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: 31st March 2021
Actual delivery date: 13th March 2021

Organisation name of lead participant for this deliverable: RSI ‘Panos Mylonas’

D6.4: Activity 6 case studies group D

Co-financed by the Connecting Europe Facility of the European Union
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Acknowledgement
The SLAIN beneficiaries are grateful to EuroRAP and iRAP for the research information provided. The report was coordinated and prepared by RSI Panos Mylonas, supported by iRAP and the Road Safety Foundation, with liaison with INEA by the project coordinator EuroRAP. Individual project partners provided the case studies.

Abbreviations and Acronyms

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<thead>
<tr>
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<th>Abreviation</th>
</tr>
</thead>
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<tr>
<td>SLAIN</td>
<td>Saving Lives Assessing and Improving Network Safety</td>
</tr>
<tr>
<td>TEN-T</td>
<td>Trans-European Network - Transport</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>SRIP</td>
<td>Safer Roads Investment Plans</td>
</tr>
<tr>
<td>RSA</td>
<td>Road Safety Audit</td>
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<td>RSI</td>
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1 Introduction

1.1 SLAIN project objectives

The project’s Action fits in 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. With partners in the different countries, Project SLAIN is a transnational project aiming to extend the skills and knowledge base of partners in performing network-wide road assessment.

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

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

The SLAIN consortium consists of eight core partners, coming from six EU member states, namely Greece, Italy, Spain, Croatia, UK and Belgium. The list of partners includes EuroRAP (Project Coordinator), Anas, FPZ, RSI Panos Mylonas, RACC-ACASA, DGT Spain, SCT and TES Spain (both Catalonia), and iRAP.

1.2 SLAIN Activity 6

Sections 1.1-1.5 of this document are common to D6.1-D6.5, with section 1.6 providing introductory notes to the relevant case study group and the case studies being appended.

The SLAIN proposal outlined how case studies are so often the most effective way of communicating often complex theoretical and complex arguments or processes. Network-wide road assessment is no exception and case studies are used here as examples to support Directive (EU) 2019/1936 (amending Directive 2008/96/EC) on road infrastructure safety management. The case studies included here demonstrate in particular the application of iRAP protocols and tools as per Activity 6 and outlined on pages 23-27 of the SLAIN Grant Agreement.

The case studies are grouped into five categories (A-E), showing how elements of the iRAP protocols may be used to support different elements of Directive (EU) 2019/1936. In keeping with the innovation element of INEA’s mission, what is presented shows procedures and practices not attempted to any great extent previously. The learnings from this exercise are applicable to roads of most types and especially to the TEN-T. The rationale in selecting example case studies was not they need be from the TEN-T but rather that they provide information, principles, techniques and practices that may be applied to the TEN-T or otherwise support Directive (EU) 2019/1936.

There are 113 case studies, slightly more than the 104 foreseen. Of these, all but 25 are from Croatia, Italy, Greece and Spain. The remainder come from Sweden (2 for case study group C (as foreseen on
page 24 of the Grant Agreement), from Bosnia and Herzegovina (1), Hungary (2), Ireland (1), Moldova (4), the Netherlands (1), Slovakia (5) and Ukraine (1) and the UK (8).

Task 6.1 (page 24 of the Grant Agreement drew attention to the need to look beyond the countries of the Action and to identify case studies “in other parts of Europe if necessary”. With this in mind, a case study derived from a European Bank for Reconstruction and Development (EBRD) project in Bosnia and Herzegovina has been included as an example of a major roads project in a country wishing to join the EU. That built on the desire to foster relationships with EBRD as expressed in Activity 8 (page 31) of the Grant Agreement. The case studies capitalise upon work done in the SENSoR and RADAR projects, as foreseen in the SLAIN proposal (section 2.2) and in the Grant Agreement (page 31), to include data and examples from Hungary (2), Moldova (4) and Ukraine (1). These studies in particular provide examples of work not previously attempted within most parts of the EU and in Moldova and Ukraine they provide examples of the Star Rating of Designs. The studies from the UK are pathfinder examples from that country, some showing new ways to approach identification of high-risk road sections and innovative funding mechanisms for their treatment.

1.3 Supporting Directive (EU) 2019/1936 Road Infrastructure Safety Management

As already mentioned, SLAIN was devised to support implementation of Directive (EU) 2019/1936 (page 9 Article I.3 of the Grant Agreement) and to provide examples of what could be done. Activities 3 and 4 in SLAIN provide the technical and practical “how to” of this exercise. Here, the case studies include examples from both major roads and from the primary roads now included in the Directive. Acknowledging the European Commission priority to consider active road users (e.g. cyclists and pedestrians), there is also some attention to these road users where appropriate and a small number of case studies include an urban setting.

The global pandemic in 2020-21 has necessarily limited the travel to countries beyond those of the Action that was originally foreseen (page 25, Task 6.2 of the Grant Agreement), but transnational learning that will benefit practice on the TEN-T and on the roads of the EU in general is possible from these case studies. On other points of detail, Task 6.3 has been achieved within the individual case studies and Task 6.4 in each of case studies in groups B, C, D and E. There has been stakeholder consultation (Task 6.5) throughout (in Italy and Spain because partners are national government stakeholders) in Greece often as a follow-through from the SENSoR project and in Croatia because good relations exist with the various arms of national roads agencies. In addition, there has been a developing relationship with Committee of European Directors of Roads (CEDR) foreseen in Task 8.4 which has provided added value in dissemination within Task 6.5. Task 6.6 has been completed.

1.4 Summary learnings from the case studies

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 increases in 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 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 road sections 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, 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 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 and for different scenarios after a bridge reconstruction and new bypass (in Spain)
- tackling the 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 longer road lengths (more than 90km in one example) 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.
1.5 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 and this issue was addressed in a study in the UK1 which explained the need for some caution in this exercise:

“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. In such situations 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-or-considered-but-not-convinced” response occasionally encountered. 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 crash risk.

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), the overall measures have a bigger

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impact. Improving the quality of low-safety of undivided single carriageways is rightly a European priority and should continue to be.

The group E case studies of Star Ratings four 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 the primary road network. There were however several examples from roads of national and international significance in other parts of this Activity and the case studies that point to how the tools may be applied on the TEN-T.

1.6 Notes on group D case studies: Maintenance-only remedies

Not all road safety remedial actions need to involve huge infrastructure spend. It is possible to upgrade the safety of a road by simple measures such as shoulder sealing, re-surfacing, re-instating or providing lining. For example, central hatching on single carriageways separates vehicles travelling in opposing directions and reduces head-on crash risk. Case studies D1-D16 deal with these issues.

iRAP has produced a comprehensive list of countermeasures on the iRAP website\(^2\). From this list it is clear which ones are likely to be used as part of a maintenance programme. Those listed link to factsheets which list the effect of each measure in reducing fatal and serious crashes and explain its role in the iRAP model. The measures link to the iRAP Road Safety Toolkit (Figure D1 – http://toolkit.irap.org/) with explanation, definition and examples of their use.

