier end	0.10	0
Large boulders >=20cm high	0.60	0
None	6.30	3

Roadside severity - passenger-side distance	km	%
0 to <1m	73.80	38
1 to <5m	104.40	54
5 to <10m	9.70	5
>=10m	6.50	3

Roadside severity - passenger-side object	km	%
Safety barrier - metal	29.60	15
Safety barrier - concrete	0.20	0
Safety barrier - motorcycle friendly	7.70	4
Safety barrier - wire rope	15.10	8
Aggressive vertical face	1.80	1
Upwards slope - rollover gradient	14.30	7
Upwards slope - no rollover gradient	16.80	9
Deep drainage ditch	0.40	0
Downwards slope	0.20	0
Tree >= 10cm dia.	41.30	21
Sign, post or pole >=10cm dia.	37.80	19
Rigid structure/bridge or building	3.90	2
Semi-rigid structure or building	18.30	9
Unprotected safety barrier end	0.10	0
Large boulders >= 20cm high	0.10	0
None	6.80	3

Shoulder rumble strips	km	%
Not present	178.40	92
Present	16.00	8

Paved shoulder - driver-side	km	%
Wide (>= 2.4m)	0.90	0
Medium (>= 1.0m to < 2.4m)	66.90	34
Narrow (>= 0m to < 1.0m)	102.30	53
None	24.30	13

Paved shoulder - passenger-side	km	%
Wide (>= 2.4m)	17.30	9
Medium (>= 1.0m to < 2.4m)	52.80	27
Narrow (>= 0m to < 1.0m)	102.20	53
None	22.10	11

Mid-block

Carriageway label	km	%
Carriageway A of a divided carriageway road	7.30	4
Undivided road	187.10	96

Upgrade cost	km	%
Low	139.50	72
Medium	22.20	11
High	32.70	17

Median type	km	%
Safety barrier - metal	0.60	0
Safety barrier - concrete	1.80	1
Physical median width >= 1.0m to < 5.0m	3.80	2
Physical median width >= 0m to < 1.0m	0.70	0
Continuous central turning lane	1.30	1
Flexipost	1.10	1
Central hatching (>1m)	2.80	1
Centre line	165.80	85
Safety barrier - motorcycle friendly	0.30	0
Wide centre line (0.3m to 1m)	16.20	8

Centreline rumble strips	km	%
Not present	177.30	91
Present	17.10	9

Number of lanes	km	%
One	193.80	100
Two	0.50	0
Two and one	0.10	0

Lane width	km	%
Wide (>= 3.25m)	72.40	37
Medium (>= 2.75m to < 3.25m)	120.70	62
Narrow (>= 0m to < 2.75m)	1.30	1

Curvature	km	%
Straight or gently curving	166.80	86
Moderate	23.20	12
Sharp	3.80	2
Very sharp	0.60	0

Quality of curve	km	%
Adequate	23.10	12
Poor	4.50	2
Not applicable	166.80	86

Grade	km	%
>= 0% to <7.5%	194.40	100

Road condition	km	%
Good	93.80	48
Medium	100.10	51
Poor	0.50	0

Skid resistance / grip	km	%
Sealed - adequate	192.50	99
Sealed - medium	1.90	1

Delineation	km	%
Adequate	142.20	73
Poor	52.20	27

Street lighting	km	%
Not present	139.00	72
Present	55.40	28

Vehicle parking	km	%
Low	172.00	88
Medium	15.30	8
High	7.10	4

Service road	km	%
Not present	191.50	99
Present	2.90	1

Roadworks	km	%
No road works	192.70	99
Major road works in progress	1.70	1

Sight distance	km	%
Adequate	188.20	97
Poor	6.20	3

Intersections

Intersection type	Points	%
Merge lane	26	1
Roundabout	17	1
3-leg (unsignalised) with protected turn lane	28	1
3-leg (unsignalised) with no protected turn lane	187	10
3-leg (signalised) with protected turn lane	1	0
3-leg (signalised) with no protected turn lane	37	2
4-leg (unsignalised) with protected turn lane	2	0
4-leg (unsignalised) with no protected turn lane	52	3
4-leg (signalised) with protected turn lane	4	0
4-leg (signalised) with no protected turn lane	6	0
None	1580	81
Railway Crossing - passive (signs only)	1	0
Median crossing point - formal	3	0

Intersection channelisation	Points	%
Not present	1934	99
Present	10	1

Intersecting road volume	Points	%
5,000 to 10,000 vehicles	1	0
1,000 to 5,000 vehicles	108	6
100 to 1,000 vehicles	124	6
1 to 100 vehicles	131	7
None	1580	81

Intersection quality	Points	%
Adequate	167	9
Poor	197	10
Not applicable	1580	81

Property access points	km	%
Commercial Access 1+	9.20	5
Residential Access 3+	17.10	9
Residential Access 1 or 2	27.60	14
None	140.50	72

Flow

Vehicle flow (AADT)	km	%
1000 - 5000	114.10	59
5000 - 10000	59.10	30
10000 - 15000	21.20	11

Motorcyclist observed flow	km	%
None	193.60	100
1 motorcycle observed	0.80	0

Motorcyclist %	km	%
Not recorded	151.50	78
1% - 5%	42.90	22

Vulnerable road user facilities and land use

Land use - driver-side	km	%
Undeveloped areas	90.90	47
Farming and agricultural	60.60	31
Residential	33.90	17
Commercial	3.40	2
Educational	0.30	0
Industrial and manufacturing	5.30	3

Land use - passenger-side	km	%
Undeveloped areas	94.60	49
Farming and agricultural	57.10	29
Residential	33.80	17
Commercial	1.70	1
Educational	0.10	0
Industrial and manufacturing	7.10	4

Area type	km	%
Rural / open area	151.50	78
Urban / rural town or village	42.90	22

Pedestrian crossing facilities - inspected road	Points	%
Grade separated facility	1	0
Signalised with refuge	1	0
Signalised without refuge	31	2
Unsignalised marked crossing with refuge	9	0
Unsignalised marked crossing without a refuge	51	3
Refuge only	1	0
No facility	1850	95

Pedestrian fencing	km	%
Not present	179.60	92
Present	14.80	8

Sidewalk - driver-side	km	%
Physical barrier	1.90	1
Non-physical separation >= 3.0m	0.60	0
Non-physical separation 1.0m to <3.0m	8.20	4
Non-physical separation 0m to <1.0m	15.00	8
None	167.40	86
Informal path >= 1.0m	1.00	1
Informal path 0m to <1.0m	0.30	0

Sidewalk - passenger-side	km	%
Physical barrier	1.40	1
Non-physical separation >= 3.0m	1.20	1
Non-physical separation 1.0m to <3.0m	8.30	4
Non-physical separation 0m to <1.0m	15.20	8
None	166.70	86
Informal path >= 1.0m	1.00	1
Informal path 0m to <1.0m	0.60	0

Facilities for motorised two wheelers	km	%
None	194.40	100

Facilities for bicycles	km	%
None	194.40	100

School zone warning	Points	%
No school zone warning	2	0
Not applicable (no school at the location)	1942	100

School zone crossing supervisor	Points	%
School zone crossing supervisor not present	2	0
Not applicable (no school at the location)	1942	100

