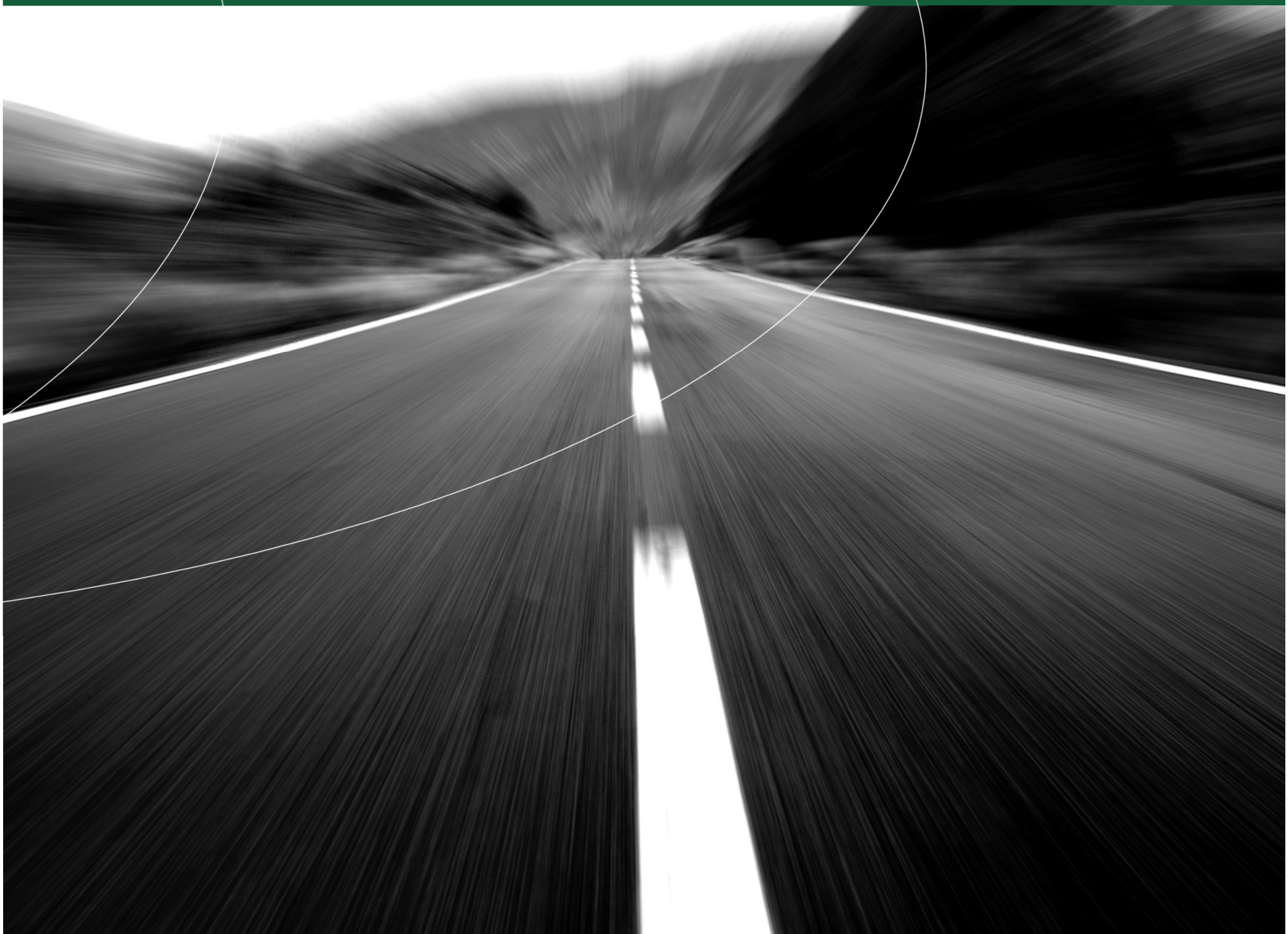
EuroRAP Portugal: Technical Report

February 2019



Submitted by

RACC

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About EuroRAP

The European Road Assessment Programme (EuroRAP) is a charity dedicated to saving lives through safer roads. Our vision is for a world free of high-risk 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 (RAP) is now active in more than 80 countries throughout Europe, Asia Pacific, North, Central and South America and Africa.

EuroRAP is financially supported by the FIA Foundation, the Global Road Safety Fund and Bloomberg Philantropies.

FIA FOUNDATION GRSF Global Road Safety Facility Bloomberg Philanthropies

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

Deaths and injuries from road vehicle 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. Road crashes are now the leading cause of death for children and young people aged between 10 and 24. The burden of road crashes is comparable with malaria and tuberculosis and costs 1-3% of the world's GDP.

According to European Commission, European roads remain the safest in the world: in 2017 (last year with available accident data), the EU counted 50 road fatalities per one million inhabitants, but the progress rate has lately slowed down. After two years of stagnation (2014 and 2015), the number of road fatalities was reduced by 2% in 2016, and by another 2% in 2017. While the last two years with available data give rise to some optimism, it will be very challenging for the EU to reach its ambitious target of halving the number of road deaths between 2010 and 2020. Further efforts are therefore needed by all actors to improve road safety.

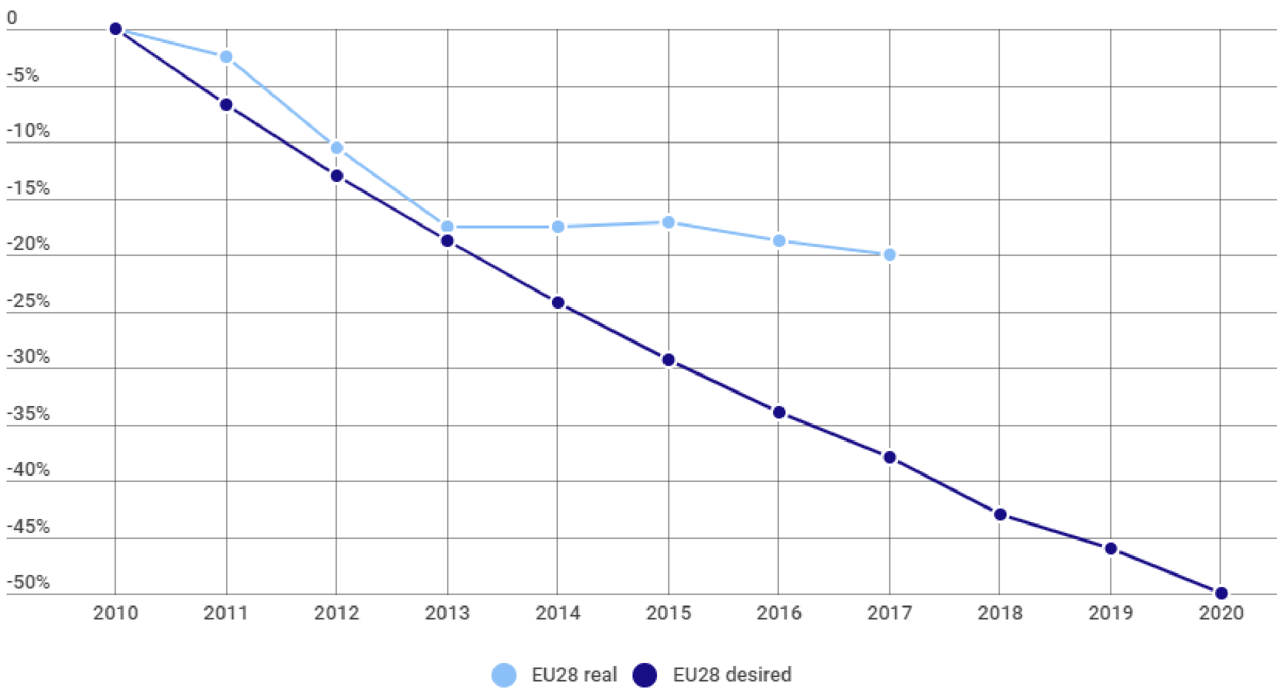

Figure 1: Road fatalities in EU since 2001 (Source: Euro Road Safety database)

Over recent years, Portugal have maintained a very good road safety performance with a reduction of -34,0% since 2010 until 2017, well below the EU average of -21,6% in the same period. When viewed in the international context the percentage of reduction from Portuguese figures is successful but every casualty is, of course, one too many. The Automóvel Clube de Portugal – ACP firmly supports the traffic education, vehicle safety and also the analysis of road infrastructures as a way to keep continuing to improve road safety in Portugal. In fact, ACP has supported a first EuroRAP pilot in Portugal, which took place in 2016 with the analysis of 194km of the EN-118 road from Montijo to Alpalhão, selected by Autoridade Nacional de Segurança Rodoviária (ANSR).