Those measures that may be considered maintenance-only measures (as per D6.4 on page 26 of the Grant Agreement) include:

- delineation and signing
- central hatching
- provision of a wide centre line
- shoulder sealing
- shoulder rumble strips
- roadside hazard clearance
- road surface rehabilitation
- skid resistance improvement
- upgrading a pedestrian facility quality.

Some additional examples border on more substantial investments but could include:

- upgrading footpath provision
- replacement of roadside barriers where existing barriers are deemed ineffective.

\(^2\) https://resources.irap.org/Methodology/iRAP%20model%20factsheet%2011%20Countermeasures.pdf
In the examples provided here (see for example case studies with prefix codes D9 and D12) it is clear that on some single carriageway roads it is possible to improve the Star Rating by one star, by improving the road surface and the signing and lining. In other situations, implementing wide central hatching, rumble strips and a wide shoulder is appropriate. In these situations, carriageway width is often an important factor. In yet other situations, see for example case study D8, it is only possible to achieve step-changes in the Star Rating with implementation of more substantial measures alongside those that are maintenance-only.
2 Appendix A – Case Studies

2.1 D1 – Croatia Road sections of A6, A8, A9, D8

INTRODUCTION
The roads and road sections selected for this Case study are a part of the Croatian TEN-T road network. These include three motorway sections (motorways A6, A8, and A9) and the state road D8 section.

Figure 1 shows the subject state road sections coloured in blue and motorway sections coloured in green. Most of the selected roads are highways, with carriageways separated by a metal safety barrier, whereas the small section of the state road D8 has only one carriageway with oncoming traffic flows separated by a centreline.

On 18% of the assessed road network there is only one lane in each driving direction, 74% of the road network has two lanes in each driving direction while 6% of the roads have three lanes. Also, there is a 2+1 lane configuration present on 1%, and a 3+2 configuration present on 2% of the road sections. Most of the lanes are wide (82%), whilst the rest (18%) are of medium width. When taking into...
consideration the driver side only, the paved shoulder is narrow on 96% of road sections, medium width paved shoulder is present on 4% of road sections and less than 1% of the paved shoulder is wide. The passenger side of has a narrow paved shoulder on about 62% of road segments; 37% of road segments have a wide paved shoulder and about 1% have medium width paved shoulders. Shoulder rumble strips are present on 32% of road sections.

The majority (73%) of road sections are straight or gently curving, 23% have moderate curvature while the remaining 4% of road sections have sharp curvature. The overall road condition is good on all of the observed road sections, with accompanying adequate delineation. Street lighting is present on 19% of road sections and parked vehicles close to the edge of the road were recorded on 3% of the overall network.

**ROAD ASSESSMENT**

A detailed risk assessment on the selected Croatian TEN-T road network sections has been carried out to assess the current state of traffic infrastructure. Star Rating results, summarised in Table 1 and geographically represented in Figure 2, indicate that no road section in the vehicle occupant category is awarded 4 or 5 stars (medium-low and low risk), while the majority (58.32%) of assessed road segments are awarded 3 stars (medium risk). About 34.21% of the road segments are awarded 2 stars (medium-high risk), while the remaining 7.46% of the road segments are awarded 1 star (high risk).

Star Ratings for the motorcyclists’ category less good, with again no road segments awarded 4 or 5 stars (medium-low and low risk), and only 2.74% of road segments awarded 3 stars (medium risk). The majority of road segments, 59.15% are awarded 2 stars (medium-high risk), while more than 1/3 (38.11%) of road segments are awarded 1 star (high-risk).

For pedestrians, the Star Rating is majorly not applicable, given that 90% of assessed road sections are motorways. On the other hand, for the small number of road segments where Star Rating for pedestrians is applicable and these road users may be expected, no 3, 4 or 5 stars were awarded. About 0.43% of segments are awarded 2 stars (medium-high risk) and the remaining 0.56% are awarded only 1 star (high risk).

For the cyclists’ category, no road section was applicable for the Star Rating assessment, these road users not being present. The results indicate high potential for road infrastructure improvement by implementing appropriate countermeasures.

<table>
<thead>
<tr>
<th>Star Ratings</th>
<th>Vehicle Occupant</th>
<th>Motorcyclist</th>
<th>Pedestrian</th>
<th>Bicyclist</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length (km)</td>
<td>Percent</td>
<td>Length (km)</td>
<td>Percent</td>
</tr>
<tr>
<td>5 Stars</td>
<td>0.00</td>
<td>0.00%</td>
<td>0.00</td>
<td>0.00%</td>
</tr>
<tr>
<td>4 Stars</td>
<td>0.00</td>
<td>0.00%</td>
<td>0.00</td>
<td>0.00%</td>
</tr>
<tr>
<td>3 Stars</td>
<td>170.60</td>
<td>58.32%</td>
<td>83.30</td>
<td>2.74%</td>
</tr>
<tr>
<td>2 Stars</td>
<td>103.60</td>
<td>34.21%</td>
<td>179.10</td>
<td>59.15%</td>
</tr>
<tr>
<td>1 Star</td>
<td>22.60</td>
<td>7.46%</td>
<td>115.40</td>
<td>38.11%</td>
</tr>
<tr>
<td>Not applicable</td>
<td>0.00</td>
<td>0.00%</td>
<td>0.00</td>
<td>0.00%</td>
</tr>
<tr>
<td>Totals</td>
<td>302.80</td>
<td>100.00%</td>
<td>302.80</td>
<td>100.00%</td>
</tr>
</tbody>
</table>
Figure 2. Star Rating maps for vehicle occupants - before the countermeasure implementation

Table 2. Overview of hazardous roadside objects, existing along the observed road sections

<table>
<thead>
<tr>
<th>Driver side of the assessed road</th>
<th>Passenger side of the assessed road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazardous object</td>
<td>Length</td>
</tr>
<tr>
<td>Rigid structure/bridge or building</td>
<td>18.90</td>
</tr>
<tr>
<td>Unprotected safety barrier end</td>
<td>16.10</td>
</tr>
<tr>
<td>Upwards slope – no rollover gradient</td>
<td>13.70</td>
</tr>
<tr>
<td>Aggressive vertical face</td>
<td>2.70</td>
</tr>
<tr>
<td>Sign, post or pole &gt;= 10cm dia.</td>
<td>2.60</td>
</tr>
<tr>
<td>Tree &gt;=10cm dia.</td>
<td>1.70</td>
</tr>
<tr>
<td>Cliff</td>
<td>1.30</td>
</tr>
<tr>
<td>Semi-rigid structure or building</td>
<td>1.20</td>
</tr>
<tr>
<td>TOTAL*</td>
<td>302</td>
</tr>
</tbody>
</table>

* - total length of road segments where hazardous objects are present

Higher levels of risk on the observed road sections of the TEN-T road network in Croatia are primarily a result of risk at the hazardous locations listed in the table above. Table 2 gives an overview of
different types of hazardous roadside objects that were present along both sides of the road. Examples of the most common types of hazardous objects present alongside the road are shown on Figure 3 and include a location with an aggressive vertical face, an unprotected safety barrier end, a rigid object and an upwards slope with no rollover gradient. These hazardous objects contribute to an overall high-risk rate on the observed road sections.