Speeds

Speed limit	km	%
40km/h	0.90	0
50km/h	51.20	26
60km/h	8.10	4
70km/h	104.50	54
80km/h	21.00	11
90km/h	8.70	4

Motorcyclist speed limit	km	%
40km/h	0.90	0
50km/h	51.20	26
60km/h	8.10	4
70km/h	104.50	54
80km/h	21.00	11
90km/h	8.70	4

Truck speed limit	km	%
40km/h	0.90	0
50km/h	51.20	26
60km/h	8.10	4
70km/h	104.50	54
80km/h	21.00	11
90km/h	8.70	4

Differential speed limits	km	%
Not present	194.40	100

Speed management / traffic calming	km	%
Not present	187.40	96
Present	7.00	4

Operating Speed (85th percentile)	km	%
<30km/h	2.20	1
35km/h	0.30	0
40km/h	2.30	1
45km/h	6.50	3
50km/h	18.00	9
55km/h	14.60	8
60km/h	12.00	6
65km/h	22.60	12
70km/h	19.10	10
75km/h	27.90	14
80km/h	21.90	11
85km/h	31.20	16
90km/h	15.80	8

Operating Speed (mean)	km	%
<30km/h	2.50	1
35km/h	2.30	1
40km/h	24.50	13
45km/h	14.60	8
50km/h	12.00	6
55km/h	22.60	12
60km/h	19.10	10
65km/h	27.90	14
70km/h	21.90	11
75km/h	47.00	24

5 Star Rating

EuroRAP Star Ratings are based on the road features listed in Section 4 and the degree to which they impact the likelihood of crashes occurring and the severity of the crashes that do occur. The focus is on the features which influence the most common and severe types of crash on roads for motor vehicles and motorcyclists. They provide a simple and objective measure of the relative level of risk associated with road infrastructure for an individual road user. Five-star (green) roads have the most safety-related features, while 1-star (black) roads have the fewest safety-related features. Star Ratings are not assigned to roads where there is very low use by a specific type of road user. For example, if no bicyclists use a section of road, then a bicyclist Star Rating is not assigned to it. In addition, is a very useful tool for:

- Comparative analysis among different roads in the same country.
- Define road safety objectives for road infrastructures.

The Star Ratings are based on Road Protection Scores (RPS). The EuroRAP models calculate an RPS at 100- m intervals for each of the four road user types (including bicyclists and pedestrians), based on relative risk factors for each of the road features shown in Section 4. The scores are developed by combining relative risk factors using a multiplicative model.

As an example of a risk factor, the relationship between delineation and the likelihood of vehicle occupants being killed or seriously injured in a crash is shown below in Table 5.1. It indicates that the relative risk of death or serious injury on a rural road is 20% greater when the delineation is poor, all other things being equal.

Figure 5.1: Motor vehicle occupant risk factors for the likelihood of death or serious injury on a rural road.

Delineation	Relative Risk
Adequate	1.00
Poor	1.20

More information on risk factors, RPS and Star Ratings is available in EuroRAP (2016) Methodology (see http://www.EuroRAP.org/en/about-EuroRAP-3/methodology).

5.1 Overall Star Ratings

The overall Star Ratings for the roads assessed is shown in Table 5.2.

Figure 5.2: Overall Star Ratings for EuroRAP Portugal network (EN-118 road)

	Vehicle Occupant		Motorcyclist	
Star Ratings	Length (kms)	Percent	Length (kms)	Percent
5 Stars	2.10	1%	0.00	0%
4 Stars	21.70	11%	7.10	4%
3 Stars	144.00	74%	30.20	16%
2 Stars	24.80	13%	5.00	3%
1 Star	0.10	0%	0.60	0%
Not applicable	1.70	1%	151.50	78%
Totals	194.40	100%	194.40	100%

5.2 Star Ratings maps

Figures 5.3 and 5.4 illustrate the Star Ratings for the EuroRAP pilot in Portugal (EN-118 road) in map for vehicle occupants and motorcyclists.