The current EuroRAP project presented in this document has analysed 4,880km of different type of roads from all the Portuguese territory, especially secondary roads but it also includes double-carriageway around the capital city Lisbon and Oporto. The main objective is proposed to be achieved through the following:

- Road Survey pre-identified road network using equipped vehicle for collecting images every 10m.
- Road coding of more than 60 road safety attributes, including traffic flow and operation speed.
- Establish Star Ratings to measure the safety performance of a road network.
- Develop Safer Roads Investment Plans calculated by estimating for each 100m of roads the number of killed and seriously injured accidents (KSI) avoided by each of the 94 countermeasures considered in the EuroRAP catalogue.

EuroRAP Road Protection Scores and Star Ratings based on detailed inspection and assessment of more than 60 road attributes at 100m intervals indicate that there are significant opportunities for improvement on the selected road network of 4,880km. Most of these lineal infrastructures are rated 3-stars out of a base of a possible of 5-stars) for car occupants but there is a considerable room for improvement as there is a huge percentage of 2-star roads (36.00%) and 1-star rated (15.59%) in selected network, and both results are considered below the IRAP's strategy of 3-stars or better for a realistic target for national and regional governments and road authorities to adopt. The surroundings of the most important cities (Lisbon and Oporto) have obtained better star ratings results than other rural roads from the interior of the country. In addition, the other transport modes such as pedestrians, bicyclists and motorcycles with a majority of 1-star and 2-star ratings have also some room for improve the road safety performance of the selected network.

	Vehicle Occupant		Motorcyclist	
Star Ratings	Length (km)	Percent	Length (km)	Percent
5 Stars	16.20	0.33%	1.20	0.02%
4 Stars	282.00	5.78%	57.80	1.18%
3 Stars	2,052.50	42.06%	1,210.60	24.81%
2 Stars	1,743.70	35.73%	2,227.40	45.64%
1 Star	777.10	15.92%	1,374.50	28.17%
Not applicable	8.50	0.17%	8.50	0.17%
Totals	4,880.00	100.00%	4,880.00	100.00%

	Pedestrian		Bicyclist	
Star Ratings	Length (km)	Percent	Length (km)	Percent
5 Stars	17.00	0.35%	19.60	0.40%
4 Stars	119.60	2.45%	77.60	1.59%
3 Stars	520.30	10.66%	1,063.40	21.79%
2 Stars	1,002.00	20.53%	1,875.90	38.44%
1 Star	1,598.40	32.75%	1,835.00	37.60%
Not applicable	1,622.70	33.25%	8.50	0.17%
Totals	4,880.00	100.00%	4,880.00	100.00%

Figure 2: General picture of star ratings map and table of Portuguese network. Source: ViDA software.

A programme of countermeasures has been developed to reduce deaths and serious injuries.

The overall EuroRAP Safer Roads Investment Plan with a benefit-cost ratio of 4 identified in this project largely focus on:

- Reducing the likelihood of head-on crashes (car occupants and motorcyclists) by duplication with median barrier and central hatching in 900km of the analysed road network.
- Reducing the likelihood and have a lower severity of run-off crashes (car occupants and motorcyclists) by incorporating roadside barriers, especially at the passenger side (114km).
- Warning drivers judge about their position on the road and provide advice about conditions ahead by incorporating shoulder rumble strips in more than 2,000km of the analysed road.
- Improving road safety for VRUs (pedestrians and bicyclists) by footpath provision adjacent to roads and upgrade pedestrian facility quality.

A series of investment options were generated for the selected road network in Portugal, and resultant reductions in deaths and serious injuries were estimated. The first option showed a total investment for the whole network of € 100 million would generate an economic benefit of € 766 million over 20 years, resulting in a benefit cost ratio higher than 8:1. This plan would result in a reduction of 4,405 killed and serious injured persons in the selected network in the following two decades. The second one showed a total investment for the whole network of € 73 million would generate an economic benefit of € 683 million over 20 years, resulting in a benefit cost ratio higher than 9:1. This plan would result in a reduction of 3,928 killed and serious injured persons in the analyzed road network in the coming 20 years. The third scenario showed a total investment for the whole network of € 54 million would generate an economic benefit of € 605 million over 20 years, resulting in a benefit cost ratio higher than 11:1. This plan would result in a reduction of 3,476 killed and serious injured persons in the analyzed road network in the coming 20 years. Finally, a total investment for the whole network of € 26 million would generate an economic benefit of € 438 million over 20 years, resulting in a benefit cost ratio higher than 17:1. This plan would result in a reduction of 2,520 killed and serious injured persons in the selected Portuguese network in the following 20 years.

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.

1 Introduction

1.1 General indicators

A total of 4,880km has been analysed from Portuguese road network is 4,880km, mostly divided roads among the different parts of the country. In addition of the field analysis and road coding, the EuroRAP methodology also includes general information about demographic and economics to assist in the collection and collation of data that supports the creation of EuroRAP Star Ratings and Safer Roads Investment Plans.

Indicators	Year	Particulars
Value of life	2018	681,851 €
Value of serios injury multiplier	2018	0.16
Value of serious injury	2018	110,941 €
Serious injury to fatality ratio	2018	3.8
Average of total deaths in selected road network	2015-2017	141 persons/year

Table 1: Demographics/Economics and crash data.

Portuguese crash data is currently 61.5 fatalities per million inhabitants for all road network, according to data from 2017 published by ANSR and Instituto Nacional de Estatística (INE).

1.2 Inspected roads

The table below shows the analysed Portuguese road network. The selection of all the road stretches and the AADT and summary data were provided by ANSR:

Road name	Section	Length (km)
EN13	Oporto – Valença	118
EN15	Bragança – Oporto	250
EN101	Valença – Vila Cova Lixa	142
EN101	Amarante – Mesão Frio	24
EN202	Viana do Castelo – Soajo	61
EN202	Lamas do Mouro – Cristoval	25
EN202	Melgaço – Monção	24
EN204	Correlha – Santo Tirso	58
EN205	Póvoa de Varzim – Arco de Baúlhe	108
EN206	Póvoa de Varzim – Bragança	237
EN3	Carregado – Castelo Branco	206
EN4	Montijo – Elvas	176
EN5	Montijo – Setubal	28
EN5	Alcácer do Sal – Torrão	28
EN 6	Cascais – Lisboa Algés	17
EN 6	Lisboa Algés – Cascais	21
EN 8	Porto de Mós – Lisboa	129
EN 9	Casalinhas – Torres	7
EN 9	Cascais – Cascais (Estoril)	3
EN 9	Estoril – Sintra	5