Figure 3. Most common types of hazardous locations on the observed road sections

MAINTENANCE REMEDIES

This case study considers roads which necessitate maintenance only countermeasures, of which several have been proposed, such as improved delineation, clearance of roadside hazards or replacement/modification/installation of roadside barriers.

The SRIP presents all the countermeasures which proved able to provide cost-effective improvements. The cost of each countermeasure is compared to the value of life and serious injuries that could be prevented, and the Benefit to Cost Ratio (BCR) is calculated for each countermeasure proposed.

The estimated costs of the implementation of the proposed countermeasures with the SRIP Plan adding up to 20,403,040 HRK (around €2.7M), which leads to safety benefits of 98,708,940 HRK (around €13M) in crash cost savings over the life of the plan. A total of 64 crashes with seriously or fatally injured people could be prevented over 20 years if the proposed countermeasures are implemented. The total benefit-cost ratio of the proposed plan is 5, and the best performing countermeasure is the installation of passenger side roadside barriers on 24.3 km of road sections, which alone could potentially prevent 44 serious or fatal injuries. Figure 3 presents the top 6 countermeasures with the highest effect proposed by the SRIP Plan.
The results showing an increase in Star Ratings are presented at next chapter (Table 3), following the assessment after the implementation of the countermeasures.

**ROAD ASSESSMENT AFTER**

Improving the Star Rating by one star is generally associated on average with a halving in the crash costs per kilometre travelled for vehicle occupants and step-changes in safety benefits too for other road users. Table 3 contains smoothed Star Rating results for the observed road sections, produced after the countermeasures implementation. From the data shown in the table, an improvement of overall Star Rating results is evident, with 67.47% of road segments awarded 3-star and 32.53% awarded 2-star in the vehicle occupant category. In the same category, after countermeasure implementation, no road segment would be awarded 1, 4 or 5 stars. A reason for this pattern of results after countermeasure implementation could be that those oriented towards maintenance with no substantial impact on road geometry or hazardous objects alongside are enough to improve the poorest road sections but insufficient to lift the road into the highest levels of crash reduction and protection.

An improvement can also be observed in the motorcyclists’ category. As in the previous example of countermeasure implementation, no road segment was awarded with 4 or 5 stars, and the number of road segments awarded 3 stars remained unchanged (2.74%). On the other hand, an increase in 2-star category is evident with 72.72% of road segments being rated in this category, which is at the same time accompanied by a decrease in the 1-star category, where 24.54% of road segments would be awarded 2 stars.

Very few road sections were rated for pedestrians and none for cyclists. For the pedestrians group, none of the proposed implemented countermeasures would have improved the Star Rating, with the same results being awarded after countermeasure implementation as they were before the implementation. 0.43% of road segments were awarded 2 stars and 0.56% of road segments awarded 1 star. No road segment scored 3, 4 or 5 stars.

On the selected road network, no road segments were rated for cyclists.

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### Table 3. Star Rating results of the selected road network sections after the countermeasure implementation

<table>
<thead>
<tr>
<th>Star Ratings</th>
<th>Vehicle Occupant</th>
<th>Motorcyclist</th>
<th>Pedestrian</th>
<th>Bicyclist</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length (km)</td>
<td>Percent</td>
<td>Length (km)</td>
<td>Percent</td>
</tr>
<tr>
<td>5 Stars</td>
<td>0.00</td>
<td>0.00%</td>
<td>0.00</td>
<td>0.00%</td>
</tr>
<tr>
<td>4 Stars</td>
<td>0.00</td>
<td>0.00%</td>
<td>0.00</td>
<td>0.00%</td>
</tr>
<tr>
<td>3 Stars</td>
<td>204.30</td>
<td>67.47%</td>
<td>8.30</td>
<td>2.74%</td>
</tr>
<tr>
<td>2 Stars</td>
<td>98.50</td>
<td>32.53%</td>
<td>220.20</td>
<td>72.72%</td>
</tr>
<tr>
<td>1 Star</td>
<td>0.00</td>
<td>0.00%</td>
<td>74.30</td>
<td>24.54%</td>
</tr>
<tr>
<td>Not applicable</td>
<td>0.00</td>
<td>0.00%</td>
<td>0.00</td>
<td>0.00%</td>
</tr>
<tr>
<td>Totals</td>
<td>302.80</td>
<td>100.00%</td>
<td>302.80</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

Figure 5 graphically represents Star Rating results after countermeasure implementation.

**Figure 5. Star Rating maps for vehicle occupants of the selected road network sections after the countermeasure implementation**

A9 – [Kanfanar – Pula]  
A8 – [Matulji – Kanfanar]  
A6 – [Bosiljevo – Rijeka]  
D8 – [Z6286 (West) – Z6286 (East)]

**CONCLUSIONS**  
In this example the Star Rating is used to illustrate how the safety of part of a network can be assessed when maintenance measures are implemented. It shows how it is not necessary to rely entirely upon crash data to demonstrate a potential safety improvement.
The maintenance carried out improved the road safety status substantially, with the Star Ratings increased by one or two stars.

The maintenance-only remedies implemented are considered effective.
2.2 D2 - Greece National Road 2 (Kavala)

INTRODUCTION
The information detailed in this Case Study has been provided by RSI ‘Panos Mylonas’. The case study predicts a reduction in risk after implementation of maintenance and some additional measures added during that process.

The National Road 2 (NR2) is a highway in Greece and connects Kipi on the Greek-Turkish border with Krystallopigi on the Greek-Albanian border. The road section has one lane in each direction.

The point of interest is located near Kavala city, where the Annual Average Daily Traffic (AADT) in 2013 was 6,500 vehicles. Figures 1 and 2 show the location and an aerial view of NR-2 (near Kavala city) respectively.

MAINTENANCE REMEDIES
Figure 3 shows the precise location of, and evidence for, the various elements requiring maintenance.
The maintenance measures that should be applied are as follows:

- re-pavement road surface
- apply shoulder and centerline rumble strips
- add a safety barrier (on the passenger-side roadside edge where signs and trees require it)
- reinstate other delineation, as required.

ROAD ASSESSMENT

The Star Rating Score (SRS) has been analysed for 100 meters of this road section before and after the proposed maintenance works.

Before the maintenance remedies, the Star Rating Score is 41.44 for vehicle occupants, 50.38 for motorcycles and not applicable for pedestrians and bicyclists, as local information suggests that pedestrians and cyclists have not been observed on this road section and are therefore not rated. The Star Rating is 1 star for vehicle occupants and motorcycles.

After the completion of the maintenance works that are proposed, the Star Rating Score is 10.41 for vehicle occupants, 14.89 for motorcycles and not applicable for pedestrians and bicyclists.