Figure 5.3: Star Ratings for vehicle occupants

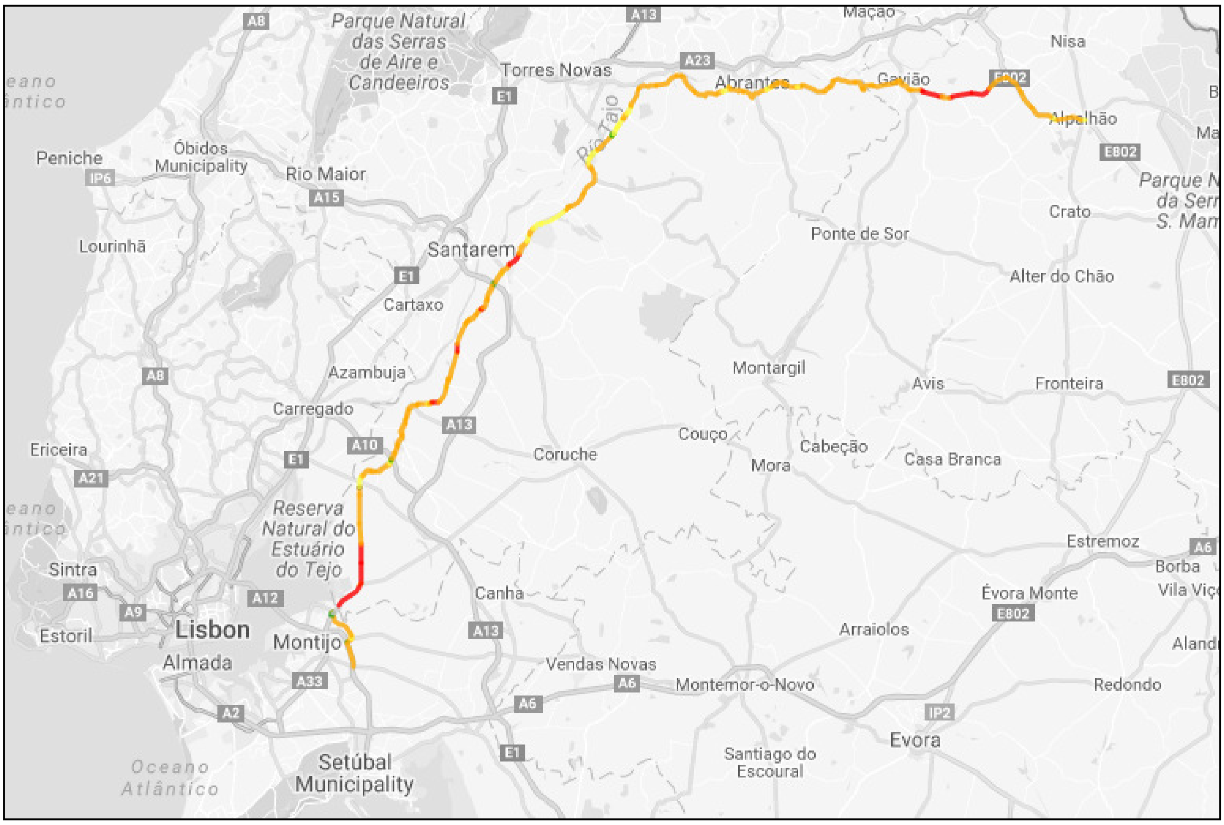
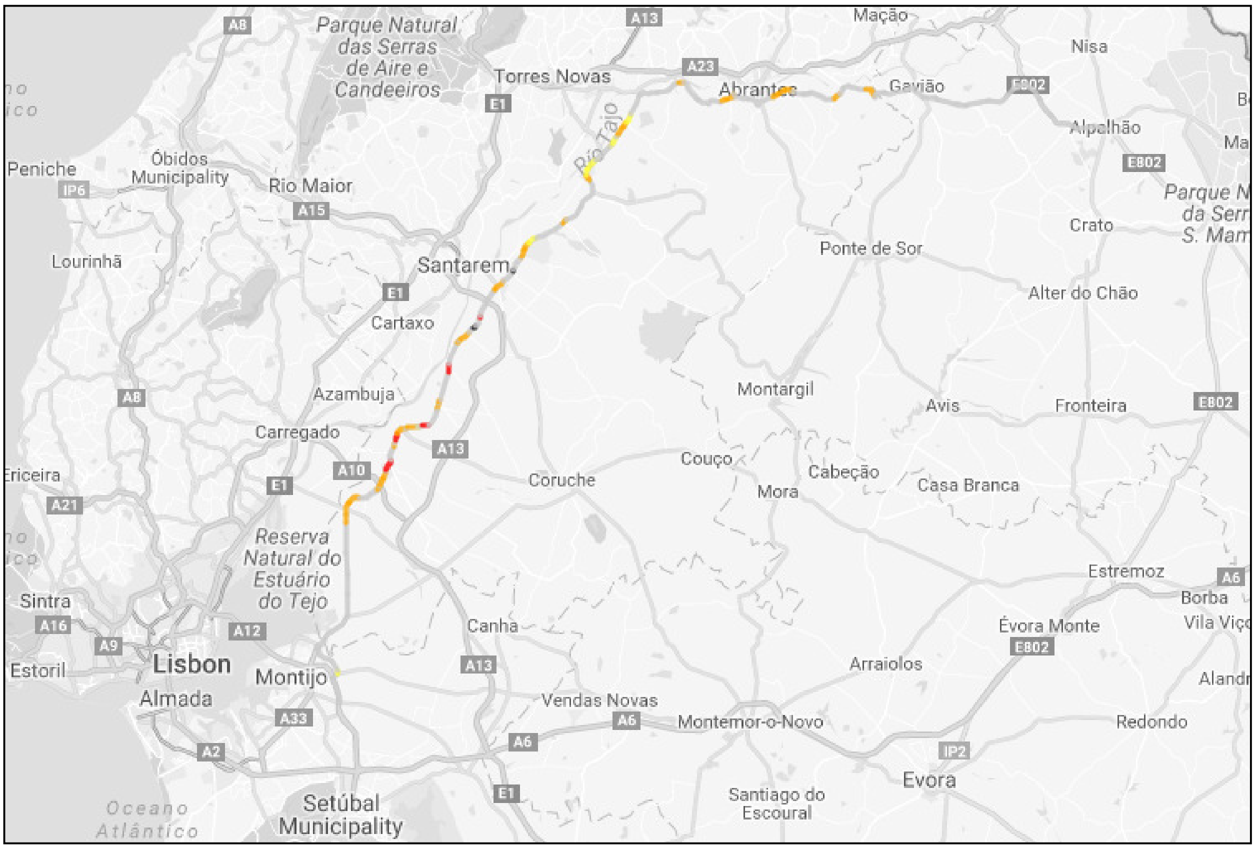


Figure 5.4: Star Ratings for motorcyclists



5.3 Road Protection Scores

Figures 5.3 and 5.4 provide an example of how the RPS varies along one particular road section (in this case from Enlace N-119 to Samora Correia). They illustrate the RPS for vehicle occupants and motorcyclists on a selected roadway section. In these charts, a low RPS indicates a relatively low level of risk while a high RPS indicates a high level of risk. Star Rating bands are overlaid on the RPS charts, with the green band representing 5-stars (the locations with the most safety features) and the black band representing 1-star (the locations with the fewest safety features). The following figures show raw and smoothed version to visualise Star Rating for each 100m:

Figure 5.5: RPS for vehicle occupants (Enlace N-119 – Samora Correia) - Raw version

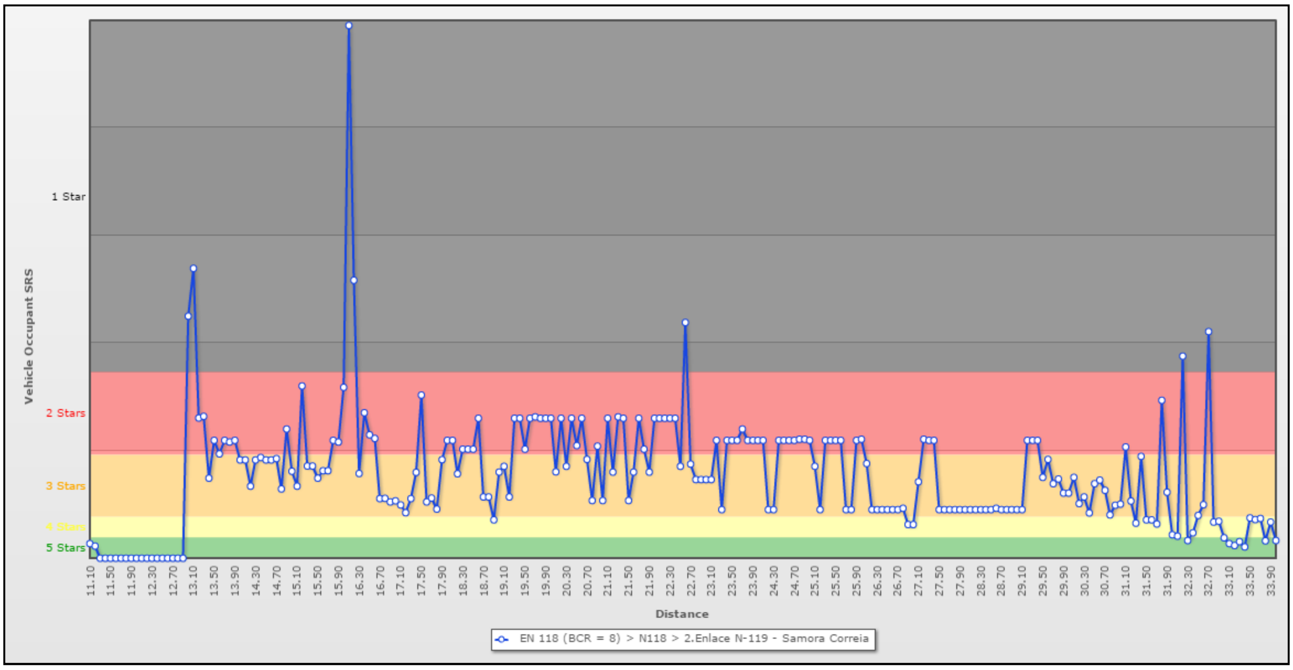


Figure 5.6: RPS for vehicle occupants (Enlace N-119 – Samora Correia) – Smoothed version

