Grant Agreement Number: INEA/CEF/TRAN/M2018/179967

Project acronym: SLAIN

Project full title:
Saving Lives Assessing and Improving TEN-T Road Network Safety

Due delivery date: 31/03/2021
Actual delivery date: 10/03/2021

Organization name of lead participant for this deliverable:
EuroRAP

D8.3: Recommendations towards the introduction of a network-wide road safety approach

Co-financed by the Connecting Europe Facility of the European Union
## Document Control Sheet

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<th>Authors</th>
<th>Summary of changes</th>
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<td>0.1</td>
<td>21/02/2021</td>
<td>Lina Konstantinopoulou, EuroRAP</td>
<td>1st draft</td>
</tr>
<tr>
<td>0.2</td>
<td>05/03/2021</td>
<td>Kate Fuller, IRAP</td>
<td>2nd draft</td>
</tr>
<tr>
<td>1.0</td>
<td>10/03/2021</td>
<td>Kate Fuller, IRAP</td>
<td>Final version for INEA</td>
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1 Executive Summary

The European Commission CEF funded project SLAIN (Saving Lives Assessing and Improving TEN-T road Network safety) aims to extend the skills and knowledge base of partners in performing network-wide road assessment. The European Road Assessment Programme (EuroRAP) is the overall Project Coordinator of SLAIN with partners: Anas, FPZ, RSI Panos Mylonas, RACC-ACASA, DGT Spain, SCT Spain, TES Spain (Catalonia) and iRAP.

The main areas to be covered within the SLAIN project are:

- The demonstration of a methodology of network-wide assessment.
- The assessment of the Safety Performance Management of the TEN-T core road network and, if possible, beyond, in four European countries: Croatia, Italy, Greece and Spain where road surveys (10,000 km of mapping) will be performed.
- Proposals for section-specific, economically viable crash countermeasures designed to raise infrastructure quality to achieve significant reductions in severe injuries and deaths.
- Review of some relevant factors associated with the preparation of the readiness of Europe’s physical infrastructure for automation.

This deliverable D8.3 provides recommendations on all activities and focuses on a set of policy recommendations to the European Member States and the European Commission emphasising the need of establishing a ‘Network-wide Road Assessment programme’ within the framework of a National Road Safety Action plan.

Chapter 2 provides an Introduction

Chapter 3 details what the network-wide road assessment is

Chapter 4 details the SLAIN activities and outcomes

Chapter 5 provides policy recommendations to support the implementation of the National Road Safety Action plan.
2 Introduction

2.1 SLAIN project objectives

The European Commission CEF funded project SLAIN (Saving Lives Assessing and Improving TEN-T road Network safety) aims to extend the skills and knowledge base of partners in performing network-wide road assessment. The European Road Assessment Programme (EuroRAP) is the overall Project Coordinator of SLAIN with partners: Anas, FPZ, RSI Panos Mylonas, RACC-ACASA, DGT Spain, SCT and TES Spain (Catalonia) and iRAP.

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- Proposals for section-specific, economically viable crash countermeasures designed to raise infrastructure quality to achieve significant reductions in severe injuries and deaths.
- Review of some relevant factors associated with the preparation of the readiness of Europe’s physical infrastructure for automation.

2.2 SLAIN Activity 8 objectives

The objective of SLAIN Activity 8 is project management and dissemination of results.

Task 8.1 - Project coordination and quality management

Task 8.2 - Project reporting to INEA and the National Ministry

Task 8.3 - Dissemination and communication

Task 8.4 Policy feedback to the EC

Figure 1: SLAIN Activity 8 tasks

The Grant Agreement (page 9) highlighted the forthcoming amendment to the Directive and the support that SLAIN would give to the revision:

“This Action fits is the EC’s 2010 Communication ‘Towards a European Road Safety Area’ and aims to contribute to the long term goal for zero road deaths in 2050.

It supports Art. 5 and 6 of Directive 2008/96 EC and the EC proposal 2018/0129 (COD) amending the Directive, in particular Art. 5 (new methods of safety ranking), Article 6 (proactive network-wide safety inspections) and the new Art. 1 la (reporting requirements). It further supports proposal 2018/0129 (COD) amending the Directive, in particular (section 3, pp. 7): “the wish to support a degree of harmonisation of the physical infrastructure to allow the smooth roll-out of higher levels of automation and to ensure that automated vehicles operate safely in mixed traffic”.”
2.3 Purpose of this deliverable

Introduction of a network-wide road safety approach will require a mindset change from many practising engineers across Europe and different high-level policy-setting across nation states. It will also require high quality implementation support when tasks, similar to Activity 2 but conducted outside the current project, are completed. Such implementation support enables analyses to inform road improvements.

In Task 8.4 EuroRAP will work with road authorities outside the project to prepare them for the changes that will come. The implementation support of Task 8.4 will take a generic form of the integration support described as Task 2.7_Italy_Croatia. It will involve leading road authorities, dependent upon the maturity of the processes in each country and the engagement of the stakeholders in each country, through the following steps:

- how local examination of proposed countermeasures can be used on their core TEN-T
- what is to be gained from detailed analysis of traffic survey and crash data (where reliably available for their part of the TEN-T)
- how to conduct preliminary scheme investigation studies, including site surveys and preliminary design
- the role of detailed design, Star Ratings of Designs, road safety audit, detailed costing and procurement, final evaluation and construction, and
- how to conduct post-construction evaluation and road safety audit, including Star Ratings for the upgraded road and analysis of crash data.

This deliverable will provide SLAIN Activity recommendations on all activities and focus on a set of policy recommendations to the European Member States and the European Commission emphasising on the need of establishing a ‘Network-wide Road Assessment programme’ within the framework of a National Road Safety Action plan.
3 What is the Network-Wide Road Assessment?

To improve road safety and reduce the number of road casualties it is necessary to implement measures which are evidence-based and are supported by relevant data (e.g., road crash and road infrastructure data).

In many countries the most severe crash hotspots have already been tackled or hotspots are no longer simple to identify as crashes become increasingly sparsely distributed across networks, so in order to further reduce the number of road fatalities and serious injuries, it is necessary to perform more detailed investigations of the relevant road traffic crash characteristics, including the circumstances of road crashes, the mechanisms and causes leading to crashes, the severity of road crashes, the involved road users, etc., as well as to periodically undertake proactive risk assessment of the road network in order be able to select and prioritise the optimal countermeasures that will be implemented in future periods.

Risk assessment methods assist in understanding the consequences of road crashes and provide information on:

- How often crashes occur
- When and where they happen
- What are the typical hazards which are present on the observed road network sections
- Which vehicle, driver and infrastructure characteristics contribute to road traffic crash occurrence

The main objective of network-wide road assessment is to support national road safety strategies and to provide an additional layer of relevant information alongside already existing approaches.

Network assessment is built on the philosophy of route safety assessment, where the risk of death and serious injury is estimated on individual road sections across a road network. Network assessment is based on the principle that different routes of a specific type are combined and shape a network.

Network assessment typically covers roads outside towns and cities, where deaths and serious injuries for vehicle occupants are mostly concentrated. Not all roads carry the same risk; and examining the statistics from a wide range of countries show that around 50% of total fatalities occur on as little as 10% of total roads. Therefore, network-wide road assessment enables the identification of the safest and most hazardous road sections within observed region or country. The classification and identity of methods used to perform network assessment are shown on Figure 2 below.
Reactive methods can be applied only on existing roads since data requirements (Crash rates, annual average daily traffic (AADT), etc.) for performing such methodologies usually require the road to already be in use. Proactive methods however can be applied to either existing roads or new roads since they examine the ‘in-built’ safety of the roads.

Road Safety Audits and Road Safety Inspections are listed in Figure 2, but undertaking a network-wide safety assessment with either can be an unpractical and a tedious process. Other methods described within Chapter 3 of SLAIN Deliverable 3.1 “Technical Justification for Network-Wide Road Assessment”\(^1\) have the potential to carry out the ranking of high crash concentration sections and network safety ranking, in accordance with an Annex III of Directive 2008/96/E.

Some network assessment methods (such as the Road Assessment Programme (RAP) protocols) support performance tracking, which demonstrates how risk on the network as a whole has changed over a given period of time. Knowing where risk has been reduced and which of the countermeasures have proven most cost-effective is essential in building best practice and knowledge transfer.

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3.1 Requirements of Directive (EU) 2019/1936 on Road Infrastructure Safety Management

In the Directive (EU) 2019/1936, it is stated that the road infrastructure safety management (‘RISM’) procedures implemented on the TEN-T network have helped reduce fatalities and serious injuries in the Union. It is clear from the evaluation of the effects of Directive 2008/96/EC that Member States which have been applying RISM principles on a voluntary basis to their national roads beyond the TEN-T network have achieved much better road safety performance than Member States which did not do so. It is therefore also desirable for those RISM principles to be applied to other parts of the European road network.

A large proportion of road crashes occur on a small proportion of roads where traffic volumes and speeds are high and where there is a wide range of traffic travelling at different speeds. Therefore, the limited extension of the scope of Directive 2008/96/EC to motorways and other primary roads beyond the TEN-T network should contribute significantly to the improvement of road infrastructure safety across the Union. In order to ensure that such extension of scope has the intended effect, it is logical that primary roads other than motorways include all roads belonging to the highest category of road below the category ‘motorway’ in the national roads classification. For the same reason, Member States should be encouraged to ensure that at least all roads to which Directive 2008/96/EC applied before the entry into force of Directive (EU) 2019/1936, including on a voluntary basis, remain covered by this Directive.