Improving the Star Rating by one star is generally associated on average with a halving in the crash costs per kilometre travelled for vehicle occupants\(^4\) and step-changes in safety benefits too for other road users.

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\(^4\) [Link to IRAP paper](https://www.irap.org/2013/05/2013-irap-paper-relationship-between-star-ratings-and-crash-cost-bruce-highway-australia/)
So, by providing only maintenance remedies, the Star Rating would be increased from 1 star to 3 stars for vehicle occupants and from 1 star to 2 stars for motorcycles.

CONCLUSIONS

The maintenance and associated measures that should be carried out would potentially increase safety and reduce the risk for vehicle occupants and motorcyclists on this road section substantially. The Star Rating for these road users would be improved by one and two risk bands. The maintenance only remedies proposed are considered an effective investment.
2.3 D3 - Greece National Road 3 (Domokos)

INTRODUCTION
The information detailed in this Case Study has been provided by RSI ‘Panos Mylonas’.

National Road 3 (NR3) connects the border station of Niki on the border with Northern Macedonia crossing the eastern side of Western Macedonia, western Thessaly and eastern Central Greece. The road section has one lane per direction and its layout is winding (moderate speed limits and sharp curves).

The point of interest is located near Domokos village, where the Annual Average Daily Traffic (AADT) in 2013 was 5,000 vehicles. Figures 1 and 2 show the location and an aerial view of NR-3 (Domokos) respectively.

![Figure 11. Location of NR-3 road stretch](image-url)
MAINTENANCE REMEDIES

Figure 3 shows the precise location of, and evidence for, the various elements requiring maintenance.

The maintenance measures that should be applied are as follows:

- Re-surface those parts of the road that are in a poor condition
- Apply shoulder and centerline rumble strips
- Reinstate other delineation, as required
- Add a new metal barrier (on the driver-side roadside edge) to protect from the cliff hazard.
ROAD ASSESSMENT
The Star Rating Score (SRS) has been analysed for 100 meters of this road section before and after the proposed maintenance works.

Before the maintenance remedies, the Star Rating Score is 111.96 for vehicle occupants, 135.36 for motorcycles and not applicable for pedestrians and bicyclists, as local information suggests that pedestrians and cyclists have not been observed on this road section and are therefore not rated.

![Figure 14. Star Rating Score: NR-3 near Domokos (Before maintenance)](image)

The Star Rating is 1 star for vehicle occupants and motorcycles.

Improving the Star Rating by one star is generally associated on average with a halving in the crash costs per kilometre travelled for vehicle occupants and step-changes in safety benefits too for other road users.

After the completion of the maintenance works that are proposed, the Star Rating Score is 11.28 for vehicle occupants, 16.37 for motorcycles and not applicable for pedestrians and bicyclists.

![Figure 15. Star Rating Score: NR-3 near Domokos (After maintenance)](image)

So, by providing only maintenance remedies, the Star Rating would be increased for the users (from 1 star to 3 stars for vehicle occupants, and from 1 star to 2 stars for motorcycles).

CONCLUSIONS
The maintenance that should be carried out would potentially increase safety and reduce the risk for vehicle occupants, motorcyclists and cyclists on this road section substantially. The Star Rating for these road users would be improved by one (motorcyclists) or two (vehicle occupants) risk bands.

The maintenance-only remedies proposed are considered an effective investment.

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2.4 D4 – Greece National Road 6 (Metsovo)

INTRODUCTION
The information detailed in this case study has been provided by RSI ‘Panos Mylonas’. It is an example of how maintenance-only remedies alongside additional measures can improve road safety.

National Road 6 (NR6) of Greece is a rural road that connects Volos with Igoumenitsa, crossing Thessaly and Epirus. It is part of European Road 92 (E92) along its entire length. In its western part, from Igoumenitsa to Panagia Trikala, most of its traffic has been replaced by the Egnatia Odos.

The case study is located near Metsovo, has one lane in each direction and the Annual Average Daily Traffic (AADT) in 2013 was approximately 2,500 vehicles. Figures 1 and 2 show the location and an aerial view of NR-6 (near Metsovo) respectively.

MAINTENANCE AND ADDITIONAL REMEDIES
Figure 3 shows the precise location of, and evidence for, the various elements requiring maintenance.
and additional measures.

The measures that should be applied are:

- apply shoulder and centerline rumble strips and any additional necessary measures to improve delineation and surfacing.
- to take advantage of the presence of maintenance works to install new safety barriers (on the driver-side roadside edge where large boulders require it and on the passenger-side roadside edge where cliff requires it).

**ROAD ASSESSMENT**

The Star Rating Score (SRS) has been analysed for 100 meters of this road section before and after the proposed maintenance works as a typical example of part of the network.

Before the maintenance remedies, the Star Rating Score is 68.86 for vehicle occupants, 77.4 for motorcycles and not applicable for pedestrians and bicyclists, as local information suggests that pedestrians and cyclists have not been observed on this road section and are therefore not rated. The Star Rating is 1-star for vehicle occupants and motorcycles.

Improving the Star Rating by one star is generally associated on average with a halving in the crash costs per kilometre travelled for vehicle occupants⁶ and step-changes in safety benefits too for other road users. After the completion of the maintenance works and additional measures that are proposed, the Star Rating Score is 6.47 for vehicle occupants, 15.16 for motorcycles and not applicable for pedestrians and bicyclists. So, the Star Rating would be increased from 1-star to 3-star for vehicles.

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and from 1 star to 2-star for motorcycles, a substantial part of this improvement coming from the installation of new barriers.

![Star Rating Score: NR-6 near Metsovo (After maintenance)](image)

**CONCLUSIONS**

The works that should be carried out would potentially increase safety and reduce the risk for vehicle occupants and motorcyclists on this road section substantially. The Star Rating for these road users would be improved by two and one stars respectively.

The remedies proposed are considered an effective investment.
2.5 D5 - Greece National Road 9 (Kallikomo)

INTRODUCTION
The information detailed in this Case Study has been provided by RSI ‘Panos Mylonas’.

The National Road 9 is located in the western Peloponnesse, Greece. It starts from Patras and ends in southern Messinia. On its way it passes through the cities of Pyrgos and Kyparissia and is part of the European Road 55 (E55). The road section has one lane in each direction.

The point of interest is located near Kallikomo village, where the Annual Average Daily Traffic (AADT) in 2013 was 5,000 vehicles. Figures 1 and 2 show the location and an aerial view of NR-9 (near Kallikomo) respectively.
MAINTENANCE REMEDIES

Figure 3 shows the precise location of, and evidence for, the various elements requiring maintenance.

The maintenance measures that should be applied are as follows:

- Re-surface those parts of the road that are in a poor road condition
- Provide or reinstate markings and centerline rumble strips and signs.
- Consult on providing a lower speed limit and reduce from 75km/h to 60km/h as part of the maintenance works, based on the proximity of nearby intersections and adjacent land-use development.