EN 9	Sintra – Saõ Pedro de Cadeira	39
EN 9	Torres Vedras – Alenquer	30
EN10	Almada - Rda. Ponte Vasco da Gama	143
EN14	Oporto – Braga	42
IC8	Vila Velha de Rodão – Carriço	117
IP2	Amieira do Tejo – Ourique	281
IP2	Trancoso – Guarda	13
IP2	Guarda – Macedo de Cavaleiros	117
IP3	Mangualde – Vendas de Santana	84
EN16	Aveiro – Vilar Formoso	219
EN17	Celorico da Beira – Coimbra	128
EN18	Ervidel – Beja	20
EN18	Évora – Santa Maria	29
EN18	Castelo Branco – Alpalhão	43
EN18	Castelo Branco – Guarda	97
EN234	Lapa do Lobo – Mangualde	21
EN234	Mira – Santa Comba Dão	61
IP7	Lisboa (A2) – Lisboa (A36)	11
IP7	Lisboa (A36) – Lisboa (A2)	10
EN105	Guimarães – Oporto	46
EN106	Entre os Rios – Nespereira	41
EN247	Peniche – Cascais	106
IC 10	Évora – Almeirim	104
IC17-A36	Lisboa Algés – Ponte Vasco da Gama	20
IC17-A36	Ponte Vasco da Gama – Lisboa Algés	20
IC19	Lisboa (A36) – Lisboa (IC30)	17
IC19	Lisboa (IC30) - Lisboa (A36)	16
EN103	Bragança – Neiva	259
EN109	Oporto – Leiria	166
EN201	Braga – Valença	63
EN1 - IC2	Vila Franca de Xira – Vila Nova de Gaia	267
EN114	Almeirim – Santarém	9
EN114	Santarém – Gaeiras	52
EN114	Gaeiras – Cabo Carvoeiro	24
IC1	Setubal – Albufeira	196

EN125	Castro Marim – Vila do Bispo	156
EN120	Lagos – Grândola	149

Table 2: Road network definition.

1.3 Methodology and results online

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.

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:

- **Coding Manual**: This manual defines the road infrastructure attributes that are used in the production of documents and explains how they are to be coded.
- **Star Ratings and Investment Plans**: Road Survey and Coding Specification: This document sets out the minimum specifications for an EuroRAP Inspection (survey and coding). The purpose of the road inspections is to collect data that can be used in the creation of EuroRAP Star Ratings and Safer Roads Investment Plans (SRIP).

Further information is available at:

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

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

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.EuroRAP.org/en-gb/results/star_rating/map.

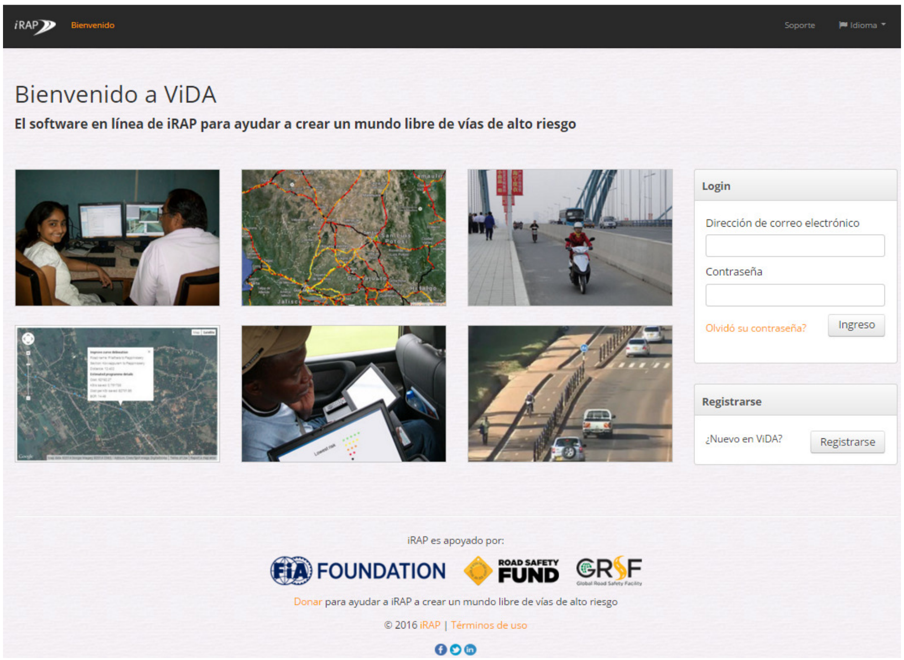

Figure 3: ViDA webpage for users. Source: IRAP

Stakeholders in Portugal (i.e. ANSR) 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.

2 Project and data

The EuroRAP project focused on a network of 4,880km as a total length which was selected by ANSR for inclusion in the study. The analysed network is 92% of single carriageway roads and 8% of divided roads. There is a quality difference between the roads around the capital city Lisbon and some of the countryside roads (i.e. EN-16). The star ratings show that, in general, the roads with more traffic flow are better in terms of road safety, however there is a room to improve in specific stretches of rural roads.

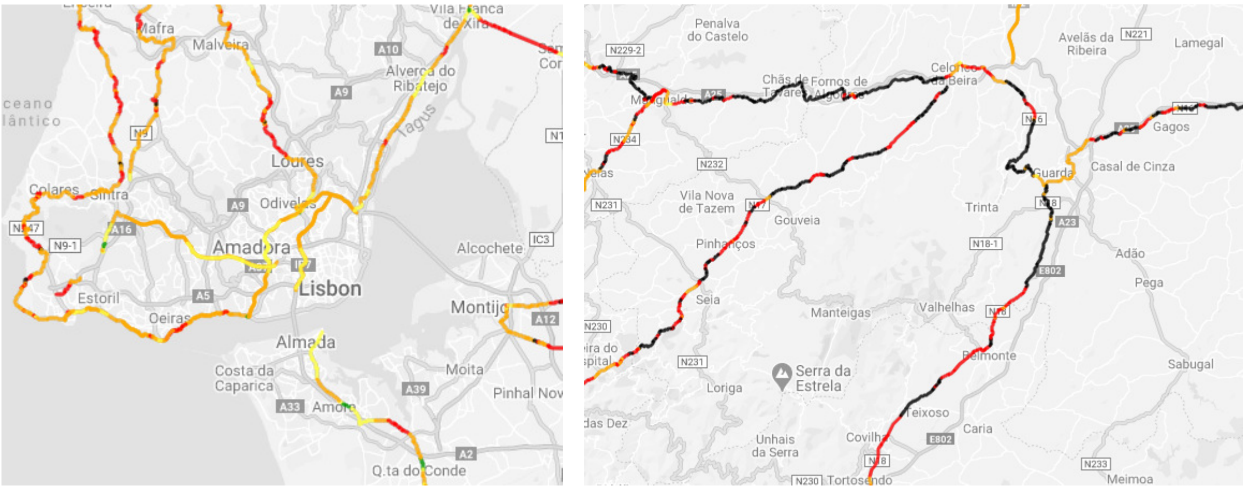

Figure 4: Screenshots of Lisbon surroundings and countryside roads. Source: ViDA software

2.1 Task objectives

The objectives of this project are:

- Survey 4,880km of roads managed by ACP and carry out coding of the video survey data according to the International Road Assessment Program (EuroRAP) Survey and Coding specification.
- Collect crash data, traffic flow and speed data for the network according to the EuroRAP Data Analysis and Reporting specification.
- Produce an EuroRAP input file which includes all road attributes and collected data.
- Produce Star Rating results and Safer Roads Investment Plan to identify areas of high risk and to shape future road safety investment.
- Produce a technical report in accordance with EuroRAP Data Analysis and Reporting specification.

3 Project development

3.1 Introduction

To attain task objectives mentioned in previous section, following Methodology have been followed: As described in flow diagram below (Figure 5), the EuroRAP execution plan is divided in 5 phases or Working Packages (WP). Each one of these contains all the tasks and subtasks, which cover all the conditions required for this project. The methodology has been optimized with the best practices learnt after similar experiences of the Consultant in other International EuroRAP projects.