Following the directive 2008/96/EC specifications, Network-Wide Road Assessment, should be carried out by experts. The amended directive has an extended scope. It applies to:

- Roads which are part of the trans-European road network, to motorways and to other primary roads, whether they are at the design stage, under construction or in operation;
- Other roads situated outside urban areas, which do not serve properties bordering on them, and which are completed using EU funding, except for roads not open to, or not designed for, general traffic.

The Network-Wide Road Assessment consists of measuring the safety performance of existing roads, then by targeting investments to the road sections with the highest level of risk (collective) and/or the greatest FSI (fatal and serious injury) reduction potential. According to the Directive 2008/96/EC:

- EU countries must carry out a network-wide road safety assessment, by 2024 at the latest and every 5 years subsequently, on the entire road network in operation covered by the directive. These assessments must assess crash and impact severity risk, based on:
  - a visual examination, either on site or by electronic means, of relevant road design characteristics; and
  - an analysis of sections of the road network which have been in operation for more than 3 years and where there have been a large number of serious crashes in proportion to the traffic flow.
- Assessment findings must be followed up by targeted road safety inspections or, if necessary, remedial action.
- Periodic road safety inspections must also be made, frequently enough to maintain adequate safety levels for the road infrastructure in question.
- The specific needs of vulnerable road users such as cyclists and pedestrians must be considered systematically in all road safety management procedures.
- Safety assessments must be published to highlight the safety level of road infrastructures across the EU.
➢ Existing and future procedures for road markings and road signs must focus on readability and detectability for human drivers and automated driver assistance systems.

➢ An assessment by a group of experts established by the Commission must, by June 2021, assess the opportunity to set common rules considering:
  ▪ The interaction between various driver assistance technologies and infrastructure.
  ▪ The effect of the weather and atmospheric phenomena as well as traffic on road markings and road signs present on EU territory.
  ▪ The type and frequency of maintenance efforts necessary for various technologies, including an estimate of costs.

➢ EU countries must notify the Commission of all the motorways and primary roads on their networks, as well as those roads exempt because they have a proven low safety risk, by 17 December 2021.

➢ The Commission must publish a map of the European road network within the scope of the directive, accessible online, highlighting different categories according to their level of safety.

The UN General Assembly has adopted resolution A/74/L.86 “Improving global road safety”, proclaiming the Second Decade of Action for Road Safety 2021-2030, with the ambitious target of halving the number of road traffic deaths and injuries during this period. The Second Decade of Action for Road Safety will continue to reinforce 12 Global Road Safety Performance Targets, including Target 3 and Target 4. The resolution also endorses the Stockholm Declaration, approved during the Third Global Ministerial Conference on Road Safety held in February 2020.

In addition, a Ten Step Plan for safer road infrastructure was produced in 2020 by the UNRSC Safer Roads and Mobility Group. This plan provides a clear process for establishing national (including urban) road safety strategies, building capacity, and creating partnerships to support the achievement of the UN Member States Agreed Global Targets 3 and 4 for safer new and existing roads. The Ten Step Plan is a key resource to support the Second Decade of Action for Road Safety (2021-2030). Road safety is also an essential component in the planning and implementation of local and regional Sustainable Urban Mobility Plan (SUMP) as sustainability is not possible without effective road safety measures.
4 SLAIN Activities Outcomes and Recommendations

4.1 Activity 1: Crash Risk Maps

4.1.1 Objective

The objective of Activity 1 was to produce maps showing total risk as an overall part of network-wide road assessment. A Crash Risk Map of death and serious injury was produced for each country illustrating both the individual risk and the collective risk for fatal and serious crashes for all sections of the TEN-T Core Network in Croatia, Greece, Spain and Italy.

This provides a preliminary and immediate basis for comparison of the safety of the networks being examined and can be used as the basis for further analysis. They can be used to compare current performance and also track that over time. The relevant beneficiaries in each territory were responsible for producing the map in that territory.

4.1.2 Outcomes

Crash Risk Mapping

The Reports and Maps detailing the results can be found here https://eurorap.org/slain-project/ in the following deliverables:

- D1.1 – Two maps for Croatia in 2020 and 2021
- D1.2 - Two maps for Italy in 2020 and 2021
- D1.3 - Two maps for Greece in 2020 and 2021
- D1.4 - Two maps for Spain in 2020 and 2021
- D1.5 - Two maps for Catalonia in 2020 and 2021

Performance Tracking

In order to further understand the significant contribution of motorway and state road network to the improvement of the road safety level across the country, the “Performance Tracking” of Risk Maps 2014-2018 and 2015-2019 has been undertaken. The EuroRAP “Performance Tracking” protocol allows a comparison to be made between the risk mapping results of two consecutive four-year periods. Both the individual and collective risk are considered. The results are below.

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2 Italy undertook performance tracking 2015-2017 and 2016-2018
Croatia

Figure 3: Comparison of the relative frequency of the individual risk bandings on the Croatian TEN-T road network

Figure 4: Comparison of the relative frequency of the collective risk bandings on the Croatian TEN-T road network
Greece

Figure 5: Development of the relative frequency of the Greek Core TEN-T network length by risk band (individual risk)

Figure 6: Development of the relative frequency of the Greek Core TEN-T network length by risk band (collective risk)
Figure 7: Comparison of the distribution of Anas TEN-T network length by risk band (individual risk)

Figure 8: Comparison of the distribution of Anas TEN-T network length by risk band (collective risk)
Spain

Figure 9: Individual risk comparison between the two periods on the Comprehensive TEN-T in Spain

Figure 10: Collective risk comparison between the two periods on the Comprehensive TEN-T in Spain

Catalonia

Figure 11: Individual risk comparison between the two periods
4.1.3 Recommendations

Specific recommendations can be found in the individual reports; however the generic recommendations are listed in the following paragraphs.

The technical specification document\(^3\) captures the usefulness of showing the risk to an individual road user. It states: "An essential focus of RAP is to improve recognition among road-users that they must share in the responsibility for a safe road system. In producing maps aimed at individual risk, it is therefore important to counter the common assumption that their purpose is to inform the road-user of how best to modify the route taken to minimise their likelihood of being involved in a crash. This is especially true where mapping covers only higher-tier road networks, since it is known that roads off the main road network typically have higher crash rates.

The main purpose of mapping individual risk is to:

- inform road-users of how and where their behaviour needs to be modified to minimise risk and, in doing so, to help them to understand the role of road infrastructure in determining the risks they face. It is hoped that, over time, this will aid clearer recognition of the influence of road design on risk and how it can vary on different types of road;
- illustrate more generally how high-level infrastructure variables, such as carriageway type and road standard, influence risk."

A Crash Rate Risk map showing crash density is designed to be useful to the road operator, showing where road sections have a high number of crashes and therefore may be used to target remedial action."

Allocation of data, normalisation, ratios and thresholds

The four countries dealt with allocation of crashes to road sections in different ways and these are listed in the individual reports.

Crash Risk Map thresholds are determined by the ratio of fatal and serious crashes to fatal crashes for the network being examined. The study has shown that, where this ratio varies widely between road types (e.g. Core TEN-T compared with other Comprehensive roads), there may be an argument for providing separate Crash Risk Map thresholds for these different categories of roads. If this is not done and only one ratio is provided for the entire network, then it may over- or understate the risk for some

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roads near the threshold boundaries. This potential limitation should be assessed further (see below).

**Mapping presentation**

Linked to the issue of normalisation is the question of presentation of the Crash Risk Maps. Countries have elected to present them in the individual styles familiar to their national audiences. This supports the discussion highlighted in D1.1-1.5 that making a direct comparison between countries using these particular Crash Risk Maps may be problematic. The maps do of course identify higher and lower risk roads, but there will potentially be a narrower distribution of risk rates, for example, in a country map using only much longer road sections. Similarly, road sections in different countries with a similar risk and close to risk thresholds may not be consistently allocated to the same risk bandings. More work needs to be done to understand the mathematics of these issues and to take appropriate approximating action when presenting Crash Risk Maps from different countries together. It is worthy of note that these same limitations in mapping risk do not exist when making transnational comparisons using the iRAP Star Rating protocols.

**Data definition**

Despite the extensive work on injury severity definition over recent years, information on the severity of non-fatal accidents is still not available in the accident database in Italy. Work to enable this should be a priority.

**Under-reporting**

There is clearly a problem with the collection of serious road crash data in Greece. The number of serious injured is recorded as less than the number of fatalities (688 deaths and 652 serious injured in 2019, while 12,350 slight injuries are reported⁴). In earlier work during the period 2002-2006 EuroRAP called for data in Italy to be improved – both the locational coding of crash data and the increased availability of traffic volume data. In the intervening 10-15 year period, data appear to have improved in Italy (with, for example, greater availability of traffic data), but it is clear that in Greece and in other countries too, there must be improvements.