ROAD ASSESSMENT

The Star Rating Score (SRS) has been analysed for 100 meters of this road section before and after the proposed maintenance works.

Before the maintenance remedies, the Star Rating Score is 27.27 for vehicle occupants, 63.51 for motorcycles and not applicable for pedestrians and bicyclists, as local information suggests that pedestrians and cyclists have not been observed on this road section and are therefore not rated.
Figure 24. Star Rating Score: NR-44 near Kallikomo (Before maintenance)

The Star Rating is 1 star for vehicle occupants and motorcycles.

Improving the Star Rating by one star is generally associated on average with a halving in the crash costs per kilometre travelled for vehicle occupants\(^7\) and step-changes in safety benefits too for other road users.

After the completion of the maintenance works that are proposed, the Star Rating Score is 5.47 for vehicle occupants, 11.31 for motorcycles and not applicable for pedestrians and bicyclists.

Figure 25. Star Rating Score: NR-44 near Kallikomo (After maintenance)

So, by providing only maintenance remedies and setting an appropriate speed limit, the Star Rating would be increased for vehicle occupants and motorcycles (from 1 star to 3 stars).

CONCLUSIONS

The maintenance that should be carried out would potentially increase safety and reduce the risk for vehicle occupants and motorcyclists on this road section substantially. The Star Rating for these road users would be improved by two risk bands.

The maintenance only remedies proposed are considered an effective investment.

2.6 D6 – Greece National Road 30 (Sofades)

INTRODUCTION

The information detailed in this Case Study has been provided by RSI ‘Panos Mylonas’.

National Road 30 is in Epirus and Thessaly, Greece. It connects Arta with Volos, through Trikala and Karditsa. The road section has one lane per direction.

The point of interest is located near Sofades village, where the Annual Average Daily Traffic (AADT) in 2013 was 6,600 vehicles. Figures 1 and 2 show the location of NR-30 (Sofades) and an aerial view respectively.

![Figure 26. Location of NR-30 road stretch](image)


![Figure 27. Aerial view of NR-30](image)

© Google Street View, 2021
MAINTENANCE REMEDIES

Figure 3 shows the precise location of, and evidence for, the various elements requiring maintenance.

Figure 28. NR-30 at Sofades

The maintenance measures that should be applied are as follows:

- Re-surface those parts of the road that are in a poor condition
- Add a new metal barrier (on the driver-side roadside edge where lighting columns and trees require it)
- Apply shoulder and centerline rumble strips
- Provide appropriate central hatching (width>1m)
- For pedestrians and cyclists, provide an unsignalised marked crossing (without a refuge) for the intersecting road
- Reinstate other delineation, as required

ROAD ASSESSMENT

The Star Rating Score (SRS) has been analysed for 100 meters of this road section before and after the proposed maintenance works.

Before the maintenance remedies, the Star Rating Score is 61.44 for vehicle occupants, 71.71 for motorcycles, 106.87 for pedestrians and 133.26 for bicyclists.

The Star Rating is 1 star for all users.

Improving the Star Rating by one star is generally associated on average with a halving in the crash costs per kilometre travelled for vehicle occupants\(^8\) and step-changes in safety benefits too for other road users.

After the completion of the maintenance works that are proposed, the Star Rating Score is 14.97 for vehicle occupants, 20.18 for motorcycles, 52.49 for pedestrians and 49.45 for bicyclists.

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So, by providing only maintenance remedies, the Star Rating would be increased for most of the users (from 1 star to 2 stars for vehicle occupants, motorcycles and bicyclists). Providing a pedestrian crossing on the side-road improves the safety for pedestrians marginally but it is likely that only the provision of a footway would improve the rating substantially.

**CONCLUSIONS**

The maintenance that should be carried out would potentially increase safety and reduce the risk for vehicle occupants, motorcyclists and cyclists on this road section substantially. The Star Rating for these road users would be improved by one risk band.

The maintenance-only remedies proposed are considered an effective investment.
2.7 D7 – Greece National Road 38 (Tymfristos)

INTRODUCTION
The information detailed in this Case Study has been provided by RSI ‘Panos Mylonas’.

The National Road 38 is located in central Greece. It connects Lamia with Thermo, in Etoloakarnania region. The route Lamia - Karpenisi - Agrinio is part of the European Road 952 (E952). It passes through Lamia, Karpenisi, Kremasta Lake, Agrinio and Thermo. The road section has one lane in each direction and its layout is winding (with speed limits of 50 km/hr up to 90km/hr and sharp curves).

The point of interest is located near Tymfristos, where the Annual Average Daily Traffic (AADT) in 2013 was 5,000 vehicles. Figures 1 and 2 show the location of EO-38 (near Tymfristos) and an aerial view respectively.
MAINTENANCE REMEDIES

Figure 3 shows the precise location of, and evidence for, the various elements requiring maintenance.

The maintenance measures that should be applied are as follows:

- Re-surface those parts of the road that are in a poor condition
- Apply shoulder and centerline rumble strips
- Reinstate other delineation, as required
- Add a new metal barrier (on the driver-side roadside edge) to protect from the cliff hazard
- Provide a lower speed limit by reducing from 70km/h to 60km/h as part of the maintenance works, based on the close proximity of nearby sharp bends.

ROAD ASSESSMENT

The Star Rating Score (SRS) has been analysed for 100 metres of this road section before and after the proposed maintenance works.

Before the maintenance remedies, the Star Rating Score is 175.77 for vehicle occupants, 199.67 for motorcycles and not applicable for pedestrians and bicyclists, as local information suggests that pedestrians and cyclists have not been observed on this road section and are therefore not rated.
The Star Rating is 1 star for vehicle occupants and motorcycles.

Improving the Star Rating by one star is generally associated on average with a halving in the crash costs per kilometre travelled for vehicle occupants and step-changes in safety benefits too for other road users.

After the completion of the maintenance works that are proposed, the Star Rating Score would be 10.11 for vehicle occupants, 14.11 for motorcycles and not applicable for pedestrians and bicyclists.

So, by providing only maintenance remedies and setting an appropriate speed limit, the Star Rating would be increased for vehicle occupants and motorcyclists (from 1 star to 3 stars for vehicle occupants and from 1 star to 2 stars for motorcyclists).

**CONCLUSIONS**

The maintenance and associated measures that should be carried out would potentially increase safety and reduce the risk for vehicle occupants and motorcyclists on this road section substantially. The Star Rating for these road users would be improved by one (motorcyclists) or two (vehicle occupants) risk bands.

The maintenance-only remedies proposed are considered an effective investment.

2.8 D8 - Greece National Road 39 (Sparti)

INTRODUCTION
The information detailed in this Case Study has been provided by RSI ‘Panos Mylonas’. It is an example of how maintenance-only remedies alongside additional measures can improve road safety.

The National Road 39 (NR39) is a national road in Peloponnese, Greece. It connects Tripoli with Sparti and Gythio. National Road 39 coincides with European Road 961. The road section has one lane in each direction.