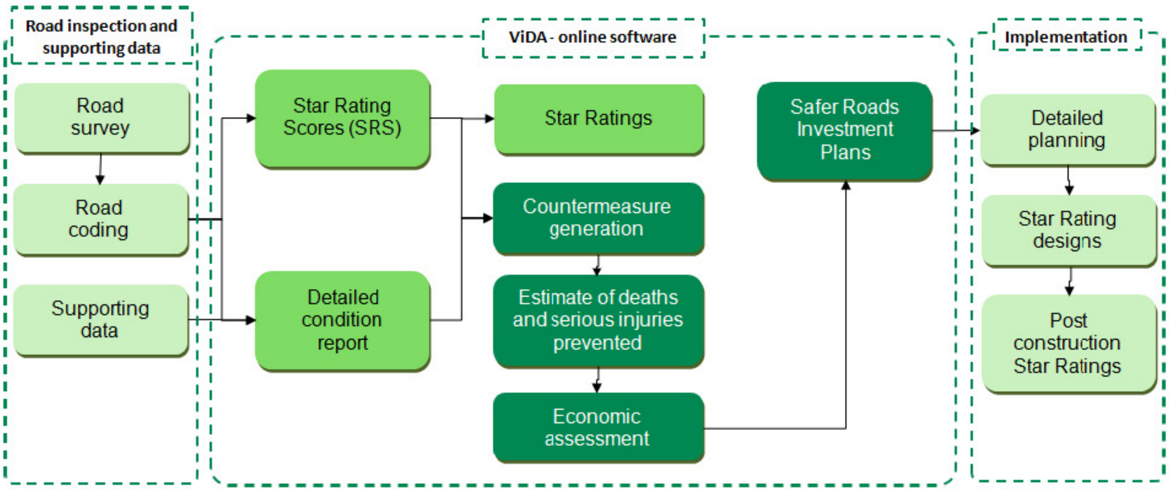

Figure 5: EuroRAP Methodology. Source: IRAP

3.2 Road inspection

It consists of the preparation and planning, which contains all the tasks to be done before starting the field work. This include WP tasks such as: Selection of Road network to inspect carried out by ANSR, creation of loc files and GPS files, calibration of the system and managing the logistics issues. In this part of the project, we gather required information of the road network selected. In this, a map of all roads along with baseline data such as AADT, length, starting and end points, traffic circulation speeds (V85 and other relevant data about the road is recorded). The field work includes the tasks related to the collection of data on the road, training of the surveyors, calibration of the system, conducting the surveys, performing quality check on the road and other related tasks.

The inspections were undertaken by EuroRAP's certified entity RACC, in July - August 2018 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 6 shows a photo of the Mercedes Vito used in the road inspections. Representatives from RACC carried out the inspections for four weeks.

Figure 6: RACC Movitest vehicle

Figure 7: RACC Movitest vehicle from passenger vision

3.2.1 Digital acquisition cameras

Three front cameras take high resolution pictures of a panoramic view of the road (both roadsides and the carriageway), every 10m.

Figure 8: RACC Movitest digital acquisition cameras

3.2.2 GPS antenna and odometer

GPS antenna enables the geo-referencing of each set of pictures taken by the cameras and odometer is the measurement device for distance travelled, allowing the triggering of the cameras every 10 m. It also provides a backup reference if the GPS is not working properly (tunnels, forests, etc).

Figure 9: RACC Movitest GPS antenna and odometer

3.2.3 Heartbeat unit and curvature alignment

The central processing unit coordinates that every different module (GPS, cameras, odometer) is properly coordinated and stores the data in the hard drive. It also includes technology to acquire the road geometry, such as vertical and horizontal gradients and road curvatures.

Figure 10: RACC Movitest heartbet unit

3.2.4 Onboard software

An onboard computer allows monitoring all the control parameters in real time, and also allows changing different acquisition variables depending on meteorology, speed limit, etc.

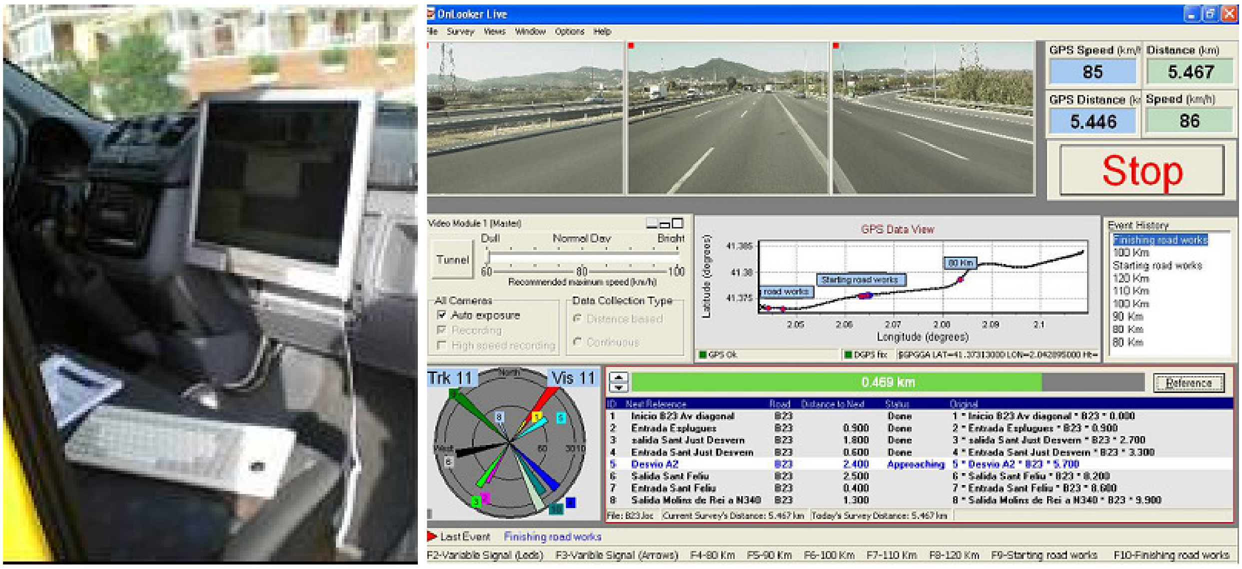

Figure 11: RACC Movitest onboard software Hawkeye.

3.3 Road Coding and analysis

It is the most important phase of the whole project, considering that from this phase the core information for the calculations is created, and processing and analysis of the data inside the ViDA software is carried out. Considering this, the phase is divided in 3 tasks:

1. **Preliminary database creation** in which we create all documentation needed, prepare the tools to be used and do the training to the road coders about the Hawkeye Processing Toolkit software and

explain how to interact to follow the procedures and protocols as per the RAP-SR-2.2 Star rating coding manual.

2. **Road feature coding** where all the roads are coded to get the required attributes from the network surveyed and same is exported to csv format.

3. The last task of this phase is the **External Quality Check Ratings** which is done at the same time as the road feature coding. In this task, the principal aim is to ensure that the data coded fulfils the protocols with the minimum mistakes while coding is in process.

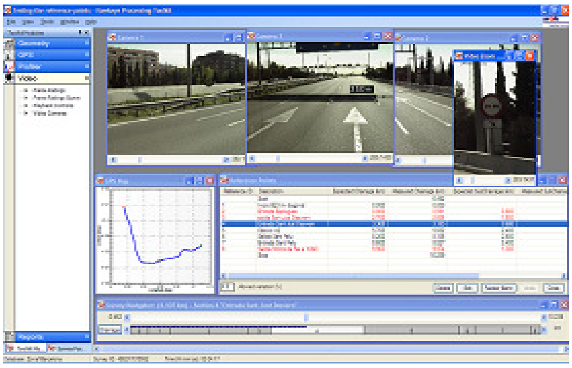

Figure 12: Portuguese road network coding at RACC headquarters.