**Documentation**

Whilst addressing procedures and protocols, it should be noted that that the EuroRAP description of the Crash Risk Mapping procedure was written originally for an assessment of the British Motorway, trunk and primary road network. The guidelines suggest that an aspirational target for 20 crashes per section when mapping. There is a balance to be struck between the number of years of data necessary to collect this total or indeed the length of the road section required. This target is not often achieved, even in the UK where data collection is good. The guidance should be revised so that countries can work towards achieving the balance of:

- a statistically reliable crash total for the section
- a time span that will not have seen substantial road changes over time, and
- a road length that can be addressed in its entirety with improvements or an improvement package.

Further, it is proposed that the guidance be revisited to incorporate some of the salient material in the calculation of thresholds for Crash Risk Mapping described above.

**Performance tracking**

The overlapping time periods used in the examples here have meant that only very small changes in performance can be demonstrated over time. It would be worthwhile to make such comparisons with

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a smaller overlap of data.

4.2 Activity 2: Star Rating

4.2.1 Objectives

The specific objective of this activity was the production of maps showing the total risk as an overall part of network-wide road assessment, together with investment plans.

Most of the countries had some Star Rating data collected from earlier projects. Greece has recent data (2014) for the entire TEN-T network, already has a Star Rating map for the relevant roads and did not repeat the exercise as part of the Action SLAIN. For Croatia data were collected for all of the Core TEN-T network and in Italy for the Anas core network. In Spain, including Catalonia, there were data conducted from other studies that were analysed and the policy implications of this work assessed.

It should be noted that at the time of writing this report, Italy had not completed their Star Rating work, this is due to be completed until the end of July 2021 and is not included here.

4.2.2 Outcomes

The Reports and Maps detailing the results can be found here https://eurorap.org/slain-project/ in the following deliverables:

- D2.2 Star Rating map for Croatia
- D2.3 Report for Spain on tailoring the methodology to national and regional needs and how to improve and develop the methodology
- D2.4 Validation study with Spanish crash data and Star Rating data

D2.2 Star Rating map for Croatia

The purpose of the iRAP methodology is to assess the contribution of the road infrastructure to risk of a road user suffering fatal or serious injury. The iRAP Star Rating protocol has been developed to separately assess the level of risk relevant to car occupants, pedestrians, bicyclists and motorcyclists on urban, and rural roads.

In a period from November 2019 to February 2020, a total of 2,748 km of the TEN-T road network in the Republic of Croatia was surveyed by the Faculty of Transport and Traffic Sciences using a dedicated survey vehicle and specialized technology.

The roads surveyed were a mixture of dual and single carriageways, some parts in need of rehabilitation, while most of the motorway sections were newly built. The older state road sections typically do not have the appropriate protection or crash-avoiding provision which is available in other high-performing parts of the network. Crash protection systems such as barriers and modern, well-designed intersections are not provided on the older parts of the observed state road sections.

The frequency of road crashes in certain parts of the observed TEN-T road network sections in Croatia depends largely on its shortcomings. Through the specific analysing software ViDA™ - courtesy of the project accessible to road authorities - it was possible to identify the dangerous high risk road sections. The Star Rating results for infrastructure safety are presented for different road users (on a 1-5 star scale) – vehicle occupants, motorcyclists, pedestrians, and cyclists. Only 0.4% of the surveyed road network was awarded 5 stars, and 11.2% was awarded 4 stars for the vehicle occupants. On the other hand, 20% of the network gained only 1 star. The rating for motorcyclists is even worse due to the fact that 63% of the road network length belongs to the one-star high-risk category.

5 Please note D2.1 Star Rating Map for Italy is not yet complete
Figure 13 shows the raw Star Rating results for the inspected network and Figure 14 shows the Star Rating map for vehicle occupants.

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Figure 13: Star Rating results (Raw) for the inspected network

If three stars is set as a desirable acceptable road safety standard, then it can be concluded that 39% of roads on the TEN-T road network in Croatia do not have a satisfactory level of road safety for vehicle occupants and 95% of the road sections are below acceptable road safety standards for motorcyclists. On state roads, 96% of road sections in the pedestrian category, and 89% of road sections in the cyclists category were rated less than three stars.
Examples in the report provide an insight of the approach in which cost-effectiveness may be used to generate a list of priority countermeasures within a limited budget. The initial SRIP involved production of a list of all countermeasures that could feasibly be built on the road, sorted in order of descending Benefit/ Cost ratio (BCR). The countermeasure download file, available online, was used to generate this list.

The estimated cost of upgrading and rehabilitation along the entire length of the network is assumed to be HRK 379,614,186.00 and will provide a BCR of more than 5. The casualty savings on the priority sections would be around 1,116 fatal and serious injury cases saved over 20 years if the TEN-T road network sections are upgraded.

Predominant proposed countermeasures that are expected to produce the maximum effect are:

- Implementing or upgrading the roadside barriers, both on passenger and driver side;
- Implementing the central median barrier (1+1) on state roads;
- Facilitation of shoulder rumble strips;
- Implementation of central hatching on state roads;
- Clearing the roadside hazards on both passenger and driver sides; and
- Traffic calming measures.

D2.3 - Report for Spain on tailoring the methodology to national and regional needs and how to improve and develop the methodology

The deliverable explains how the EuroRAP applications and policy formulation have been improved thanks to the Spanish experiences in road safety projects during the last few years and the different ways to tailor the methodology to national and regional needs. The document has been structured in six different chapters representing the different subtasks of the project, with the involvement of one or several Spanish participants. The six sections are listed in the next paragraphs.

**Subtask 2.8.1. Define final objectives of Star Ratings:** RACC-ACASA and TES developed several EuroRAP projects in Catalonia with the first experiences in Star Ratings and Safer Roads Investment Plans in that region. Hence, the methodology has been tested and at this stage a further step has been developed to define the final objectives of the EuroRAP methodology. After a detailed analysis of RACC data and after a wide analysis of the staff performance of TES in terms of conservation and maintenance, the results will be incorporated to the existing road maintenance and a monitoring protocols will be deployed by the public administration. The strategy will be focused in two ways:

- Combine all the data that TES has in the different management systems from all the territory, obtain accurate conclusions about what is happening in the road network and therefore make evidence-based decisions when investing the conservation budget in road countermeasures, using RACC’s Safer Roads Investment Plans.
- Perform the cost-benefit analysis of conservation operations, in terms of road safety and not only within the scope of each management system associated with specific risks. The planning of the maintenance work will be conducted more efficiently and will obtain the best combination of personal work and external contracts.

The final objectives above have been developed in the SLAIN framework and therefore all of them can be replicated in other countries.

**Subtask 2.8.2. Country strategy:** With the RACC-ACASA’s data management, the Spanish public administrations have defined their strategy on data collection: DGT has developed specific methodologies for obtaining supporting data inputs required in an EuroRAP project: value of life,
annual average daily traffic, countermeasure cost, type of crashes and operating speed. On the other side, TES from the Catalan government is working on developing an automated coding for obtaining the information (all parameters required by the methodology) and avoiding human errors during the process. Hence, the country strategy of Spain is covering all the Star Ratings methodology: the collection of external data and coding of road attributes. RACC-ACASA has contributed with the strategy definition and will continue the contribution assessing the implementation of a systematic collection protocols.

DGT has classified the Spanish actors according to the road authorities, traffic management centres and other stakeholders. 93 countermeasures have been defined by DGT to be used as a basis for the Spanish Safer Roads Investment Plans and a how to collect all supporting data has been reported.

**Subtask 2.8.3. Training on road survey and road coding for Star Ratings:** RACC-ACASA has developed a training course about the first steps of EuroRAP methodology: “Road survey for data collection and road coding to process all the information from the infrastructure”. All the contents of the training are included and, in general terms, are divided in the following aspects:

- **Road survey:** detailed information of the field work and all devices of the equipped vehicle and its calibration, the selection of road segments/routing and how to conduct surveys and data collection process every 10m.
- **Road coding:** how to code the images collected during the inspections and the back-office process to obtain all the 52 road attributes. In addition, the characteristics of the output file to calculate the road safety action plan are analysed in the training documents.
- **Supporting data:** which type of additional data from other sources is needed: traffic volumes (AADT), crash data (location, types, modes, fatal and serious victims, etc.) on the road network under study, operation speed versus 85th percentile and costs of countermeasures.

DGT and its subcontractors will be trained to be capable of creating road surveys and all coding process according to EuroRAP manuals.

**Subtask 2.8.4. Training on ViDA software:** RACC-ACASA has also developed training on use of the ViDA tool, especially on Star Ratings for each mode of transport and Safer Roads Investment Plans with different benefit/cost ratios. Both are part of a systematic, proactive approach to road infrastructure risk assessment and renewal based on research about where severe crashes are likely to occur and how they can be prevented. The training includes:

- **Star Ratings:** the objective is to measure the safety performance of a road network. The 52 road attributes coded are scored (from 1 to 5 stars) and combined to reflect the overall safety of car occupants, motorcyclists, bicyclists and pedestrians. The ViDA online simulator is a key aspect of the training.
- **Safer Roads Investment Plans:** the main goal is to know how the EuroRAP algorithm estimates the number of killed and seriously injured persons (KSI) and the display of countermeasures for reducing casualties. The different periods of time and cost-benefit ratios are key aspects of the training.