The point of interest is located near Sparti, where the Annual Average Daily Traffic (AADT) in 2013 was 4,500 vehicles. Figures 1 and 2 show the location and an aerial view of NR-39 (near Sparti) respectively.
MAINTENANCE AND ADDITIONAL REMEDIES

Figure 3 shows the precise location of, and evidence for, the various elements requiring maintenance and additional remedies.
The measures that should be applied are as follows:

- add safety barriers (on both roadside edges where is required)
- apply shoulder and centerline rumble strips
- provide a facility on both sides for pedestrians and cyclists with non-physical separation from 1m to 3m width.

**ROAD ASSESSMENT**

The Star Rating Score (SRS) has been analysed for 100 meters of this road section before and after the proposed maintenance and additional works.

Before the remedies, the Star Rating Score is 19.49 for vehicle occupants, 20.76 for motorcycles, 58.88 for pedestrians and 32.05 for bicyclists. The Star Rating is 2 stars for all users.

Improving the Star Rating by one star is generally associated on average with a halving in the crash costs per kilometre travelled for vehicle occupants\(^\text{10}\) and step-changes in safety benefits too for other road users.

After the completion of the works that are proposed, the Star Rating Score is 5.38 for vehicle occupants, 11.7 for motorcycles, 28.37 for pedestrians and 26.98 for bicyclists.

So, by providing these remedies, the Star Rating would be increased from 2 stars to 3 stars for vehicle occupants and from 2 stars to 3 stars for motorcycles, pedestrians and bicyclists.

Therefore, this road section would fulfill the road infrastructure safety level that is considered the minimum desirable in European countries that are leaders in road safety. This substantially reduces the risk of death or serious injury when a crash occurs.

CONCLUSIONS

The works that should be carried out would increase safety and reduce the risk for all users on this road section substantially. The Star Rating for all road users would reach the 3-star rating now being targeted by many countries in Europe.

On the upgraded roads a vehicle is now less likely to leave the carriageway and if it does there is less likelihood of a serious collision occurring. Furthermore, the vulnerable road users would have their own space for travel.

The remedies proposed are considered an effective investment.
2.9 D9 – Greece National Road 44 (Amarynthos)

INTRODUCTION
The information detailed in this Case Study has been provided by RSI ‘Panos Mylonas’.

The National Road 44 is located in Euboea, Greece and connects Chalkida with Aliveri, as the major road for the south part of Euboea island. The road section has one lane in each direction and its layout is winding (with speed limits of 50 kph and 70 kph and sharp curves).

The point of interest is located at Amarynthos, a village that NR-44 passes through, where the Annual Average Daily Traffic (AADT) in 2013 was 7,600 vehicles. The location of NR-44 (Amarynthos) is shown in Figure 1. Figure 2 provides an aerial view.

![Figure 41. Location of NR-44 road stretch](Image)

![Figure 42. Aerial view of NR-44](Image)
MAINTENANCE REMEDIES

Figure 3 shows the precise location of, and evidence for, the various elements requiring maintenance.

![Figure 3. NR-44 at Amarynthos](image)

The maintenance measures that should be applied are as follows:

- Re-surface at least the parts of the road in need of repair (where road condition is scoring “medium” quality in the iRAP system); maintenance should include renewal of vertical and horizontal signs and improve delineation alongside the carriageway and clarity of the pedestrian crossing and signs
- Warning signs should be added on both sides to improve intersection quality
- Centerline rumble strips should be added to discourage overtaking and highlight other safety considerations,
- School zone static signs should be provided and/or road markings should be applied to the road pavement
- Consider such other measures, if any needed beyond those mentioned here, as may be necessary to provide a decrease in the operating speed of at least 5km/hr.

ROAD ASSESSMENT

The Star Rating Score (SRS) has been analyzed for 100 metres of this road section before and after the proposed maintenance works.

Before the maintenance remedies, the Star Rating Score is 18.57 for vehicle occupants, 21.03 for motorcycles, 79.92 for pedestrians and 34.79 for bicyclists.
The Star Rating is 2 stars for all users. Improving the Star Rating by one star is associated on average with a halving in the crash costs per kilometre travelled for vehicle occupants\(^{11}\) and step-changes in safety benefits too for other road users.

After the completion of the maintenance works that are proposed, the Star Rating Score would be 10.7 for vehicle occupants, 12.2 for motorcycles, 30.88 for pedestrians and 17.1 for bicyclists.

So, by providing only maintenance remedies, the Star Rating would be increased for all users (from 2 to 3 stars).

**CONCLUSIONS**

The maintenance that should be carried out would potentially increase safety and reduce the risk for all road users on this road section substantially. The Star Rating would be improved by one risk band for vehicle occupants, motorcyclists (this one only just), pedestrians and bicyclists.

The maintenance-only remedies proposed are considered an effective investment.

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2.10  D10 – Italy SS 16 Adriatica

INTRODUCTION
The information detailed in this Case Study has been provided by ANAS. It illustrates the improvement to a road as a result of maintenance-only measures.

The SS 16 Adriatica is a national road and it extends from the city of Padua (CH.4+340), in northern Italy, to the city of Otranto (CH.1,000+44), in southern Italy and crosses six regions with an extension of about 996 km. The section varies along the road axis, in some sections having two lanes in each direction and in others only one lane.

For this case study two sections of the SS 16 in Veneto Region have been analysed.

The first section (D1.a) is located between CH.40+300 and CH.40+400 in the municipality of Rovigo. On this stretch the SS 16 has two lanes in each direction with undivided carriageway. The AADT is about 13,000 vehicles.

The second section (D1.b) is located between CH.56+170 and CH.56+270 in the municipality of Polesella. On this stretch the SS 16 has one lane in each direction and the AADT is about 10,500 vehicles.
MAINTENANCE REMEDIES
Section D1.a

Figure 50 shows the section analysed and highlights the various elements requiring maintenance (carriageway surface, shoulders and road markings).

The maintenance measures that should be applied are the following:

- Re-surface this stretch of the road
- Add a new metal barrier motorcycle friendly on the passenger-side, where a downwards slope and poles require it
- Apply shoulder rumble strips
- Increase the width of both shoulders
- Provide central hatching.

**Section D1.b**

Figure 7 shows the section analysed and highlights the various elements requiring maintenance (pavement surface, shoulders and pedestrian footpath).

The maintenance measures that should be applied are the following:

- Re-surface this stretch of the road that is not in a good condition
- Add a new metal barrier on both sides. This measure will eliminate the unprotected safety barrier end (as shown in image 8 - passenger side) and at the same time it will create a protected path for pedestrians (informal path) who surely walk on the edges of the road. In fact, there are suburban bus stops on this and adjacent sections
- Apply shoulder rumble strips
- Increase the width of both shoulders.

**ROAD ASSESSMENT**

The Star Rating Score (SRS) has been analysed for 100 meters of these road sections before and after the proposed maintenance works.