At this stage, all the preparation and pre-processing of the data coded (add speeds, AADT, vehicle flows, etc) are done under the Preparation of the coded survey data task. Once everything is clear, the task of Upload data to ViDA starts and in the process, translation of the data into ViDA software language, creation of the country project, setting up of requirements for calculation of the countermeasures and the processing of the data are done. Finally, once the processing of the data has been completed, the Analysis tasks starts. This task consists of checking the accuracy of the data processed (results) with stakeholders and reprocessing the data when it is required. This phase is very important since it is from this phase that the final reports will be generated based on the information related to the countermeasures.

3.4 Report and quality control

Once the calculations are finished and checked, a report will be created under in order to manage all the requirements of the client. This task will include the creation of a draft version in accordance with the reporting specifications included in the tender, release of the document to stakeholders and client for feedback and finally, submission of the final version of the document, which will be the base for the work for the next phase.

In order to ensure a good quality control of the tasks under this project, we have followed the actual quality control requirements of the EuroRAP. All the requirements included in the documents created by EuroRAP about this topic will be followed in order to get the highest quality possible as mentioned inside the file RAP-SR-2-4 Road Coding Quality Assurance Guide.

4 Star Ratings

4.1 Star Rating methodology

EuroRAP Star Ratings are based on the road features (Road condition) 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, motorcyclists, bicyclists and pedestrians (bicyclists and pedestrians are excluded of our project). 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 are the safest while one-star (black) roads are the least safe. 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, it is a very useful tool for:

- Benchmarking 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 a RPS at 100-m intervals for each of the four road user types, based on relative risk factors for each of the road features shown. 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. 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 similar.

Delineation	Relative Risk
Adequate	1.00
Poor	1.20

Table 3: Vehicle occupant risk factors for the likelihood of death or serious injury on a rural road. Source: IRAP

More information on risk factors, RPS and Star Ratings is available in iRAP (2018) Methodology (see http://www.IRAP.org/en/about-IRAP-3/methodology).

4.1.1 Star Rating Scores

A Star Rating Score (SRS) is calculated for each 100-metre segment of road and each of the four road users, using the following equation:

SRS = Σ Crash Type Scores

Where:

- The SRS represents the relative risk of death and serious injury for an individual road user; and

- Crash Type Scores = Likelihood x Severity x Operating speed x External flow influence x Median traversability

4.2 Overall star ratings results

The overall Star Ratings for the roads assessed is shown in the following tables for each transport mode:

Star Ratings	Lenght (km)	Percentage
5 Stars	16.2	0,33%
4 Stars	282.0	5.78%
3 Stars	2,052.5	42.06%
2 Stars	1,743.7	35.73%
1 Star	777,1	15.92%
Not aplicable	8.5	0.17%
Totals	**4,880**	**100%**

Table 4: Vehicle occupant risk factor table.

Star Ratings	Lenght (km)	Percentage
5 Stars	1.2	0,02%
4 Stars	57.8	1.18%
3 Stars	1,210.6	24.81%
2 Stars	2,227.4	45.64%
1 Star	1,374.5	28.17%
Not aplicable	8.5	0.17%
Totals	**4,880**	**100%**

Table 5: Motorcyclist risk factor table.

Star Ratings	Lenght (km)	Percentage
5 Stars	17.0	0,35%
4 Stars	119.6	2.45%
3 Stars	520.3	10.66%
2 Stars	1002.0	20.53%
1 Star	1,598.4	32.75%
Not aplicable	1,622.7	33.25%
Totals	**4,880**	**100%**

Table 6: Pedestrian risk factor table.

Star Ratings	Lenght (km)	Percentage
5 Stars	19.6	0,40%
4 Stars	77.6	1.59%
3 Stars	1,063.4	21.79%
2 Stars	1,875.9	38.44%
1 Star	1,835.0	37.60%
Not aplicable	8.5	0.17%
Totals	**4,880**	**100%**

Table 7: Bicyclist risk factor table.

4.2.1 Examples of Star Ratings

The following figures show examples of sections of roads that include their Star Ratings and the road attributes that influenced their assessment. The figures illustrate Star Ratings for car occupants, as they account for the majority of roads deaths.

The figures help to illustrate the fact that the level of risk associated with a road’s infrastructure, and hence its Star Rating, is a function of numerous attributes, including travel speeds. You can see at the figures:

- Green Road attributes associated with a low risk level.
- Yellow Road attributes associated with an intermediate risk level.
- Red Road attributes associated with a high risk level.

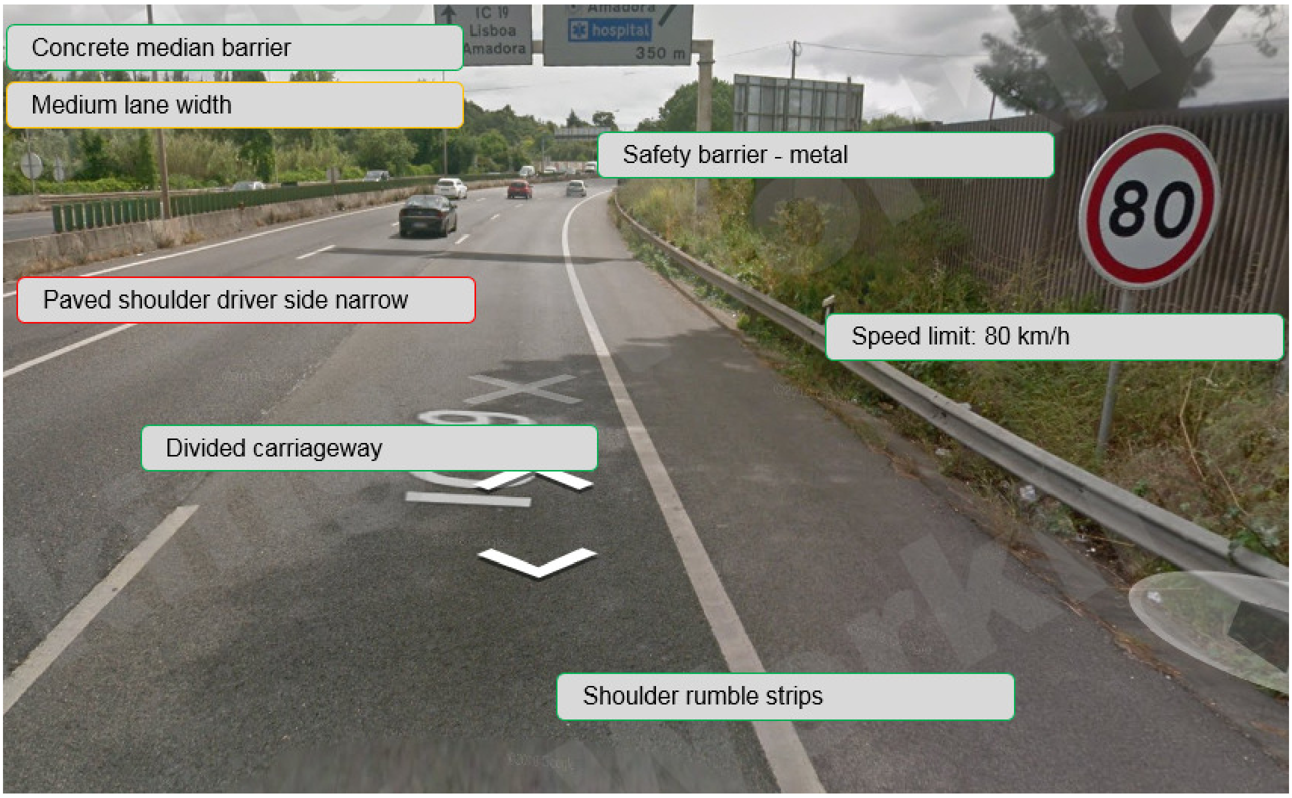

Figure 13: Example of Star Ratings of a 4-star road segment.