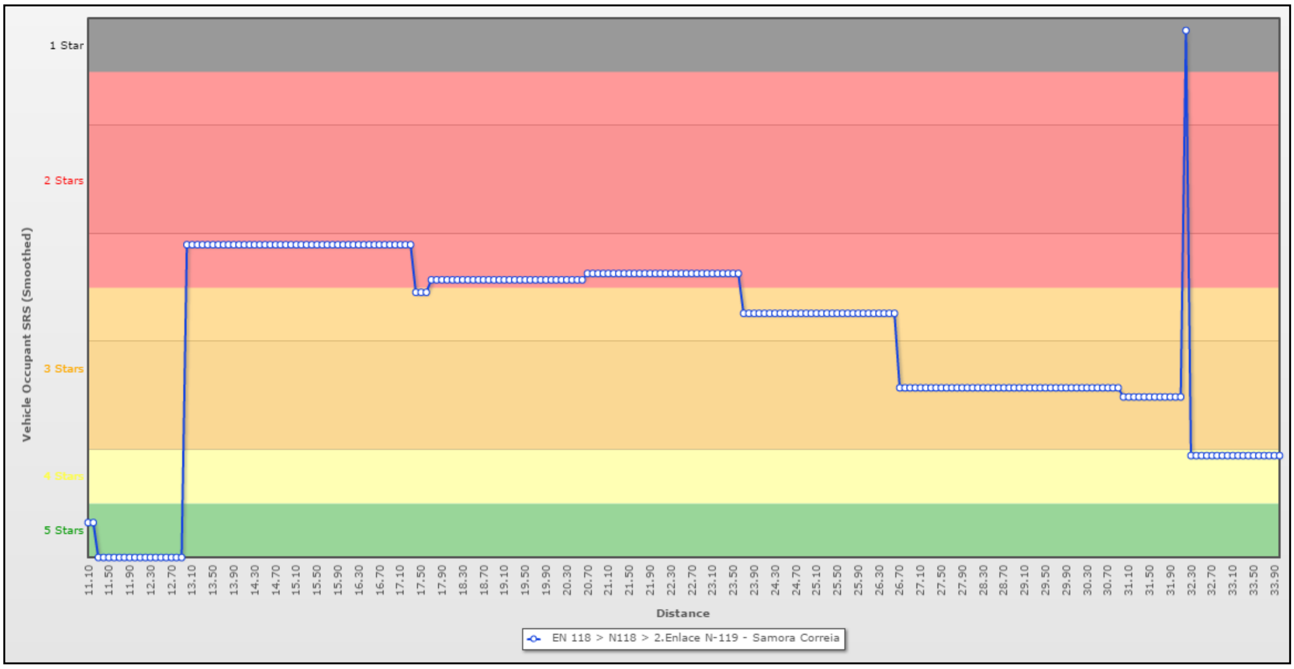


Figure 5.7: RPS for motorcyclists (Enlace N-119 – Samora Correia) – Raw version

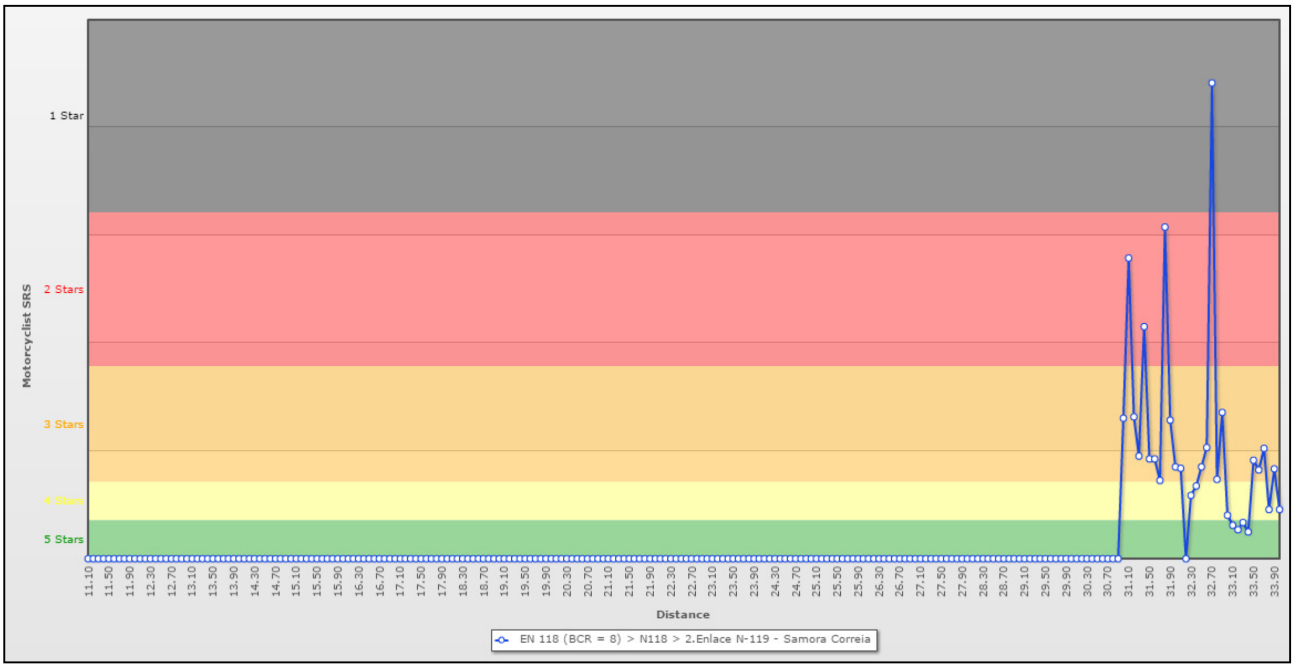
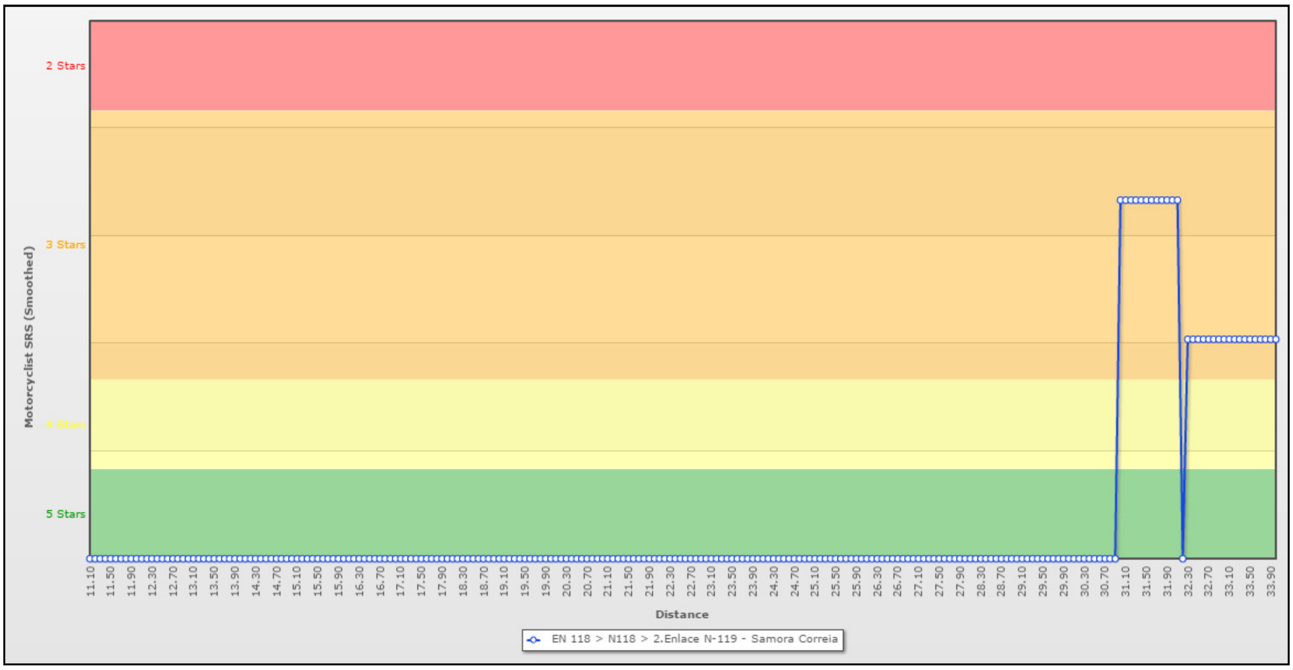