**Section D1.a**

Before the maintenance remedies, the Star Rating Score is 33.91 for vehicle occupants, 41.79 for motorcycles and 129.81 for bicyclists. This road section cannot be used by pedestrians, so they are not
The Star Rating is 1 star for all road users, which is not acceptable. Improving the Star Rating by one star is generally associated with a halving in the crash costs per kilometre travelled for vehicle occupants and step-changes in safety benefits too for other road users. After the completion of the maintenance works that are proposed, the Star Rating Score is 11.41 for vehicle occupants, 19.79 for motorcycles, and 81.73 for bicyclists.

So, by providing only maintenance remedies, the Star Rating would be increased for vehicle occupants from 1 to 3 stars and from 1 star to 2 stars for motorcycles. The score improves slightly for bicyclists but the rating remains at 1 star because no specific measure is foreseen for this type of road users.

**Section D1.b**

Before the maintenance remedies, the Star Rating Score is 12.75 for vehicle occupants, 15.53 for motorcycles, 164.15 for pedestrian and 58.24 for bicyclists.

The Star Rating is 2 stars for vehicle occupants, motorcycles and bicyclists, while it is only 1 star for pedestrians. After the completion of the maintenance works that are proposed, the Star Rating Score is 4.43 for vehicle occupants, 8.23 for motorcycles, 94.9 for pedestrians and 36.66 for bicyclists.
So, by providing only maintenance remedies, the Star Rating would be increased for vehicle occupants from 2 to 4 stars, from 2 star to 3 stars for motorcycles and from 1 star to 2 star for pedestrian. The score improves for bicyclists but the rating remains at 2 star because no specific measure is foreseen for this type of road users.

CONCLUSIONS

The maintenance that should be carried out would potentially substantially increase safety and reduce the risk for vehicle occupants and motorcyclists on this road section. The maintenance-only remedies proposed are considered an effective investment.
2.11  D11 – Italy SS 52 Carnica

INTRODUCTION

The information detailed in this Case Study has been provided by Anas S.p.A.. The case predicts reduction in risk after implementation of maintenance measures.

The SS 51 Carnica is a national road and it extends from the town of Carnia (km0+000), in the municipality of Venzone, in the province of Udine (Friuli Venezia Giulia region), to the town of San Candido (km 124+400) in the province of Bolzano (Trentino Alto Adige region) in northern Italy. The section managed by Anas is the one that runs through the Veneto region. The road is undivided with one lane in each direction.

The section analysed is located south of the town of Santo Stefano di Cadore in the province of Belluno. This stretch of the SS 52 has one lane in each direction and the ADDT is about 3,800 vehicles per day.

Figure 58. Location of SS 52 in north east Italy and local map (right)

Figure 59. Aerial view of SS 52 at CH.86+600
MAINTENANCE REMEDIES

The main safety issues of this section related to the poor condition of the road markings and the pavement (with particular reference to the skid resistance) and the narrow width of the pedestrian footways. The latter is particularly critical due to the presence of a retaining wall on the passenger side and of a downwards slope beyond the safety barrier on the other side (Figures 3 and 4).

The following Figures show the analysed section and highlight the various elements requiring maintenance.

The maintenance measures that should be applied would be to:
- re-surface this stretch of the road since it is not in a good condition, thereby obtaining improving the skid resistance
- improve the delineation
- apply shoulder rumble strips to warn road users of dangers on the side (local conditions effectively mean that shoulder widening is impossible).
ROAD ASSESSMENT

The Star Rating Score (SRS) has been analysed for 100 meters of this section before and after the maintenance works.

Before the maintenance remedies, the Star Rating Score is 42.38 for vehicle occupants, 67.16 for motorcycles, and 171.11 for bicyclists. This road section is not used by pedestrians, so the rating for them is not applicable. The Star Rating is 1 star for all the road users.

![Figure 62. Star Rating Score: SS 52 at CH.86+600 (Before maintenance)](image)

After the maintenance works, the Star Rating Score is 17.4 for vehicle occupants, 23.36 for motorcycles and 59.42 for bicyclists. So, by providing only maintenance remedies, the Star Rating would be increased for vehicle occupants and bicyclists from one to two stars. The score improves considerably for motorcycles but the rating remains at 1 star.

![Figure 63. Star Rating Score: SS 52 at CH.86+600 (After maintenance)](image)

Since the operating speed on this stretch of road is about 55 km/h, the possibility of lowering the speed limit, which is currently 70 km/h, could be considered. With the implementation of this operational countermeasure, and if there is enforcement and compliance, the Star Rating would further improve significantly for all users, as shown in the Figure below.

![Figure 64. Star Rating Score: SS 52 at CH.86+600 (further operational measure)](image)
CONCLUSIONS

By providing only maintenance remedies, the Star Rating would be increased for vehicle occupants and for bicyclists from 1- to 2- stars. The risk reduces for motorcyclists but the rating remains at 1-star.

The maintenance that should be carried out would potentially increase safety and reduce the risk for vehicle occupants and bicyclists on this road section substantially.

The maintenance-only remedies implemented are considered effective.
2.12 D12 – Italy SS 51 di Alemagna

INTRODUCTION
The information detailed in this case study has been provided by Anas. The case study shows a reduction in risk after implementation of maintenance and some additional measures added during that process.

The SS 51 di Alemagna is a national road and it extends from the city of Conegliano (km 0+000) to the border with the Trentino Alto Adige region (km 118+150) in northern Italy. The road extends for a further 16 km into the Trentino Alto Adige region but this section is not managed by Anas. The road is undivided with one lane in each direction.

For this case study a section in Veneto Region has been analysed. The section is located between CH.2+700 and CH.2+800 in the municipality of Conegliano in the province of Treviso. This stretch of the SS 51 has one lane in each direction and there is an intersection with a secondary road leading to an urban area. The ADTT is about 15,100 vehicles per day.

Figure 65. Location of SS 51 case study in north east Italy and local map (right)

Figure 66. Aerial view of SS 51 at CH.2+700
MAINTENANCE REMEDIES

The main safety issues of this section related to the small size of the shoulders available to the high level of bicyclists and pedestrians flow and to the poor layout of the intersection, with the bus stops near the intersection.

Figure 3 and 4 show the section and highlight the various elements requiring maintenance or modification.

Maintenance works were carried out in 2019 and some modification to the layout done during that time by:

- improving intersection conditions, adding new signs and a pedestrian crossing marking
- building a shared facility for pedestrians and cyclists
- resurfacing.
ROAD ASSESSMENT

The Star Rating Score (SRS) has been analysed for 100 meters of this section before and after the maintenance works.

Before the maintenance remedies, the Star Rating Score is 25.15 for vehicle occupants, 30.11 for motorcycles, 149.77 for pedestrians and 59.55 for bicyclists. The Star Rating is 1 star for vehicle occupants, motorcycles and pedestrians and 2 stars for bicyclists.

After the maintenance works, the Star Rating Score is 11.29 for vehicle occupants, 16.47 for motorcycles, 123.29 for pedestrians and 53.02 for bicyclists.