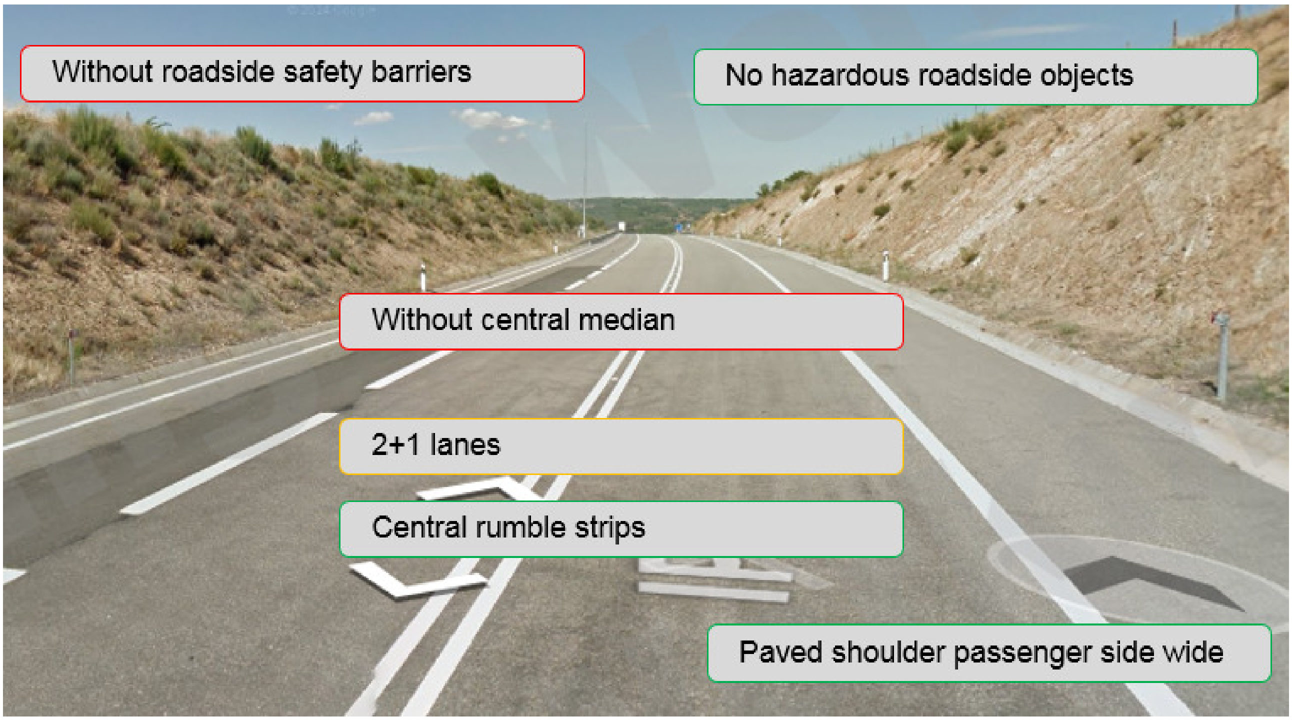

Figure 14: Example of Star Ratings of a 3-star road segment.

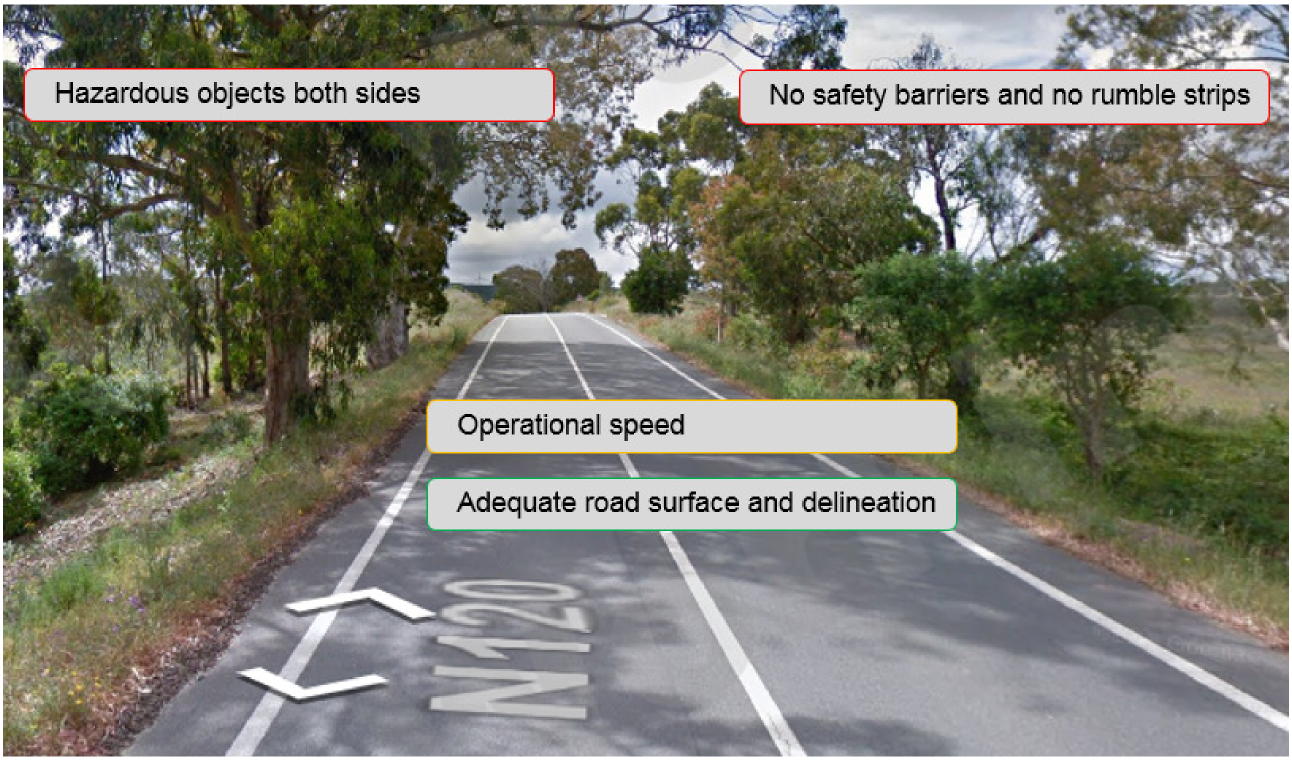

Figure 15: Example of Star Ratings of a 2-star road segment.