The DGT and its subcontractors will be trained to understand how to calculate both results of the EuroRAP methodology. In addition, they will also receive all the indication to maintain both Star Ratings and Safer Roads Investment Plans updated with road infrastructure modifications.

**Subtask 2.8.5. Analyse and assess final results from Star Ratings and Safer Roads Investment Plans:** In order to validate that EuroRAP results are useful for assessing the road infrastructure upgrades, RACC-ACASA and DGT went one step further and developed criteria to select the road network to be assessed based on crash rates and road authority categorisation (based on ownership) for those roads carrying AADT>2,000 vehicles/day. As part of this, the Spanish TEN-T network has been extensively analysed, enabling identification of the TEN-T network and analysis of its safety characteristics.
There are various ways to consider the relationship between Star Ratings and Crash Risk Mapping and the application of this relationship is listed in the recommendations of this section.

DGT has led an assessment of the application of the iRAP tools, suggesting some improvements on iRAP methodology based on its own SRIP country experience.

**Subtask 2.8.6. Data analysis and reporting leading to Star Rating and Safer Roads Investment Plans:**
This subtask was developed by DGT with the objectives to take advantage of the Star Ratings results and Safer Roads Investment Plans, as a natural continuation of the methodology and the task. DGT’s objective is to improve the translation of technical reports into political decisions to effectively improve the road network and make roads safer. The subtask focused on the use of evidence-based results and by the allocation of road maintenance budget. The document shows one step further with what the specific countermeasures to improve the road safety currently are implemented in Spain and what are the difficulties to deploy the SRIP in the Spanish road network. This information from public information and based on proven experience will be very valuable for developing road safety strategies in other countries in the SLAIN framework.

**D2.4 Validation Study with Spanish crash data and Star Rating data**
The validation study had the outcomes detailed in the following paragraphs.

It was observed that means decrease as the number of Stars increases, apart from the 1-Star rate, which may be due to there being too many factors which have a negative effect in the score of the road, and it cannot be presumed that these results are relevant into 1-Star group.

The relative risks obtained based on the 4-Star Rating group indicate that in the sections of 2-Stars there is almost seven times more likelihood of having a crash than in those sections of 4-Stars and those of 3-Stars are about four and a half times more likely to have crashes than those of 4-Stars (relative risk 2-4 = 6.80 (95% CI: 4.01 to 11.54) and relative risk 3-4 = 4.56 (95% CI: 2.76 to 7.54).

Figure 15 shows the relative risk ratio (with respect to 4-Star rating group).

![Figure 15: Relative risk ratio (with respect to 4-Star rating group)](image)

Therefore, it could be stated that the risk of having a crash is higher the lower a road’s Star Rating is,
that means, it is demonstrated that crashes decrease as Star Rating improves.

The confidence interval (95%) shows that there can be 95% confidence (not the certainty) that the true relative risk value in the population is between the calculated parameters in each case.

On the other hand, DGT has been involved in a study in which associated costs with traffic crashes including victims were estimated. Results have been updated taking as a reference the baseline variation of Gross Domestic Product (GDP) per capita (as of 1st January 2018); these costs add up to:

- Deceased: 1,580,318 €
- Serious injury: 247,207 €
- Minor Injury: 6,886 €

Applying the above costs to the number of deaths, hospitalized injuries and non-hospitalized injuries in crashes in 2018 yields that costs associated with victims are estimated to be at least € 5,956 million, although according to other information systems they could reach € 11,217 million. Taking into account that GDP at market prices on January 1st, 2018 was 1,208,248 million €, the percentage of GDP represented by these costs is at least 0,49%, although it seems reasonable to assume 0,93%, which is obtained by jointly analysing sources of information from transport and health sectors. (published data on: http://www.dgt.es/es/seguridad-vial/estadisticas-e-indicadores/publicaciones/principales-cifras-siniestralidad/)

Conclusions of this study and the above financial data show that, even though there are many factors that can contribute for a traffic crash to happen; it could be stated that an improvement on Star Rating would lower the number of traffic crashes (the relative risk of having a traffic crash happen on 2-Star Rated roads is 6,80 times more likely than those of 4-Star Rated roads; and 4,56 times on 3-Star Rated roads compared to 4-Star Rated roads).

4.2.3 Recommendations

Further work with larger and better data sets is required to refine and examine the relationship between the Star Rating and crash costs or crash rates. Often such analyses are problematic because of the quality of the crash data rather than any deficiency in the iRAP model. It should also be noted that often the crash data in such comparisons do not match sufficiently accurately the individual component of the Star Rating being compared (e.g. only vehicle occupant crashes). The comparison is in any case only assessing the infrastructure element of the crash (in the Star Rating) with the entirety of the human-vehicle-road element and thus a perfect match should not be expected.

In terms of using Crash Risk Mapping and Star Rating to select priorities, road authorities may take the following approach:

- Roads which have a high Crash Risk Rating and low Star Rating have both crash risk and infrastructure safety deficiencies. These roads may be prioritised for safety investment if they carry sufficient traffic for this to be economically viable.
- Roads with a low Crash Risk Rating and high Star Rating have little evidence of danger to the road user and so may be low on the priority list.
- Roads with a low Crash Risk Rating and low Star Rating may require further investigation since infrastructure safety deficiencies may lead to crashes in the future.
- Roads with a high Crash Risk Rating and high Star Rating may indicate the need for a review of road user behaviour.

Star Rating enables within country and between country comparison of the safety built into a road network. It would be useful if the European Commission would explicitly reinforce its support for between-country comparisons. Such comparisons would have major benefits in enabling examples of
good practice to be shared and would demonstrate where parts of the TEN-T network are less good than others.

4.3 Activity 3: Technical justification for network-wide road

4.3.1 Objectives

This activity compared network-wide road assessment alongside other methods – providing information and know-how to countries who are yet to carry out network assessment.

4.3.2 Outcomes

There has been a review of different forms of network-wide road assessment and a comparison of these strategies with traditional “crash cluster” and “hot spot” approaches. This has used the data available from Greece to explain and provide a rationale for potential users of a network assessment approach.

There is a comparison of the methodologies and assessment of the implications of selection strategies. It provides a scientific and technical illustration of why it is best to use a network safety approach rather than other methods.

The report and flyer detailing the results can be found here https://eurorap.org/slain-project/ in the following deliverables:

- D3.1 Report on the technical justification for network-wide road assessment
- D3.2 Flyer leaflet on the technical justification for network-wide road assessment

4.3.3 Recommendations

The Deliverable D3.2 Leaflet on Technical Justification for Network-wide Road Assessment is drawn from SLAIN Deliverable D3.1 and consists of an overall review of the different road risk assessment approaches, focusing specifically on “black spot”, route safety and network-wide road assessment, the techniques by which these approaches are implemented, as well as the primary principles and features of each approach.

On higher-order road networks (such as the TEN-T or national strategic roads), a proactive road assessment approach is recommended in accordance with other international guidance every 5 years. These relatively short networks carry such high volumes of traffic that this thorough approach along with an annual blackspot surveillance programme, is commensurate with the level of investment necessary. This allows various investment package scenarios to be modelled at a network-wide level, allows the setting of (and monitoring against) road safety infrastructure performance metrics (as proposed by the WHO), and tracking and modelling of progress towards short term casualty reduction goals and longer-term road safety ambitions (e.g. towards zero road deaths by 2040 or 2050).

On lower-order networks with roads carrying above 5000 AADT, a three-step approach is recommended:

- As an initial step it is important to perform an iRAP Crash Risk Map of the network, where the higher risk or higher potential return routes will be identified.
- The second step, according to the available resources, focuses on the most critical routes. The route assessment may be performed through iRAP Star Rating which provides detailed information about risk along the routes, an estimation of where fatal and serious injuries are likely to occur in the future and an initial Safer Roads Investment Plan.
In the third step, development of a user defined investment plan (UDIP) is required and this may be focused where the greatest concentration of fatal and serious injuries are expected, where risk is high and where countermeasures show initial good returns in the iRAP model. It is important to apply local knowledge and engineering judgement to the iRAP model recommendations to ensure that the UDIP is practicable and appropriate to local conditions and practice. Since this step is the most resource-consuming, it greatest benefit to decision makers to apply it only where the interventions are likely to offer the highest Benefit to Cost Ratio.

So, to upgrade the road safety performance of a network, a top-down approach should be followed, narrowing the area of application, from a network to a road section level through well-documented and widely-accepted techniques that are now being used worldwide.

4.4 Activity 4: “How to” guide for network-wide road assessment

4.4.1 Objectives

Activity 4 will build on material used in activity 3 to produce a step-by-step guide for the practitioner. This is a guide which will explain the circumstances, data and steps required to make network-wide road assessment.

4.4.2 Outcomes

The Report detailing the results will be found here⁶ https://eurorap.org/slain-project/ in the following deliverables:

- D4.1 A step-by-step guide
- D4.2 Updates published on the beneficiaries webpages

4.4.3 Recommendations

The “How to” guide for network wide road assessment was based on the work provided in Activity 3: Technical justification for network wide road assessment. In order to prevent the obsolescence of the guide, a comment section should be provided in order to incorporate additional comments provided by guide users. Also, as new EU directives will be published, amended versions of the guide should elaborate on recommendations relevant for the network wide safety assessment.