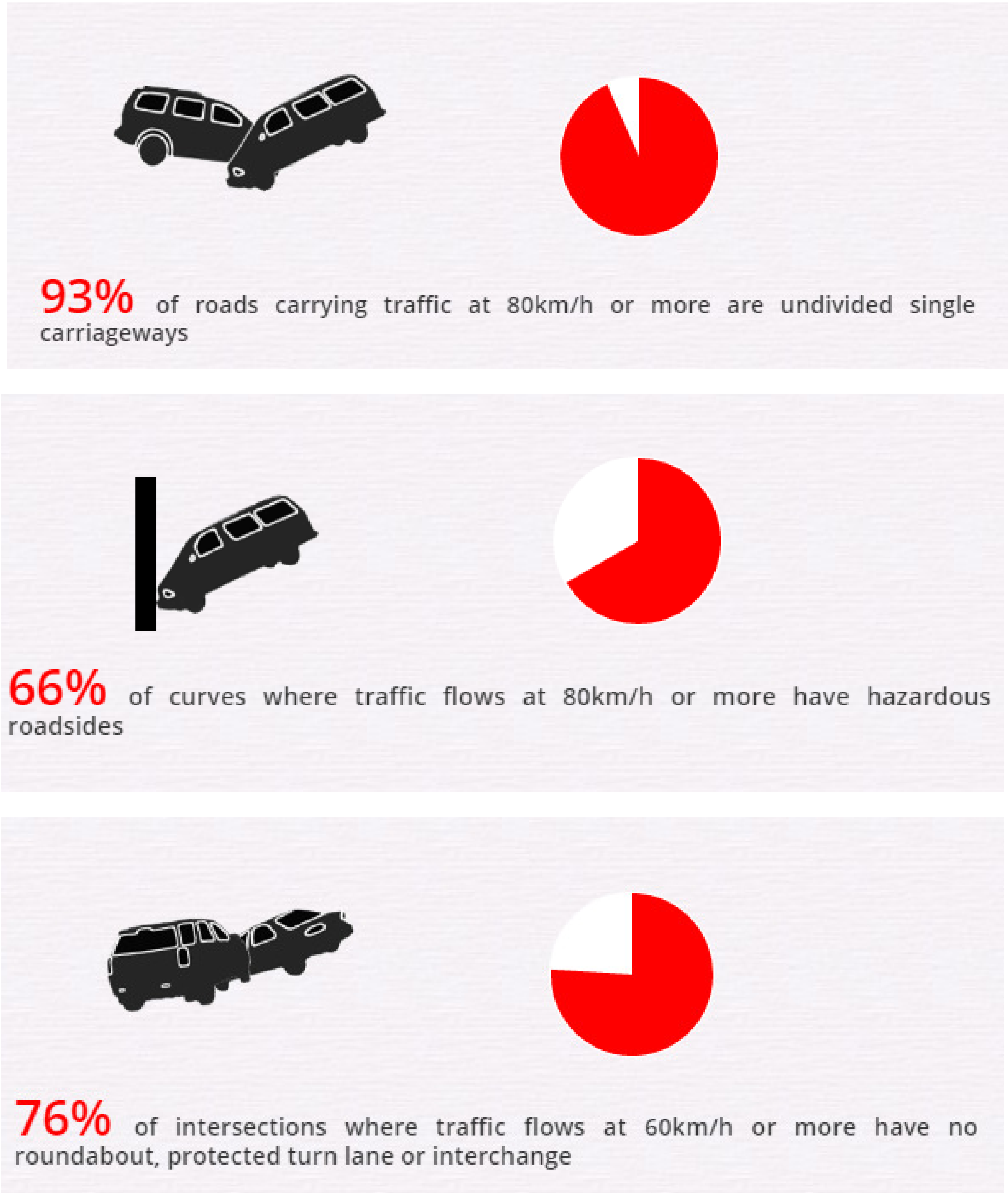
Figure 5.8: RPS for motorcyclists (Enlace N-119 – Samora Correia) – Smoothed version



5.4 Road attributes snapshot

EuroRAP online software also highlights different aspects regarding coded infrastructure:

Figure 5.9: Additional information provided by EuroRAP online software.



6 Safer Road Investment Plans

EuroRAP considers more than 70 proven road improvement options to generate affordable and economically sound Safer Road Investment Plans that will save lives. Road improvement options range from lower cost items such as road markings and pedestrian refuges to higher cost items such as intersection upgrades and full roadway 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 throughout the road network.

2. For each 100-m section 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 the application of pedestrian refuge, pedestrian crossing, or signalised pedestrian crossing countermeasures.

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 ensures that a plan that is affordable for a country while still representing a positive investment return and responsible use of public money can be generated.

The methodology underpinning this process is available in Star Ratings and Investment Plans: (http://www.EuroRAP.org/en/about-EuroRAP-3/specifications).

6.1 Road Protection Scores

Although the EuroRAP 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. In this section of this report, the key data and methodology that relates specifically to the roads being assessed in this project are described.

6.1.1 Traffic volumes

Traffic volume data is used by the EuroRAP model in the generation of estimates of the number of deaths and serious injuries that could be prevented on the roads. For this project, data was provided by the ANSR with the collaboration of Infraestruturas de Portugal (IP).

6.1.2 Motorcycle traffic volumes

Available AADT data for motorcycles is difficult in interurban roads according to EuroRAP's experience. For that reason, there motorcycle traffic volume is not recorded in rural stretches of EN-118. However, ANSR estimated that motorcycles constitute 1 to 5 percent of traffic volumes in urban areas of this study. This estimate of flows was used in the analyses.