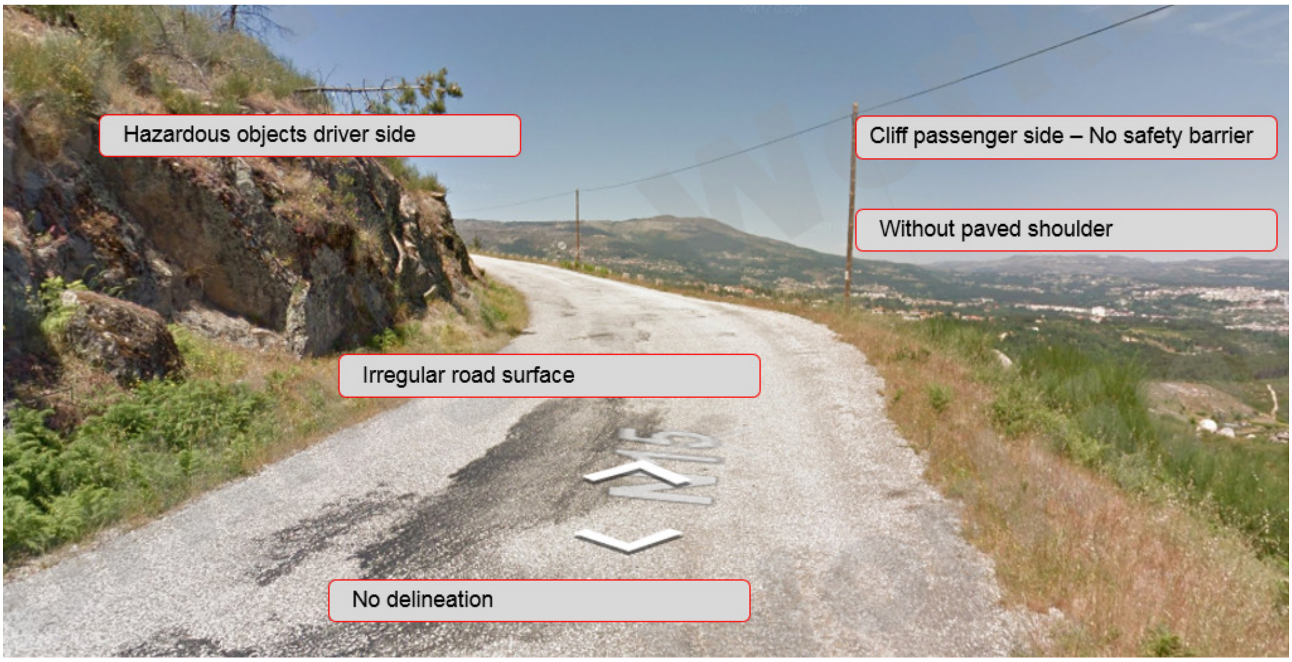

Figure 16: Example of Star Ratings of a 1-star road segment.

4.2.2 Smoothened Star Rating

A Star Rating Score (SRS) is calculated for each 100-metre segment of road for vehicles occupants and motorcyclists. 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 road map, 100 metres is too much detail. Hence, Star Ratings are smoothed (or averaged) over longer lengths in order to produce more meaningful results. For urban road segments, the minimum length is 1km and for rural road segments, the minimum length is 3km.

4.3 Safer Road Investment Plan Methodology

EuroRAP considers 94 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. The methodology underpinning this process is available in Star Ratings and Investment Plans: (http://www.IRAP.org/en/about-IRAP-3/specifications).

4.3.1 SRIP Support Data

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.

Traffic volume data for vehicle occupants and motorcycles 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, AADT data for vehicle occupants was obtained from Portuguese road authorities data.

4.3.2 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. While a specific investment option is recommended, the ultimate decision on an appropriate investment level to improve safety rests with road authorities in Portugal. The benefit-cost ratios used in this project are BCR=3, BCR=4, BCR=5 and BCR=8 and the following table shows a benchmarking about each strategy:

Economic benefits				
Minimum benefit cost ratio	3:1	4:1	5:1	8:1
Investment (€)	100,465,611	72,662,057	53,526,484	26,015,682
Economic benefit 20 years (€)	766,004,467	683,056,678	604,520,761	438,188,533
Programme benefit cost ratio	8:1	9:1	11:1	17:1
Deaths (per year)				
Before countermeasures	141	141	141	141
After countermeasures	92	98	103	113
Prevented	49	43	38	28
Reduction	34.6 %	30.8 %	27.3%	19.8%
Deaths and serious injuries (20 years)				
Before countermeasures	12,746	12,746	12,746	12,746
After countermeasures	8,341	8,818	9,270	10,226
Prevented	4,405	3,928	3,476	2,520
Reduction	34.6 %	30.8 %	27.3%	19.8%
Cost per death and serious injury prevented (€)	22,810	18,500	15,398	10,325

Table 8: Investment Plan for a BCR=3, BCR=4, BCR=5 and BCR=8.

4.3.3 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-metre 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 Table 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.

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

Table 8: A sample of triggers for the delineation countermeasure.

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

4.4 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 estimation average costs provided by ANSR and the adaptation to the EuroRAP requirements was made by RACC team thanks to their experience in previous EuroRAP projects carried out in Spain in 2017. 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.

4.4.1 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 estimated to be: 70 x Gross Domestic Product (GDP) per capita (current price)
- the economic cost of a serious injury is estimated to be: 0.16 x economic cost of a death in Portugal.

On this basis:

- the economic cost of a death is estimated to be: € **681,800**
- the economic cost of a serious injury is estimated to be: **€109,096**

4.4.2 Discount rate

To calculate Net Present Costs and Benefits, a discount rate of 3% was used.

4.4.3 Number of deaths and serious injuries

Reported road deaths on surveyed road is 423 fatalities in the period from 2015 to 2017 (4 years), most of them vehicle occupants (54,6%). The estimated number of fatalities on analysed road network per year is 141. The reported ratio is 1 and it means that the underreported is not present in the Portuguese accident data and the serious injury to fatalities ratio 3.52 according to official data.

4.4.4 Road deaths on the road 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 ANSR:

Road user type	Estimated fatalities per year	Proportion of road deaths
Vehicle occupants	77	54.6%
Motorcyclists	28	19.8%
Pedestrians	28.7	20.4%
Bicyclists	7.3	5.2%
Total	**141**	**100%**

Table 9: Road fatalities in the analysed network for an average year.

4.4.5 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 the purposes of this project, roads have been split into sections roughly according to important towns, traffic volumes and changes in road features.

4.4.6 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. BCR=3, BCR=5 and BCR=8 are the values used in the present project and the common values in IRAP projects but for this project BCR=4 has been added in order to compare the best practices carried out by Highways England in UK.

4.5 Implementation

This section of the report presents the criteria used for identifying appropriate countermeasures and 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.IRAP.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.

4.5.1 Safe System

In order to improve road safety in Portuguese road network, 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.IRAP.org) and United Nations Road Safety Collaboration Good Practice Manuals provide further information on this issue.

4.5.2 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:

- opposing traffic is physically separated and roadside hazards are well managed
- traffic speeds are 90km/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, rather than on posted speed limits, because the real traffic speed is a better estimator of the safety performance of a roadway than the posted speed limit. The real traffic speeds (85^{th} percentile and 50^{th} percentile) were based on INRIX API. INRIX is one of the leading information data providers and obtained from loop sensor data and floating car data.

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.

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 appropriate 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 local 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.

ANNEX 1: FIRST SCENARIO (Minimum BCR=3)

Countermeasure	Length / Sites	FSIs saved	PV of safety benefit	Estimated Cost	Cost per FSI saved	Program BCR
Duplication with median barrier	593.20 km	2,336	406,297,006	46,863,760	20,061	9
Shoulder rumble strips	2,257.90 km	501	87,141,718	5,203,670	10,385	17
Central median barrier (no duplication)	86.00 km	374	65,082,994	6,745,068	18,013	10
Roadside barriers - passenger side	203.40 km	295	51,376,103	13,555,064	45,882	4
Skid Resistance (paved road)	197.20 km	210	36,597,781	3,964,446	18,843	9
Roadside barriers - driver side	108.50 km	160	27,811,617	7,181,908	44,932	4
Improve Delineation	215.60 km	129	22,447,479	3,373,032	26,132	7
Central hatching	514.20 km	117	20,288,274	4,124,661	35,366	5
Unsignalised crossing	3,662 sites	66	11,452,077	1,697,162	25,796	7
Improve curve delineation	64.80 km	49	8,508,221	1,434,302	29,303	6
Implement one way network	3.00 km	43	7,471,955	266,271	6,194	28
Footpath provision driver side (informal path >1m)	60.00 km	37	6,430,921	2,004,370	54,224	3
Additional lane (2 + 1 road with barrier)	6.80 km	23	3,947,147	958,5	42,205	4
Lane widening (>0.5m)	0.80 km	12	2,147,249	573,18	46,395	4
Parking improvements	15.70 km	10	1,668,303	412,748	43,045	4
Street lighting (mid-block)	2.50 km	10	1,808,862	418,56	40,217	4
Shoulder sealing passenger side (>1m)	8.40 km	6	1,100,424	302,17	47,795	4
Central median barrier (1+1)	1.50 km	5	844,672	228	46,955	4
Footpath provision passenger side (adjacent to road)	2.10 km	4	689,599	338,539	85,386	2
Signalise intersection (4-leg)	1 sites	4	736,54	212,308	50,099	3
Road surface rehabilitation	1.70 km	4	725,553	196,347	47,034	4
Upgrade pedestrian facility quality	74 sites	3	594,157	103,065	30,164	6
Duplicate - <1m median	1.20 km	1	257,767	83,077	56,357	3
Centreline rumble strip / flexi-post	4.60 km	1	192,217	63,935	57,81	3
Sight distance (obstruction removal)	0.20 km	1	112,139	43,039	66,705	3
Footpath provision driver side (adjacent to road)	0.50 km	1	187,19	108	100,277	2
Signalised crossing	3 sites	0	13,974	2,468	30,736	6
Grade separated pedestrian facility	1 sites	0	72,528	7,962	19,08	9
		4,405	766,004,467	100,465,611	22,81	8