As a step-up approach, future work should focus on the development of teaching and training materials, suitable for a wider range of target groups. The current guide version is helpful for road authorities to gain an understanding of available road assessment methodologies however, as a standalone deliverable, it does not provide clear guidance on how to perform the road assessment.

Activity 4 is linked to Activity 3 and therefore the recommendations are based on the use and application of the justification and rationale explained in that report.

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⁶ Please note that at the time of writing this report, these deliverables had not been completed
4.5 Activity 5: Global analysis of the safety of the TEN-T – research and mining of data from previous network-wide road assessment

4.5.1 Objectives

The specific objective of this activity is the production of a technical report. In particular, the report will include an analysis of road survey data for roads held in the iRAP ViDA data platform.

The purpose of this activity is to provide to the European Commission a more formal estimate than previously available of the overall safety of the Core TEN-T network and demonstrate what must be done to improve that.

A secondary objective is that, using data from Greece (the applicant country with good data), but also from other countries, it will be possible to show the detailed applications now possible within ViDA. These will be used as an “advertising brochure” for a new way of working and for the new tools now available. It will demonstrate how a network-wide road assessment can provide the capability for programme planning.

The tangible outcomes from this module are that the Commission will have a confirmed and refined view of the safety of its network and what must be done to raise its standards. There will also be awareness among engineers that there are new and better ways of approaching their daily work. Engineers’ skillsets are improved and they and their employing organisation have a better view of what is required nationally to reduce death and serious injury on the roads for which they have responsibility.

4.5.2 Outcomes

Activity 5 includes a detailed and extensive assessment of the extent of the Core TEN-T network that achieves the 3 star or more international benchmark for infrastructure safety. The purpose is to provide the Commission with a more formal estimate of the Core TEN-T network’s overall safety than previously available.

It will also provide an estimate of the potential casualty savings available and cost required to achieve these, and it will provide proposals for an investment plan designed to improve the standards of this network. The tangible outcomes from this activity are that the European Commission will have a confirmed and refined view of the safety of its network and what must be done to raise its standards.

The deliverable will focus on the assessment of the safety of the Core TEN-T network, presenting an indicative overview of the safety of roads on the Core TEN-T, particularly in respect of the 3 star or more benchmark. All of the countries with Core TEN-T roads are included – i.e. not just the 28 countries within the EU (when the project began) – although the data available, and hence estimates, are more crude for many of the Neighbouring countries.

The Report detailing the results will be found here https://eurorap.org/slain-project/ in the following deliverables, once the report is completed

- D5.1 Technical report on the global budget for raising the entire TEN-T network to a higher level of safety

Initial results which are currently being consulted on include Figure 16 the Draft Estimated proportion of travel on roads on the Core TEN-T network in each country relative to the UN Infrastructure Safety Performance Target and Figure 17 the Draft Indicative map of estimated average star rating on each TENtect road section on the Core TEN-T network.
Figure 16: Draft Estimated proportion of travel on roads on the Core TEN-T network in each country relative to the UN Infrastructure Safety Performance Target

Figure 17: Draft Indicative map of estimated average star rating for vehicle occupants on each TENtec road section on the Core TEN-T network (Mapbase © Google)
4.5.3 Recommendations

The work in this activity used details about the core TEN-T held by TENtec. An update to the TENtec dataset had been scheduled for 2020, but was postponed; this update would enable the estimates made in this activity to be more accurate.

The approach used could easily be extended beyond the core TEN-T to cover all of the comprehensive TEN-T; this would enable further prioritisation of the highest risk roads across the entire trans-European network.

Roads which appear to be 1 or 2 star need to be reviewed in more detail: the current results are indicative and high-level only, and more data would enable the estimates to be more accurate. Detailed investigation should focus on countries which currently appear to be the furthest from achieving the 3 star plus target, and there are plenty of opportunities to improve road safety in these countries, whether they are in the EU or are Neighbouring countries.

Where full star rating data are already available, investment is required on roads which have been confirmed as being 1 or 2 star. This could pay for itself many times over, ensure that the UN target is achieved, and save numerous lives.

4.6 Activity 6: Case studies using the application of network-wide road assessment

4.6.1 Objectives

The specific objective of this activity is the collection of a series of 110 examples or case studies in total using the following five techniques:

- Case Study A: Risk Mapping to guide selective Star Rating
- Case Study B: Before and after studies of network upgrading
- Case study C: Identifying road sections to install 2+1 barrier
- Case study D: Maintenance-only remedies
- Case study E: Network-wide road assessment and Star Rating from design plans

4.6.2 Outcomes

The Reports and Maps detailing the results will be found here [https://eurorap.org/slain-project/] in the following deliverables:

- D6.1 Case Study A report
- D6.2 Case Study B report
- D6.3 Case Study C report
- D6.4 Case Study D report
- D6.5 Case Study E report

As part of a process of focusing in on risk, selective Star Rating in the Group A studies on part of a network was used after Crash Risk Mapping the entire network. This can identify different levels of infrastructure safety risk within a road section shown to fall into one overall crash risk category.
Selective Star Rating can be done for the four road user groups: vehicle occupants, motorcyclists, pedestrians and bicyclists. There are good examples of this for Croatia, Greece, Hungary, Italy, Spain and the UK.

In Croatia and Italy the process has been taken further and risk assessed at 100m intervals using the risk worm and a Safer Roads Investment Plan (SRIP). Some examples from England show the location of particular treatments and the anticipated benefit-cost ratio returns.

“Before and after” studies from Group B show the role of the iRAP tools in demonstrating the role of the tools in increasing the Star Rating (or assessing the component parts of that risk by reducing the Star Rating Score) for locations and for sections of road. The iRAP Demonstrator is often used in this process to illustrate how risk can change in one or more contiguous 100m sections (see in particular the examples from Spain and Italy). The reduction in risk after implementing countermeasures is clear, even when crash and injury data are sparse and not of a quality able to fully support that argument. The examples from Slovakia illustrate this process over longer lengths of the motorway network.

Studies in Group C were used as an illustration of how Vision Zero principles can be applied to the network. The examples from Sweden explain this at a national and local level and those from the Netherlands and Catalonia in Spain at a regional and local level. Fatal and serious injuries can be reduced by half using the road configuration of a 2+1 layout with a median barrier. Examples from Greece, the Netherlands and from Hungary show how the iRAP software may be used to identify sites or support the case for such configurations. A pilot study in Ireland has been identified and further work should be undertaken to examine the policy outcomes from that project.

Maintenance-only measures shown in the case studies in Group D may be used to increase the Star Rating and to reduce risk (as also measured by the Star Rating Score showing the component parts of the risk in the Star Rating). These measures may include reinstatement of road surfaces, better signing and lining, provision of rumble strips, sealing of shoulders and central hatching to separate opposing flows. There are examples from all four countries involved in the Action (Croatia, Greece, Italy and Spain). It is noticeable too that when these measures are combined with primary safety features such as roadside barriers that the safety improvement shown is of course even greater.

For Group E case studies, various iRAP tools have been used in conducting Star Rating for Designs (SR4D). Four methods are used: the specially-developed iRAP SR4D app; runs of different future scenarios on the iRAP ViDA software platform; by using the iRAP demonstrator and by using the Star Rating for Schools (SR4S) app. These methods are used in a variety of different situations:

- assessing potential and actual schemes from a few hundred metres to 20+ kilometres in Italy and Croatia with the SR4D app
- using the Demonstrator to assess an urban and freeway settings in Greece, for different scenarios after a bridge reconstruction and new bypass (in Spain)
- tackling a widespread and common problem of poor pedestrian crossing quality around schools in Moldova with the SR4S app
- working from first principles using the iRAP software platform ViDA to show how much longer road lengths (10km-100km in these examples) of international significance may be assessed from the design plans after funding from European and international donors or lenders (in Bosnia and Herzegovina and in Moldova).

The iRAP Demonstrator is also used to encourage familiarity with typical design profiles and their risk factors for both for rural roads and motorways.
4.6.3 Recommendations

The Group A case studies encountered a perennial road safety problem – whether it is better to identify high risk sections on the basis of individual risk (crashes per billion vehicle-kilometre) or collective risk (crashes per kilometre). In these case studies both methods have been used at various times, as required, and this is recommended. This issue was addressed in a study in the UK\(^7\) which explained the need for some caution in this exercise in the following recommendations:

“The road sections were identified for the Safer Roads Fund on the basis of risk (crashes per billion vehicle kilometres driven) rather than a more traditional metric of crash density (fatal or serious crashes/km). This means that the roads were not always considered by the local authorities to be high priority. Selecting purely on the basis of crash risk meant inclusion of some roads that were very low flow, with crash numbers subject to random fluctuation. Moreover, because of the time gap between the analysis period on which the selection was done and the start of the work, some authorities had already made efforts to address safety concerns on their section.

“Selection of further tranches should include safeguards such as a crash density threshold, further analysis to ensure statistical robustness (e.g. the persistently higher risk calculation that the Road Safety Foundation uses or Bayesian modelling) and a check to ensure that eligible roads have not already been treated in the inevitable time lag between analysis and selection.”

A clear emphasis from the Group A case studies has been the issue of roadside hazards, notably in Croatia. There have been numerous examples of roadside safety deficit identified on roads of national and international significance and this should be tackled.