6.1.3 Pedestrian and Bicyclist volumes

Pedestrian and bicyclist flow in EN-118 road is not relevant and Star Ratings for both user types were not calculated by EuroRAP software. EuroRAP is able to obtain pedestrian and bicyclist results. In this case, data on observed pedestrian and bicycle usage of the roadways can be recorded during the coding of road features and flows can be estimated from those observations using algorithms developed by EuroRAP.

6.1.4 Number of deaths and serious injuries

There were 478 reported fatalities in road crashes 2015 in Portugal. Reported road deaths on surveyed road is 44 fatalities in the period from 2010 to 2015 (6 years), most of them vehicle occupants. Hence, the estimated number of fatalities on EN-118 per year is 7.3. The reported ratio of serious injuries to fatalities on that Portuguese road is 2.9, thus it is estimated that a total of 28.5 fatalities and serious injuries per year occur on EN-118 assessed in this project.

However, the ratio of serious injuries to fatalities it is estimated to be 10:1 (McMahon and Dahdah, 2008). There is a huge difference between 2.9:1 (reported by ANSR) and 10:1 (EuroRAP source of information worldwide).

6.1.5 Road deaths on the EuroRAP Portugal network by road user type

In order to allocate deaths and serious injuries to the network, the EuroRAP model also requires the distribution of deaths by road user type. The proportion of deaths on the road by road user type was obtained following a review of data from the ANSR.

Figure 6.1: Proportion of road deaths on the EURORAP network by road user type

Road user type	Estimated fatalities per year	Proportion of road deaths
Vehicle occupants	4,8	66%
Motorcyclists	2,0	27%
Pedestrians	0,2	2%
Bicyclists	0,3	5%
Total	**7,3**	**100%**

Figure 6.2: Relationship between ANSR recorded crash types and EuroRAP description of crash types for vehicle occupants:

ANSR crash type	Driver's action	Intersection	EuroRAP crash type
Colisão choque em cadeia	Parado ou estacionado	Em entroncamento	Intersection
Colisão frontal	Em marcha normal	NÃO DEFINIDO	Head-on LOC i Head-on overtaking
		Fora da intersecção	Head-on LOC i Head-on overtaking
Colisão lateral com outro veículo em movimento	Em marcha normal	Em entroncamento	Intersection
		Fora da intersecção	Run-off both sides
	Mudança de direcção para a esquerda	Em cruzamento	Property access
Despiste com capotamento (vuelco)	Desvio brusco/ saída de fila de trânsito	Fora da intersecção	Run-off both sides
	Em marcha normal	Fora da intersecção	Run-off both sides
		Em rotunda	Intersection
Despiste com colisão com veículo imobil. ou obstáculo	Em marcha normal	Fora da intersecção	Run-off both sides
Despiste com dispositivo de retenção	Ultrapassagem pela esquerda	Fora da intersecção	Run-off driver side
Despiste com transposição do dispositivo de retenção lateral	Em marcha normal	Fora da intersecção	Run-off passenger side
Despiste simples	Em marcha normal	Fora da intersecção	Head-on LOC i Run-off both sides

Figure 6.3: Relationship between ANSR recorded crash types and EuroRAP description of crash types for motorcyclists:

ANSR crash type	Motorcyclist's action	Intersection	EuroRAP crash type
Colisão frontal	Em marcha normal	Fora da intersecção	Head-on LOC o overtaking
Colisão lateral com outro veículo em movimento	Em marcha normal	Em entroncamento	Intersection
	Em marcha normal	Fora da intersecção	Head-on LOC
	Em marcha normal	NÃO DEFINIDO	Head-on LOC
	Inversão do sentido de marcha	Fora da intersecção	Head-on overtaking
	Mudança de direcção para a esquerda	Em entroncamento	Intersection
	Saída de parqueamento ou de rua particular	Em entroncamento	Property access
Colisão traseira com outro veículo em movimento	Em marcha normal	Fora da intersecção	Head-on LOC
Despiste com colisão com veículo imobil. ou obstáculo	Em marcha normal	Fora da intersecção	Run-off passenger side
Despiste sem dispositivo de retenção	Em marcha normal	Em rotunda	Run-off passenger side
Despiste simples	Em marcha normal	Em rotunda	Intersection

6.1.6 Countermeasure costs

The EuroRAP model requires the input of local construction and maintenance costs for the 94 countermeasures that are considered in the development of the Safer Roads Investment Plans. The costs are categorised by area type (urban and rural) and upper and lower costs (low, medium and high). The countermeasure costs were based on estimates provided by the technical team thanks to their experience in previous EuroRAP projects carried out in Spain. The countermeasure costs were used to represent the typical costs of countermeasure construction or installation in rural areas where no major physical constraints are present. Higher costs were assumed in urban and in rural areas with greater constraints. A sample of the data is shown Annex 1.

6.1.7 Economic cost of a death and serious injury

The document Safer Roads Investment Plans: The EuroRAP Methodology used to estimate the economic cost of a road death and a serious injury in for EuroRAP projects. This approach is applied globally by EuroRAP and is based on research undertaken by McMahon and Dahdah (2008). It is noted that this approach may result in estimates that differ from those undertaken in the past using a different methodology.

The key equations used are:

- the economic cost of a death (value of life) is provided by "Update of the Handbook on External Costs of Transport (DG MOVE)"
- the economic cost of a serious injury is also provided by the same source

On this basis:

- the economic cost of a death is estimated to be: **1,505,000€**
- the economic cost of a serious injury is estimated to be: **201,100€**

6.1.8 Discount rate

To calculate Net Present Costs and Benefits, a discount rate of 4% was used.

6.1.9 Road sections

Each record has a section code. Section codes are used to group together 100-m segments for both processing and reporting purposes. Road sections are typically aligned with road authority inventory data, obvious changes in road condition or with obvious landmarks such as towns. For example, EN-118 road, as long corridor pass through a number of important towns such as Samora Correia, Marinhais, Almeirim, Chamusca, Tramagal and Concavada as well. For the purposes of this project, roads have been split into sections roughly according to important towns, traffic volumes and changes in road features.

Figure 6.2: Detailed sections

Section number	Start section	End section	Lenght
1	Beginning of the project road	Enlace N-119	11km
2	Enlace N-119	Samora Correia	23km
3	Samora Correia	Marinhais	21km
4	Marinhais	Almeirim	20km
5	Almeirim	Chamusca	23km
6	Chamusca	Tramagal	29km
7	Tramagal	Concavada	20km
8	Concavada	Desvío IP-2	32km
9	Desvío IP-2	End of the project road	15km

6.2 Investment Plans

Using inspection and supporting data with the EuroRAP methodology, a series of investment plan options have been produced for the roads that make up the study network. Different assumptions about the benefit-cost ratio (BCR) thresholds for safety improvements were found to be applicable as an example for Portuguese pilot. Smaller BCR thresholds must be considered to develop an investment program of meaningful size and greater BCR thresholds to maximize the efficiency of the investments.

Candidate investment plans with differing BCR thresholds and differing investment levels have been developed. While a specific investment option is recommended, the ultimate decision on an appropriate investment level to improve safety rests with road authorities in Portugal.