ANNEX 2: FIRST SCENARIO (Minimum BCR=4)

Countermeasure	Length / Sites	FSIs saved	PV of safety benefit	Estimated Cost	Cost per FSI saved	Program BCR
Duplication with median barrier	485.60 km	2,132	370,867,866	37,700,832	17,68	10
Shoulder rumble strips	2,075.30 km	498	86,681,350	4,771,005	9,572	18
Central median barrier (no duplication)	63.50 km	339	58,976,638	5,018,646	14,79	12
Roadside barriers - passenger side	114.50 km	209	36,307,522	7,670,632	36,743	5
Skid Resistance (paved road)	166.60 km	207	35,930,095	3,270,380	15,832	11
Improve Delineation	168.90 km	117	20,418,770	2,576,509	21,943	8
Central hatching	368.90 km	103	17,873,792	2,904,907	28,266	6
Roadside barriers - driver side	47.70 km	102	17,729,908	3,236,308	31,773	5
Unsignalised crossing	3,108 sites	63	10,977,137	1,437,455	22,792	8
Improve curve delineation	50.60 km	44	7,628,037	1,097,232	25,003	7
Implement one way network	3.00 km	43	7,471,955	266,271	6,194	28
Footpath provision driver side (informal path >1m)	28.90 km	23	3,962,948	951,647	41,782	4
Additional lane (2 + 1 road with barrier)	1.60 km	8	1,451,037	249	29,825	6
Duplicate - <1m median	3.90 km	7	1,291,409	306,54	41,255	4
Lane widening (>0.5m)	0.40 km	7	1,226,875	260,536	36,908	5
Street lighting (mid-block)	1.20 km	6	1,081,598	207,66	33,369	5
Parking improvements	6.10 km	5	826,96	156,136	32,833	5
Shoulder sealing passenger side (>1m)	3.00 km	3	498,169	112,246	39,23	4
Upgrade pedestrian facility quality	60 sites	3	539,426	84,478	27,231	6
Footpath provision passenger side (adjacent to road)	1.00 km	2	349,49	157,5	78,326	2
Central median barrier (1+1)	0.70 km	2	296,577	84	49,227	4
Road surface rehabilitation	1.00 km	2	392,12	75,475	33,454	5
Centreline rumble strip / flexi-post	2.10 km	1	103,606	30,49	51,148	3
Sight distance (obstruction removal)	0.10 km	1	92,917	26,539	49,641	4
Signalised crossing	2 sites	0	10,948	1,672	26,544	7
Grade separated pedestrian facility	1 sites	0	72,528	7,962	19,08	9
		3,928	683,059,678	72,662,057	18,5	9

ANNEX 3: FIRST SCENARIO (Minimum BCR=5)

Countermeasure	Length / Sites	FSIs saved	PV of safety benefit	Estimated Cost	Cost per FSI saved	Program BCR
Duplication with median barrier	384.80 km	1,878	326,563,251	28,947,335	15,416	11
Shoulder rumble strips	1,892.80 km	490	85,131,460	4,335,844	8,857	20
Central median barrier (no duplication)	50.60 km	315	54,805,626	3,891,567	12,341	14
Skid Resistance (paved road)	145.00 km	202	35,175,519	2,804,764	13,869	13
Roadside barriers - passenger side	62.00 km	142	24,692,491	4,269,924	30,08	6
Improve Delineation	134.60 km	107	18,528,932	2,012,207	18,884	9
Central hatching	276.00 km	95	16,484,414	2,230,560	23,534	7
Roadside barriers - driver side	22.60 km	70	12,272,922	1,538,631	21,832	8
Unsignalised crossing	2,542 sites	58	10,082,985	1,172,352	20,237	9
Implement one way network	3.00 km	43	7,471,955	266,271	6,194	28
Improve curve delineation	36.80 km	38	6,593,798	796,721	21,003	8
Footpath provision driver side (informal path >1m)	14.90 km	14	2,459,735	492,046	34,799	5
Additional lane (2 + 1 road with barrier)	1.10 km	6	962,766	174	31,411	6
Duplicate - <1m median	1.70 km	4	726,506	138,847	33,217	5
Shoulder sealing passenger side (>1m)	2.50 km	3	456,294	91,2	34,798	5
Parking improvements	3.30 km	3	539,308	83,699	26,986	6
Upgrade pedestrian facility quality	41 sites	3	436,86	58,867	23,431	7
Street lighting (mid-block)	0.60 km	3	582,604	90,48	26,992	6
Footpath provision passenger side (adjacent to road)	0.40 km	1	149,566	61,5	71,466	2
Road surface rehabilitation	0.60 km	1	250,145	47,511	33,011	5
Centreline rumble strip / flexi-post	1.00 km	0	57,353	12,523	37,95	5
Signalised crossing	2 sites	0	12,638	1,672	22,994	8
Grade separated pedestrian facility	1 sites	0	83,633	7,962	16,546	11
		3,476	604,520,761	53,526,484	15,398	11

ANNEX 4: FIRST SCENARIO (Minimum BCR=8)

Countermeasure	Length / Sites	FSIs saved	PV of safety benefit	Estimated Cost	Cost per FSI saved	Program BCR
Duplication with median barrier	178.20 km	1,266	220,216,475	13,318,482	10,519	17
Shoulder rumble strips	1,466.90 km	451	78,353,198	3,349,938	7,435	23
Central median barrier (no duplication)	29.60 km	234	40,678,840	1,879,587	8,031	22
Skid Resistance (paved road)	93.20 km	175	30,505,201	1,783,941	10,171	17
Improve Delineation	80.60 km	82	14,297,234	1,158,428	14,088	12
Central hatching	163.00 km	78	13,611,926	1,266,977	16,186	11
Roadside barriers - passenger side	15.50 km	62	10,803,082	1,089,323	17,543	10
Roadside barriers - driver side	8.90 km	48	8,420,375	625,939	12,955	13
Implement one way network	3.00 km	43	7,471,955	266,271	6,194	28
Unsignalised crossing	1,273 sites	39	6,782,682	581,557	14,915	12
Improve curve delineation	17.30 km	26	4,549,863	375,656	14,35	12
Footpath provision driver side (informal path >1m)	4.30 km	6	1,005,561	142,292	24,614	7
Duplicate - <1m median	1.00 km	4	635,71	76,923	21,031	8
Upgrade pedestrian facility quality	21 sites	2	293,304	31,012	18,382	9
Street lighting (mid-block)	0.10 km	1	132,611	15,6	20,446	9
Shoulder sealing passenger side (>1m)	0.70 km	1	137,006	21,9	27,782	6
Parking improvements	1.00 km	1	201,667	23,019	19,839	9
Signalised crossing	1 sites	0	8,209	876	18,547	9
Grade separated pedestrian facility	1 sites	0	83,633	7,962	16,546	11
		2,52	438,188,533	26,015,682	10,325	17