The Group B case studies identified the need for better quality crash data. Small numbers and large variation are familiar problems in crash analysis. The iRAP Demonstrator can be a reliable source of evidence of a safety improvement, often more reliable than crash data. The assessment of crashes and injuries before and after engineering interventions could also be strengthened by the use of crash control data either of similar sites or the national picture for the network as a whole.

Group C – the selection of roads the configuration of a 2+1 with median barrier – needs more understanding of why this configuration may be popular in some countries and not in others and the reasons behind the “tried-but-not-convinced” response in Ireland. In Sweden, this configuration is being used on certain designs of road irrespective of the crash risk and mainly as a means of proactively reducing head-on risk. Consideration should be given to this approach elsewhere.

Group D – maintenance-only measures can improve Star Ratings in some situations, notably on a reasonably high-standard 2-star undivided road, but not in all circumstances. Obviously, if complemented by elements such as barrier installation or replacement (where it has been assumed in the latter case that existing barrier has no positive effect on safety), they have a bigger impact. Improving the quality of low-safety of undivided single carriageways is rightly a European priority and should continue to be. More opportunities should be taken to improve the standard of undivided roads.

The Group E case studies of Star Ratings for Designs have shown four ways to do such a rating: via a ViDA run; using the iRAP Demonstrator; the SR4D app; and the SR4S app. More work can be done to provide examples from the TEN-T. It is possible that there are relatively few recent network-wide efforts on those roads that have been documented in the countries of the Action but it is also likely that this shows how the relative road safety engineering priority has been on the primary road network. There were however several examples from roads of national and international significance in other

4.7 Activity 7: Preparing the physical infrastructure for automation

4.7.1 Objectives

The specific objective of this activity is to perform a three-part study to show readiness of physical infrastructure for automation.

4.7.2 Outcomes

The Reports and Maps detailing the results can be found here: https://eurorap.org/slain-project/ in the following deliverables:

- Deliverable D7.1 Report - Quality of horizontal and vertical signs - ‘Roads that cars can read’
- Deliverable D7.2 Report - Other initiatives to meet the needs of automated cars
- Deliverable D7.3 Automatic coding methodology of the network for network wide road assessment
- Deliverable D7.4 Evaluation of improvements achieved with an automated coding methodology

For Task 7.1, a consultation exercise on road signs was undertaken in a workshop on 10 December 2019 validating the needs and requirements of the stakeholders. A Best practice workshop with Austroads was also held. The two current CAV readiness pilots (SLAIN and AustRoads) provide basis for such a framework. It was found that the harmonised framework for road safety assessment for the readiness of infrastructure for CAVs needs to consider not only road markings and traffic signs but all the road environment and geometry attributes (e.g. following the 52 iRAP road attributes) as well as considering weather conditions and digital infrastructure. The content of such a road safety assessment on CAV readiness would need to be carefully considered to ensure the full range of potential impacts are considered and that key attributes are able to be measured in a meaningful and consistent manner.

In Task 7.2, the SLAIN project performed a desk-based research and technical review on the current state of the art between horizontal and vertical signs. For this task, EuroRAP was supported by the European Road Federation and 3M as experts on Standardisation of road markings and also received contributions by the UN ECE WP.1 on the Convention on Road Signs and Signals.

With the support of the subcontractors (TomTom, ANDITI, FACTUAL), the SLAIN project performed the pilot study as part of Task 7.3 to determine what are the key physical parameters for lines and signs required to assess if a road is CAV ready and then use these parameters to assess the CAV readiness of 2000 km of road across four countries (Croatia, Greece, Italy, and Spain shown in Figure 18). A validation workshop was organised on the 20th November. For Task 7.4 ANAS also analysed the comparison of both data sets collected in Italy, one by the “readability pilot on road markings” conducted by EuroRAP and the other by the “Standard measurement of marking quality” elaborated by Anas through the DELPHI survey.
The assessment by country included:

- **Croatia** – Lines and Signs along 36 road segments (500 km) (undivided and divided roads)
- **Greece** – Lines and Signs along four (4) road segments (500 km) (undivided and divided roads)
- **Italy** – Lines along nine road segments (500 km) (divided roads only)
- **Spain** – Lines along four road segments (500 km) (undivided and divided roads).

### 4.7.3 Task 7.3 CAV readability of Lines

Results for line detection using 360-degree imagery and computer vision techniques indicate that lines across the majority (88.5%) of the Core Ten-T network are CAV readable with the remaining 11.5% being made up of approximately 7.3% tunnel, 3.2% undivided road, and 1% divided road. Recorded dropout lengths (i.e. where the line was not detectable for greater than approximately 16 metres) ranged from 0 km (0%) on divided roads in Croatia to 62.3 km (82.1%) on undivided roads in Greece.

- Analysis indicates that the main reasons for dropouts by country and road type are as follows:
  - **Croatia** – Faded or undetectable right lines on undivided roads (1.6 km) out of 128.1 km analysed on undivided roads.
  - **Greece** – Faded right line (30.7 km) and no right line (23.9 km) on undivided roads out of a total of 75.9 km analysed on undivided roads.
  - **Italy** – Faded left line (6.7 km) on divided road out of a total of 500.3 km analysed on divided roads.
  - **Spain** – No lines (2.3 km) on divided road out of 459.3 km analysed on divided roads.

### 4.7.4 Task 7.3 CAV readability of signs

Based on the assessment undertaken as part of this study:

- In Croatia approximately 10.6% of the five key sign types (predominantly Speed signs) were not detected using computer vision techniques on undivided roads and 24.9% on divided
roads. These signs are unlikely to be CAV readable. The majority of these were Speed signs which in Croatia was mainly due to them being placed low on safety barriers or high on poles and in Greece predominantly because the signs were cluttered (i.e. several signs at one location) or multi-lane Speed signs (i.e. more than one speed shown on the same sign).

- In Greece approximately 5.4% of signs were not detected using computer vision techniques on undivided roads and 4.1% on divided roads. These signs are unlikely to be CAV readable.

4.7.5 Comparison of results from the “readability pilot” and Anas quality evaluation Index

The scope of the task was to understand if standard measurement of the quality of markings, always adopted by road operators both to verify painting works and to evaluate the quality of existing markings, could give indication on the readability of markings for automated vehicles.

A comparison of results obtained in the “readability of lines” conducted by EuroRAP and in the “Standard measurement of marking quality” elaborated by Anas through the DELPHI survey has been conducted by Anas.

Results obtained from the comparison showed that failures in line recognition are linked to degradation of the quality index based on driver’s need, resulting that only 5% of lines detectable by the CAV perspective have a poor quality index from driver’s point of view.

In line with the “Recommendations from work on the CAV readability of signs and lines”, the comparison work also indicates that the road marking qualification process carried out by Anas and the standard of 150 [mcd/lux/sqm] required for Italian motorways, guarantee a very high likelihood that the lines will be detected.

4.7.6 Recommendations from work on the CAV readability of signs and lines

These recommendations are taken from those in the Anditi report 8 for the SLAIN project:

“From a CAV readability perspective, excluding tunnels, only 4.2% of lines on roads were not CAV readable. The main reason for this was either faded or non-existent lines. The lines on many of the roads analysed appeared to have been in place for several years and were either faded, cracked, impacted by dirt and grime or just not there. More frequent application of line markings would address this issue.

“Analysis indicates that using CAV computer vision techniques which take into account a multiple of road surface attributes, the width of the line (i.e. whether it is 100 mm wide of 150 mm wide) impacts on CAV readability of a line to a far lesser extent than if the line is clearly delineated from the adjoining road surface. (i.e. sufficient contrast and consistency between the line and the road surface). With machine learning approaches that are trained to visualise lines, consistency or reduced variability can be more important than contrast.

“Wider lines (i.e. 150 mm) are more likely to be visible to humans (who have broad range of vision capabilities) and under a wider range of road conditions. As a result, it is likely that humans, not CAV will be the controlling factor in determining line width specifications.

“In regard to LiDAR detection of lines, the relatively small footprint of each LiDAR beam means that line markings in a consistent good condition will be more reliably detected than wider lines in a less consistent condition. The wider the line the greater number of samples that can be recorded due to the greater number of returns per line segment. However if the lines are not frequently updated the wider line could, from a CAV perspective introduce more variability and uncertainty due to the small size of the beam footprint that is used to sample the road. As a result, from a CAV perspective there is

8 SLAIN task 7.3 Final Report from Anditi, 23 October 2020
a trade-off between greater width of line which would make the line more detectable for humans and how frequently the line marking is re-applied with more frequent applications on narrower lines likely to provide greater CAV readability.

“In addition, the type of materials used for the road surface and for shoulders also need to be considered as these can impact on the Intensity of Return values obtained from LiDAR. Analysis indicates that some road surface materials such as concrete have similar reflectivity to lines making lines hard to detect where lines are in close proximity to concrete shoulders and concrete safety barriers.

“Findings from the project indicate that matters affecting CAV readability of signs were predominantly to do with:

- non-standard sign types (i.e. multiple signs on one pole or multiple speeds on one sign)
- non-standard locations of signs (i.e. low on safety barriers or high on poles).