Figure 6.3: Investment plan options for EuroRAP Portugal road

	Option A	Option B	Option C
Minimum benefit cost ratio	3	5	8
Investment (M €)	8,731,638	4,366,898	1,508,225
Economic benefit 20 years (M €)	49,600,088	35,646,962	21,954,477
Programme benefit cost ratio	6	8	14
Deaths (per year)			
Before countermeasures	7.3	7.3	7.3
After countermeasures	5.3	5.9	6.4
Prevented	2.0	1.4	0.9
Reduction	26.5%	19%	12%
Deaths and serious injuries (20 years)			
Before countermeasures	430	430	430
After countermeasures	315	348	379
Prevented	115	82	51
Reduction	26.5%	19%	12%
Cost per death and serious injury prevented	75,927€	53,254€	29,573€

Figure 6.4: Countermeasures options for safer roads investment plan (Option B)

Countermeasure	Length/Sites	FSIs saved	PV of safety benefit	Estimated cost	Cost per FSI saved	Program BCR
Roadside barriers passenger side	13.70km	23	10,039,400	1,894,500	82,464	5
Shoulder rumble strips	44.70km	18	7,688,572	683,630	38,856	11
Central hatching	45.50km	14	6,066,257	369,127	26,591	16
Improve delineation	19.20km	11	4,970,419	582,130	51,181	9
Roadside barriers driver side	4.50km	9	4,126,001	631,500	66,884	7
Improve curve delineation	3.30km	4	1,908,353	104,099	23,838	18
Delineation and signing (Intersection)	4 sites	1	555,449	79,372	62,445	7
Sight distance (obstruction removal)	0,60km	1	292,510	22,540	33,674	13
	TOTAL	**82**	**35,646,962**	**4,366,898**	**53,254**	**8**

6.3 Engineering criteria for developing countermeasure options

This section of the report presents the criteria used for identifying appropriate countermeasures and formulating countermeasure options.

6.3.1 Engineering criteria: countermeasure triggers

For each countermeasure, a series of triggers (or prerequisite conditions) have been defined. A trigger must be satisfied before that countermeasure is considered suitable for a section of road. The triggers are applied for each 100-m section of road throughout the network, and are typically a function of:

1. Star Ratings, which are based on Road Protection Scores

2. Road condition, such as lane width or adequacy of delineation.

3. Traffic volume.

An example of the triggers for improving delineation is provided in Figure 6.5 below. Trigger 1 requires that delineation be improved on any section of road that has a traffic flow greater than 0, has poor delineation and is not rated 5-stars (the safest level) for car occupants. However, trigger 2 requires that even if a section of road is rated 5-stars good delineation should be provided at moderate curves and where there are severe roadsides present. Trigger 3 requires that good delineation be provided on all sections of road where there is a sharp or very sharp curve.

Figure 6.5: A sample of triggers for the delineation countermeasure

Trigger	Variable	Requirement
1	Traffic flow	Greater than 0
	Delineation	Poor
	Vehicle occupant Star Rating	1 to 4-stars
2	Traffic flow	Greater than 0
	Curvature	Moderate
	Delineation	Poor
	Roadside severity	Deep drainage ditches, steep fill embankment, distance to object 0-5m, distance to object 5-10m
	Vehicle occupant Star Rating	5-stars
3	Traffic flow	Greater than 0
	Curvature	Sharp curve or very sharp curve
	Delineation	Poor
	Vehicle occupant Star Rating	5-stars

The EuroRAP model includes more 300 different triggers for the assessment of potential countermeasures across the road network.

6.3.2 Engineering criteria: application rules

In addition to the triggers, the EuroRAP model applies a series of application rules for certain countermeasures. These ensure that the countermeasure recommendations align with good engineering practice.

For example:

- grade-separated pedestrian crossings must be at least 1-km apart
- new signalised pedestrian crossings (non-intersection facilities) must be at least 600 m apart
- additional lanes (such as overtaking lanes or 2+1 cross section) must be required for a minimum length of 1 km before they are considered viable.

6.3.3 Engineering criteria: application rules

The countermeasures are also subject to a hierarchy, with the most comprehensive countermeasures taking precedence. This ensures that there is no duplication of treatments that impact the same road feature. For example:

- if a grade separated pedestrian facility is feasible then that treatment will take precedence over all other pedestrian measures (such as a pedestrian refuge or signalised crossing)
- if a horizontal realignment is feasible then any treatments that are no longer relevant can be removed (for example, curve delineation and shoulder widening)
- if a segregated motorcycle lane is feasible then any lower standard motorcycle lanes (such as an on-road motorcycle lane) can be removed from the plan.

This approach assumes that comprehensive countermeasures are designed with safety as a key criterion, and the new treatment reflects best practice in safety design (for example, motorcycle lanes must manage conflicts at intersections).

6.3.4 Economic criteria: Benefit-Cost ratio

Following these steps, the countermeasures are subject to a benefit-cost analysis, comparing the cost of the countermeasure (life-cycle cost) with the economic benefits in terms of crash costs avoided.

7 Implementation

In interpreting the results of this report, it is important to recognise that EuroRAP is designed to provide a network-level assessment of risk and cost-effective countermeasures. 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)
- preliminary scheme investigation studies
- detailed design and costing of each proposal, final evaluation and then construction.

The detailed results of the project and online software that enabled the EuroRAP analyses to be undertaken will be made available to stakeholders for further exploration and use. The Road Safety Toolkit (http://toolkit.EuroRAP.org) also provides guidance on the implementation of road safety countermeasures. While this report and the online software include recommendations for consideration, the ultimate decision on an appropriate investment level to improve safety and the specific countermeasures to be implemented rests with road authorities in Portugal.

In the following sections, key issues that should be taken into consideration during the implementation process are discussed.

7.1 A safe system

In order to make the first EURORAP study in Portugal safer, efforts that go beyond traditional engineering improvements will be necessary. For example, 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.

In addition to taking a more comprehensive approach to road safety engineering, significant benefits could be realised through coordinated targeting risk factors for road users (such as speeding, seat belt wearing, drugs and alcohol) and vehicles. This would be consistent with taking a Safe System approach to the programme. The Road Safety Toolkit (http://toolkit.EuroRAP.org) and United Nations Road Safety Collaboration Good Practice Manuals provide further information on this issue.

7.2 Speed management

The issue of speed management is particularly important in road safety. Traffic speeds also have a significant bearing on the EuroRAP Star Ratings. As such, it warrants special attention in this report.

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 traffic speeds are 40km/h or less

- opposing traffic is physically separated and roadside hazards are well managed
- traffic speeds are 70km/h or less for occupants of cars on roads where opposing traffic is not physically separated or roadside hazards exist.

An issue that has emerged during EuroRAP's assessments in some countries is a discrepancy between permitted (posted) speeds and the speeds at which vehicles actually travel. In some locations posted speed limits are set at very low speeds, and are unlikely to be complied with without continuous enforcement or robust traffic calming measures.

The results of this study have been based on estimates of the real speed of traffic for each 100m road section, rather than on posted speed limits, because the real mean speed of traffic is a better estimator of the safety performance of a roadway than the posted speed limit. The real speeds (85^{th} percentile and 50^{th} percentile) were based on field measurements and RACC traffic database.

In the EuroRAP results, roads on which traffic operates at very low speeds may achieve a relatively high Star Rating (4- or 5-star), even though the engineering features may be of a lower standard. A good example is the intersection between EN-118 and N-119, were vehicles travelling at less than 30km/h. This short segment achieves 5-star due to the low real speed.