“All of the issues identified in this study in regard to CAV readability of signs could be addressed by standardisation of sign types, symbols used, shapes, heights, locations and orientations. It is likely that any CAV will be sold and utilised globally within individual cars likely to travel across many countries, particularly in Europe.

“Artificial Intelligence techniques used by CAV require algorithms to be trained using labelled examples. The more diverse and variable the range of sign types and formats used, the larger the training set that is required. Similarly, in regard to sign location, the wider area that a CAV needs to search to look for signs, the wider the field that needs to be scanned, the greater the amount of data that needs to be processed and the greater the number of decisions need to be made before detection occurs and appropriate actions undertaken.”

4.7.7 D7.1 Quality of horizontal and vertical signs and D7.2 Other Initiatives to meet the needs of automated vehicles

The SLAIN project provided a state-of-the-art summary review on the infrastructure implications for automated vehicles and crash analysis literature review. The key activities and findings are summarised below:

- More than 160 references/bibliographies have been collected and assessed covering the period of 2013-2020) on physical infrastructure and CAVs.
- There is no doubt that research on digital infrastructure and CAVs is well established across EU and International Cooperation, whereas the research on the physical infrastructure and CAVs is relatively scarce. For example, a TU Delft study titled “Research report summarizing the scientific knowledge, research projects, test sites, initiatives, and knowledge gaps regarding infrastructure for automated vehicles”, reviewed FP7-H2020 European Commission projects from 2008 till 2017 on 1) cooperative systems, 2) automated vehicles, 3) cooperative and automated vehicles, and 4) vehicle platooning, and their relation to the physical road infrastructure. The same study also focused on EU and International Cooperation pilots. It concluded that all projects/pilot results focused ONLY on the digital infrastructure perspective.
- The current state of the art evidence used scientific and technical papers, simulations, and small pilot projects results. There is no clear published (or otherwise available) knowledge at this point regarding the changes required in physical infrastructure to scale up the changes required to make CAV operation possible.
- The D7.2 state of the art review reaffirms that the road markings and traffic signs and pilot results as analysed in SLAIN D7.1 are not the sole physical infrastructure requirements for CAVs. All iRAP road risk attributes are relevant for Automated Driving Systems (ADS) dynamic driving tasks. There is no sufficient research published (or otherwise available) to come to a
A definitive conclusion on the extent of relevance (e.g., exact specifications/parameters). This would require extensive research and large-scale pilots. The available literature indicates a diversified view among different authors on the few road attribute parameters/specifications required for CAV operation.

- The scientific literature reaffirms that there is still a lot of research to be done in relation to physical road attributes and ADS crash types/rates/patterns. When evaluating safety features using data for collisions involving CAVs it is of particular importance to understand how the crash occurrence and the safety features of ADS relate to each other. Future research is needed to the effectiveness of individual countermeasures (e.g., rumble strips, striping, adjustments to lane widths) with the increase in CAV penetration rate.
- Although technology is continuously being improved by CAV developers, the automated driving system / dynamic driving tasks still need to be further developed to bridge the gap between research and deployment.

4.7.8 Task 7.6 Automatic coding of the network for network wide road assessment

Additionally, the SLAIN project has developed an automatic coding methodology for Network-Wide Road Assessment. A preliminary feasibility study of automatic recognition of road safety attributes according to the iRAP methodology has been undertaken. The methodology initially relied on monocular video as the only input modality and it was later extended to process rasterized 2D projections of point-cloud input data, provided such data is available. SLAIN formulates the problem of automatic coding as a separate multi-class classification of each iRAP attribute for a given road segment. To classify a segment, each classifier takes a georeferenced video clip and/or a point-cloud projection that corresponds to that particular road segments.

The proposed solution is based on an efficient multi-task model with a shared image feature extractor backbone and one classification head for each attribute. It can recognize all attributes with a single forward pass and learn in an end-to-end fashion. The high-level architecture of the system is shown in Figure 19 and it is the crucial part of the proposed automatic coding methodology. A detailed technical description of the system and experimental results on real-world datasets acquired by FPZ can be found in the paper Multi-Task Learning for iRAP Attribute Classification and Road Safety Assessment that was published and presented at The 23rd IEEE International Conference on Intelligent Transportation Systems (ITSC 2020) as part of this applied artificial intelligence research effort.

Figure 19: Architecture of the system

In the preliminary studies, SLAIN addressed a subset of 33 iRAP attributes that had sufficient coverage in the acquired datasets, though the model was later extended to handle all 52 attributes. The per-
attribute results of the best model are shown in Error! Reference source not found., and we provide a discussion of class imbalance and other problems that hamper correct recognition of some attributes. The recognition success wildly varies across the attributes. The study shows that the described setup suffers from many problems that are not present in academic datasets. The most important among them is the extreme class imbalance that affects a lot of attributes.

The results are shown in Table 1.

Table 1: Results

<table>
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<th>Attribute name</th>
<th>M-F1</th>
<th>Acc.</th>
<th>MCB</th>
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<tr>
<td>Delineation</td>
<td>96,3</td>
<td>97,2</td>
<td>73,9</td>
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<td>Divided carriageway</td>
<td>96,2</td>
<td>98,1</td>
<td>92,5</td>
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<tr>
<td>Sidewalk - passenger-side</td>
<td>90,7</td>
<td>95,3</td>
<td>70,4</td>
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<tr>
<td>Sidewalk - driver-side</td>
<td>89,5</td>
<td>94,3</td>
<td>84,2</td>
</tr>
<tr>
<td>Area type</td>
<td>87,1</td>
<td>87,3</td>
<td>60,9</td>
</tr>
<tr>
<td>Street lighting</td>
<td>81,5</td>
<td>84,0</td>
<td>50,4</td>
</tr>
<tr>
<td>Roadworks</td>
<td>77,6</td>
<td>99,4</td>
<td>99,1</td>
</tr>
<tr>
<td>Land use - passenger-side</td>
<td>71,0</td>
<td>75,0</td>
<td>41,8</td>
</tr>
<tr>
<td>Land use - driver-side</td>
<td>70</td>
<td>73,4</td>
<td>44,9</td>
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<tr>
<td>Lane width</td>
<td>65,4</td>
<td>92,4</td>
<td>86,3</td>
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<tr>
<td>Sight distance</td>
<td>63,6</td>
<td>88,6</td>
<td>85,7</td>
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<tr>
<td>Quality of curve</td>
<td>61,3</td>
<td>75,8</td>
<td>59,1</td>
</tr>
<tr>
<td>Paved shoulder - passenger-side</td>
<td>60,4</td>
<td>91,7</td>
<td>63,6</td>
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<tr>
<td>Paved shoulder - driver-side</td>
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<td>Median type</td>
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<td>Grade</td>
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<td>97,6</td>
</tr>
<tr>
<td>Vehicle parking</td>
<td>56,2</td>
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<td>84,7</td>
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<tr>
<td>Roadside severity - driver-side distance</td>
<td>54,4</td>
<td>66,7</td>
<td>62,3</td>
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<tr>
<td>Roadside severity - passenger-side dist.</td>
<td>54,2</td>
<td>66,9</td>
<td>71,0</td>
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<td>Property access points</td>
<td>52,9</td>
<td>75,8</td>
<td>47,2</td>
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<td>Upgrade cost</td>
<td>52,9</td>
<td>69,3</td>
<td>67,0</td>
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<td>Road condition</td>
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<td>Curvature</td>
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<td>Sealed road</td>
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<td>98,2</td>
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<td>Pedestrian crossing - inspected road</td>
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<td>99,0</td>
<td>99,1</td>
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<td>Roadside seventy - passenger-side object</td>
<td>47,9</td>
<td>58,5</td>
<td>20,9</td>
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<tr>
<td>Number of lanes</td>
<td>47,2</td>
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<td>91,4</td>
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<tr>
<td>Pedestrian crossing quality</td>
<td>46,3</td>
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<td>98,9</td>
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<td>Intersection quality</td>
<td>45,5</td>
<td>96,9</td>
<td>96,9</td>
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<tr>
<td>Intersection type</td>
<td>43,9</td>
<td>96,9</td>
<td>97</td>
</tr>
<tr>
<td>Roadside severity - driver-side object</td>
<td>39,7</td>
<td>53,5</td>
<td>21,2</td>
</tr>
<tr>
<td>Pedestrian crossing - side road</td>
<td>39,5</td>
<td>99,7</td>
<td>99,6</td>
</tr>
</tbody>
</table>

In Table 1, Acc. denotes the standard accuracy metric, while M-F1 is a more strict metric called macro-
F1. Macro-F1 gives equal importance to underrepresented classes in the dataset, which is important because of the severe class imbalance present in the dataset.

As can be seen from the results, some attributes such as Delineation or Divided carriageway are ready for full automation, even with our simple model and a limited quantity of training data. On some other attributes, our model is not yet ready for industrial exploitation, either because of too few training data (class imbalance; e.g. Pedestrian crossing, Sealed road) or because of the sheer difficulty of the recognition problem (e.g. Intersection quality, Roadside severity).

Examples in Figure 20 show which areas of the image the model has learned to look at to make a decision for particular attributes.

Figure 20: Heatmaps that show which parts of images the model focuses on to make decision for particular attribute

4.8 Linkages between the activities


As outlined in the project description (section 2), this Action fits is the European Commission’s 2010 Communication ‘Towards a European Road Safety Area’ and aims to contribute to the long term goal for zero road deaths in 2050.

When signed, the Grant Agreement (page 9) referenced that SLAIN:

“...supports Art. 5 and 6 of Directive 2008/96 EC and the EC proposal 2018/0129 (COD) amending the Directive, in particular Art. 5 (new methods of safety ranking), Article 6 (proactive network-wide safety inspections) and the new Art. 1 la (reporting requirements).”

Responding to these needs:

- Crash Risk Mapping (Activity 1) and Star Rating (Activity 2) have been shown to be tools to support this process. In particular, Crash Risk Mapping may guide selective Star Rating and the Safer Roads Investment Plans provide indicative crash countermeasures that may be implemented on particular road sections
- Activity 3 explains the rationale for this approach alongside other measures and Activity 4 provides a “how to guide”
- Activity 5 shows the extent of the task involved in bringing the entire TEN-T network up to a higher safety standard and estimates the measures and costs required to do this work.
- Activity 6 brings all of Activities 1-5 together with case studies of Crash Risk Mapping and Star Rating and illustrations and explanations of processes required in Directive 2019/1936. It does this with reference to the tools available in the iRAP software suite of tools within ViDA and links to “Vision Zero” and Safe System concepts.

The Grant Agreement also said that SLAIN:
“...further supports proposal 2018/0129 (COD) amending the Directive, in particular (section 3, pp. 7): “the wish to support a degree of harmonisation of the physical infrastructure to allow the smooth roll-out of higher levels of automation and to ensure that automated vehicles operate safely in mixed traffic””.

Activity 7 has provided a state of the art summary of the readiness of the network for automated vehicles and collected data on the readability of signs and lines in Croatia, Greece, Italy and Spain.
5 Policy Recommendations to support the implementation of the National Road Safety Action plans

EuroRAP welcomes Directive 2019/1936 – Amendment of Directive 2008/96 on Road Infrastructure Safety Management Directive (RISM). 20 EuroRAP national programme leaders have published a report with a set of concrete recommendations to the European Member States and the European Commission emphasising on the need of establishing a “Network-wide Road Assessment programme” within the framework of a National Road Safety Action plan9. Building on successful work globally10, the recommendations from the EuroRAP national programme document are provided in three levels, as shown in Figure 21 below and described below as related to SLAIN.

![EU Road Safety Goals](image)

**Figure 21: EU road safety goals within network-wide road assessment**

**Level 1: Member States could carry out gap analysis that incorporates:**

- Holding a National Safer Road Infrastructure workshop to review the current systems and capacity to deliver safer road infrastructure.
- Defining the key responsibilities and accountabilities for Road Infrastructure Management
- Review of policies standards, guidelines, and funding mechanisms to establish how safety performance is built in.

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10 [https://www.who.int/roadsafety/publications/20200219-202801-4216-unrsf-10-steps-infrastructure.PDF?ua=1](https://www.who.int/roadsafety/publications/20200219-202801-4216-unrsf-10-steps-infrastructure.PDF?ua=1)
Level 2: Member States could develop their National Road Safety Action Plans by embedding

- EC Road Safety Strategy Goals (RISM Directive) and UN Global Road Safety Performance Targets 3 and 4.

Level 3: Member States could establish a stepwise programme for assessing road infrastructure that provides a holistic approach to the whole lifecycle of the road network. It should include:

a. A road safety partnership that involves the key stakeholders; road authority/operators, civil society, national road safety agency, police, and research organisations, and others.

b. Routine road safety assessments that target the highest risk roads and that are integrated with wider asset management inspections and utilise a common data structure is used to encourage compatibility. As SLAIN has shown, selection of high-risk roads may be made on the basis of Crash Risk Mapping (using individual or collective risk dependent upon circumstances) or by use of the Star Rating.

c. Monitoring using crash data and proactive safety assessments which take into consideration all road users in the way that SLAIN has done for vehicle occupants, motorcyclists, pedestrians and cyclists.

d. Reporting of road safety infrastructure KPIs (following all types of the road network) such as the Star Rating of roads on a 1-5 scale of infrastructure safety provision.

e. Capacity building/training/best practices (using the justification and teaching material presented in Activities 3 and 4 and the examples provided in Activities 1, 2, 5, 6 and 7) to ensure that the road safety community stays abreast of latest developments and the Safe System approach is embedded.

f. Encourage “designing roads right the first time” through aligning road design standards with the UN Global Road Safety Targets, and the integration of road design assessments (such as those using the Star Rating of Design techniques demonstrated in Activity 6) and Road Safety Audits.

g. The definition of network appropriate intervention levels to prioritise investment based on proactive fatal and serious injury estimations as is available within the iRAP software and tools suite ViDA and demonstrated in Activity 2, 5 and 6.

h. A network-wide road safety assessment methodology that visually represents the needs of every road user type in regard of the local context (see, for example Activity 2) – by mapping risk and appropriate crash countermeasures. The methodology needs to be transparent and based on published scientific evidence and harnesses a framework that allows for innovation and evolution to account for developments in both road infrastructure and vehicle technology (see, for example, https://www.irap.org/methodology/ and also Activity 7 on automation).

i. Utilise investment plans to guide financing so that the true value of life is reflected in road maintenance, road upgrades, and major infrastructure improvements (see, for example, Activities 2, 5 and 6 and the comparison of the costs and benefits of crash countermeasures).

j. Celebrate the successes in delivering safer roads (as illustrated in the numerous group B case studies included in Activity 6).
6 Annexes

About EuroRAP

The European Road Assessment Association (“EuroRAP”) was established in 2000 as a sister organisation to the successful Euro NCAP to develop parallel protocols for road assessment and to develop systematic large scale infrastructure safety investment programmes.

EuroRAP is the ‘gatekeeper’ of the iRAP global protocols in Europe ensuring quality and consistency in applying the RAP protocols nationally and locally. The RAP protocols measure the risk of roads that are in operation:

- The first uses a Proactive approach which is based on a visual examination of « in-built safety » of roads. This safety rating is called the Star Rating. EuroRAP inspections and road safety assessments focus on more than 50 different road attributes that are known to influence the likelihood of a crash and its severity. These features include intersection design, road markings, roadside hazards, footpaths and bicycle lanes - all fully in line with RISM ANNEX IIa-Indicative elements of targeted road safety inspections and ANNEX III-Indicative elements of network. Our cooperation with technology suppliers, can even provide these data in a more frequent basis through our ai-RAP innovation framework.

- The second protocol uses a Reactive approach using reported crashes and traffic data. Many authorities have their own systems of crash mapping, but the RAP protocols could be complemented to those and can also allow ‘performance tracking’.

- Fatality Estimation Mapping illustrates the distribution of the expected number of fatalities and serious injuries across a road network and can support higher risk roads identification.

- The RAP protocols take into consideration roads that are at the design stage (Star Rating for Design) and under construction. The inclusion of the Star Rating of a Design as part of the Road Safety Auditors assessment of a road design is encouraged.

The continuous improvement of these protocols has been made possible by global philanthropy, multilateral banks, international institutions, governments, NGOs, motor and roads industries and individuals. RAP metrics are applied in projects by the World Bank and regional development banks worldwide including the European Investment Bank and EBRD in Europe.

EuroRAP has already supported road safety assessments in 40 European countries inside and outside the EU based on globally recognised methods. More than 170,000 kms of road has been Star Rated for in-built safety. Crash Rate Risk Mapping has been carried out on more than 1.3 million km with important tracking of progress over time in improving safety. Roads of all types have been assessed including roads on the TEN-T network, primary, regional and urban networks. More than 4,275 people have been trained and more than 25 billion euro of investment has been shaped to drive infrastructure upgrades that save lives. Those assessments have either been performed by the EuroRAP national programme leads as national initiatives or within European Commission projects (e.g. SENSOR, RADAR, SLAIN).

In 2009, EuroRAP received a Prince Michael International Road Safety award for establishing iRAP as a global umbrella for road assessment during the first inter-Ministerial meetings on road safety in Moscow. The Moscow meeting led to the UN Decade of Action 2011-2020. Today, as we reach the launch of the 2nd UN decade of Action on Road Safety, iRAP (the International Road Assessment Programme) is recognised as one of the successes of the UN’s global collaboration and in 2020 also received the Prince Michael International Road Safety award. It is the umbrella programme for Road Assessment Programmes (RAPs) that are working to save lives. Worldwide, iRAP and its regional ‘X’RAP programmes, among which includes EuroRAP, are influencing the safety of large-scale investment. RAP programmes and projects have now been undertaken by partners in more than 100 countries.
worldwide covering Europe, Asia Pacific, North America, Latin America and the Caribbean, and Africa.

**About EuroRAP National Programmes**

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<thead>
<tr>
<th>Country / State</th>
<th>Program Lead</th>
<th>Supporting Public Authorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albania</td>
<td>Automobile Club Albania</td>
<td>Ministry of Infrastructure and Energy and Albanian Road Authority</td>
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<td>Belgium</td>
<td>VIAS Institute</td>
<td>2 region (Flanders and Wallonia) pilot is under way <em>(supported by BRRC)</em></td>
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<td>Bosnia Herzegovina</td>
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<td>Ministry of Communication and Transport</td>
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