In terms of speed management more broadly, the raw condition data collected as part of the EuroRAP process will provide a valuable resource to authorities investigating appropiate speed management initiatives. This may include a more detailed analysis of results to investigate where there are lower speed limits without accompanying engineering solutions, or may include a review of the speed limits and facilities in place on roads that rate poorly for pedestrian or bicycle safety.

The EuroRAP results therefore should help enable a professional discussion between police and highway authorities about their goals and respective roles in enforcement and engineering so each can contribute best to ensuring safe speeds. It is for Portugal's stakeholders to decide if and when a nationwide debate which educates the public about the importance of speed limits should occur. Clearly such a debate is likely to make more sense if launched alongside a major programme of safety engineering improvements with emphasis on safe driving, safe vehicles and safe roads.

8 Recommendations

The following are initial recommendations for consideration by the ANSR. It is envisaged that these advice will be refined following the consultation with stakeholders:

- Use this project as a pilot to validate EuroRAP preventive strategy. It is recommended to link EuroRAP methodology with road management in order to maximize road safety in Portuguese road network.
- Consider EuroRAP methodology as a useful tool to carry out comparative analysis among different roads in Portugal and to define road safety objectives for Portuguese road network.
- ANSR should review the countermeasures proposed with a view to implementing a safety improvement plan in order to reduce deaths and serious injures in EN 118 road. “Before and after” studies should be undertaken to assess the road safety impact of various road infrastructure upgrades after they are implemented.
- Monitoring and collecting of key data required for EuroRAP analysis. Apart from traffic volume data, crash type data and countermeasure cost data should be obtained according EuroRAP methodology.
- Formal training sessions can be conducted with ANSR engineers, design staff and consultants likely to be undertaking road construction and maintenance operations in Portugal.

Annex 1: Countermeasures costs

Countermeasure	Unit of costs	Service Life	Cost Rural-Low
Unsignalised raised crossing	unit	10	13500
School zone - crossing guard or supervisor	unit	1	9000
School zone warning - flashing beacon	unit	20	5400
School zone warning - signs and markings	lane km	5	4500
Wide centreline	per linear km	20	6030
Roadside barriers (seg MC lane) driver side	per km	20	135000
Sideslope improvement (seg MC lane) driver side	per km	20	3663000
Clear roadside hazards (seg MC lane) driver side	per km	20	180000
Central median barrier (1+1)	per km	20	180000
Realignment (sight distance improvement)	lane km	20	74700
Shoulder sealing driver side (>1m)	per linear km	20	74700
Shoulder sealing driver side (<1m)	per linear km	20	37800
Footpath provision driver side (adjacent to road)	per linear km	20	156600
Footpath provision driver side (>3m from road)	per linear km	20	114840
Footpath provision driver side (with barrier)	per linear km	20	297540
Footpath provision driver side (informal path >1m)	per linear km	10	18000
Footpath provision passenger side (informal path >1m)	per linear km	10	18000
Footpath provision passenger side (with barrier)	per linear km	20	297540
Side road unsignalised pedestrian crossing	intersection	10	31500
Side road signalised pedestrian crossing	intersection	20	45000
Side road grade separated pedestrian facility	intersection	20	14653800
Pedestrian fencing	per carriagew	20	6300
Sight distance (obstruction removal)	per linear km	20	25200
Parking improvements	per carriagew	20	12600
Shoulder rumble strips	per carriagew	10	9000
Street lighting (ped crossing)	unit	20	18000
Street lighting (intersection)	intersection	20	36000
Street lighting (mid-block)	lane km	20	72000
Pave road surface	lane km	10	180000
Skid Resistance (unpaved road)	per carriagew	10	19800
Skid Resistance (paved road)	lane km	10	162000
Central median barrier (MC lane)	per km	10	180000
Speed management reviews (MC Lane)	per carriagew	5	2250
Roadside barriers (seg MC lane) passenger side	per km	20	135000
Sideslope improvement (seg MC lane) passenger side	per km	20	3663000
Clear roadside hazards (seg MC lane) passenger side	per km	20	180000
Roadside barriers (bike lane)	per km	20	135000
Sideslope improvement (bike lane)	per km	20	3663000
Clear roadside hazards (bike lane)	per km	20	180000
Median crossing upgrade	intersection	10	540000
Overtaking lane	per linear km	20	1350000
Vertical realignment (major)	lane km	20	1221300
Traffic calming	per carriagew	10	22500
Speed management reviews	per carriagew	5	2250
Footpath provision passenger side (>3m from road)	per linear km	20	114840
Footpath provision passenger side (adjacent to road)	per linear km	20	156600
Restrict/combine direct access points	per km	10	276300
Shoulder sealing passenger side (>1m)	per linear km	20	88200
Shoulder sealing passenger side (<1m)	per linear km	20	44100
Roadside barriers - driver side	per linear km	20	135000
Roadside barriers - passenger side	per linear km	20	135000

Countermeasure	Unit of costs	Service Life	Cost Rural-Low
Road surface rehabilitation	lane km	10	33300
Grade separated pedestrian facility	unit	20	14653800
Signalised crossing	unit	20	45000
Unsignalised crossing	unit	10	31500
Refuge Island	unit	10	22500
Upgrade pedestrian facility quality	unit	10	13500
Implement one way network	per carriagew	20	540000
Additional lane (2 + 1 road with barrier)	per km	20	1350000
Service road	per km	20	1350000
Duplicate - >20m median	per carriagew	20	7200000
Duplicate - 10-20m median	per carriagew	20	7200000
Duplicate - 5-10m median	per carriagew	20	6300000
Duplicate - 1-5 m median	per carriagew	20	6300000
Duplicate - <1m median	per carriagew	20	5400000
Duplication with median barrier	per carriagew	20	5400000
Central median barrier (no duplication)	per km	10	180000
Central turning lane full length	per km	10	1156500
Centreline rumble strip / flexi-post	per km	10	8100
Central hatching	per km	10	4500
Roundabout	intersection	20	900000
Rail crossing upgrade	unit	20	900000
Grade separation	intersection	20	11030400
Signalise intersection (4-leg)	intersection	20	900000
Signalise intersection (3-leg)	intersection	20	720000
Protected turn provision at existing signalised site (4-leg)	intersection	10	180000
Protected turn provision at existing signalised site (3-leg)	intersection	10	160200
Delineation and signing (intersection)	intersection	5	4500
Protected turn lane (unsignalised 4 leg)	intersection	10	135000
Protected turn lane (unsignalised 3 leg)	intersection	10	100800
Lane widening (>0.5m)	lane km	10	576900
Lane widening (up to 0.5m)	lane km	10	248400
Improve curve delineation	per carriagew	5	9000
Horizontal Realignment	lane km	20	487800
Motorcycle Lane (Segregated)	per km	20	135000
Motorcycle Lane (Construct on-road)	per km	20	9000
Motorcycle Lane (Painted logos only on-road)	per km	5	8100
Bicycle Lane (off-road)	per km	20	131400
Bicycle Lane (on-road)	per km	20	18000
Improve Delineation	lane km	5	4500