The implementation of maintenance remedies focused on the intersection and the vulnerable road users have improved the rating of vehicle occupants, pedestrians and cyclists. For motorcyclists the score improved but the rating remained at 1 star.

If a second step were carried out:
- centerline rumble strips could be added to discourage overtaking
- shoulder rumble strips on could be added to encourage lane-keeping
- traffic calming and pedestrian crossing facilities could be provided across the main carriageway.
If these things were done it would be possible to achieve a further reduction in risk and the Star Rating Score for all users and motorcyclists would achieve a 2-star rating and cyclists 4 stars.

**CONCLUSIONS**

The maintenance carried out improved the road safety status substantially, with the Star Ratings increased from 1- to 2- stars for vehicle occupants and pedestrians and from 2- stars to 3- stars for cyclists. Additional measures could further improve this site.

The maintenance-only remedies implemented are considered effective.
2.13  D13 – Italy SS309 Romea

INTRODUCTION
The information detailed in this Case Study has been provided by ANAS. The case study shows a predicted reduction in risk after implementation of maintenance and some additional measures added during that process.

The SS 309 Romea extends from the city of Ravenna (km 0+000) to the city of Venice (km 126+770) at the intersection with the A57 motorway, and crosses the regions of Emilia Romagna and Veneto in northern Italy. The road is undivided with one lane in each direction.

For this case study a section in Veneto Region has been analysed. The section is located between CH.68+900 and CH.69+100 in the municipality of Porto Viro in the province of Rovigo. This stretch of the SS 309 has one lane in each direction and there is an intersection with a secondary road leading to an industrial area. The ADDT is about 13,200 vehicles per day.

Figure 73. Location of SS 309 in north east Italy and local map (right)
Figure 74. Aerial view of SS 309 at CH.69+000
MAINTENANCE REMEDIES

The main safety issues of this section are related to the narrow width of the shoulders (mainly on the left side in Figure 3), to the presence of roadside hazards (poles and signs) and to the hide speeds of vehicles approaching the intersection.

Figures 3-5 show the analysed section and highlight the various elements requiring attention.

The maintenance measures and other modifications that should be applied are as follows:

- increase the width of the left shoulder;
• add a new metal barrier motorcycle friendly on the driver-side, where downwards slope and pole hazard require it. (This measure will eliminate the roadside hazards and at the same time will create a protected path for pedestrians (informal path) who walk on the edges of the road)
• improving delineation and apply shoulder rumble strips
• consider modest traffic calming such as transverse rumble strips and visual gateways on the approach to the intersection to reduce the speed.

ROAD ASSESSMENT
The Star Rating Score (SRS) has been analysed for all the section (300 meters) before and after the proposed maintenance works.

Before the maintenance remedies the Star Rating Score is between 14.57 and 17.88 for vehicle occupants, between 20.73 and 22.2 for motorcycles, between 108.59 and 218.83 for pedestrians and between 82.73 and 99.42 for bicyclists (Figures 6-8). The Star Rating is 2 stars for vehicle occupants and motorcycles and 1 star for pedestrian and bicyclists (Figures 6-8).

After the maintenance works that have been proposed, the Star Rating Score is between 10.06 and 11.29 for vehicle occupants, between 14.84 and 16.47 for motorcycles, between 35.1 and 123.29 for pedestrians and between 44.98 and 53.02 for bicyclists (Figures 9-11). Star Rating for vehicle occupants is raised to a 3-star rating and bicyclists to 2-star.
CONCLUSIONS

By providing only maintenance remedies and some associated measures, the Star Rating would be increased for vehicle occupants from 2 to 3 stars and from 1 star to 2 stars for bicyclists. The risk reduces slightly for motorcyclists and pedestrians but the rating remains at 1 star.

The maintenance that should be carried out would potentially increase safety and reduce the risk for vehicle occupants and bicyclists on this road section. The maintenance-only remedies proposed are considered an effective investment.
2.14  D14 - Spain A-318 Road (CH.60+000, Córdoba)

INTRODUCTION

The information detailed in this Case Study has been provided by DGT.

The road A-318 is located in Cordova province (South of Spain) and connects A-92 highway (near Seville/Cordoba provinces border) and N-432 road. The road authority in charge is “Junta de Andalucía”, which is part of the Regional Government of Andalusia (Spain).

The road section has one lane per direction and its layout is winding (moderate speed limits and sharp curves). This road has been entirely coded (between CH.0+000 and CH.72+600).

The point of interest is located at CH.60+000, where the Annual Average Daily Traffic (AADT) in 2018 was 6,033 vehicles. Figure 1 shows the location of A-318 (CH.60+000).

![Location of A-318 road stretch](image1)

Figure 84. Location of A-318 road stretch

The next figure is an aerial view of the A-318 (CH.60+000).

![Aerial view of A-318](image2)

Figure 85. Aerial view of A-318
The pavement condition was not at the desired level, due to general deterioration over time.

**MAINTENANCE REMEDIES**

The maintenance measure was to re-surface the poor road condition stretches along the road. Additionally, markings and guardrails were included at the maintenance works. The maintenance was carried out by “Junta de Andalucía” Regional Government and, the investment budget was around 200,000 €/km.

The following images show the road surface condition, before and after the surface rehabilitation.

![Figure 86. A-318 CH.60+000 (in 2009 and 2019)](image1)

![Figure 87. A-318 CH.33+000 (in 2016 and 2018)](image2)

As it can be seen in Figure 87, the metal guardrails were changed at CH.33+000.

**ROAD ASSESSMENT**

The Star Rating Score (SRS – a measurement of the component parts of the risk where the higher the score, the higher the risk) has been analyzed for 100 meters of the resurfaced stretch before and after the maintenance works in both sections (CH.60+000 and CH.33+000).

Before, the maintenance remedies at CH.33+000 (Figure 5), the Star Rating Score was 10,24 for vehicle occupants, 23,03 for motorcycles and 128,46 for bicyclists. The road was not assessed for pedestrians. The Star Rating (the simplified assessment of risk where the higher the number of stars, the safer the road) was 2 stars for vehicles occupant and motorcycles and 1 star for bicyclists.
After the completion of the maintenance works at CH.33+000 (Figure 6), the Star Rating Score was 4,35 for vehicle occupants, 9,41 for motorcycles, not applicable for pedestrians and 47,79 for bicyclists. So, due to maintenance remedies only, the Star Rating was increased for all road users (4 stars for vehicles occupant, 3 stars for motorcycles and 2 stars for bicyclists).

Before the maintenance remedies at CH.60+000 (Figure 7), the Star Rating Score was 36,18 for vehicle occupants, 51,31 for motorcycles, not applicable for pedestrians and 209,01 for bicyclists. The Star Rating was 1 star for vehicles occupant, motorcycles and bicyclists.

After the completion of the maintenance works at CH.60+000 (Figure 8), the Star Rating Score was 11,38 for vehicle occupants, 13,54 for motorcycles, not applicable for pedestrians and 57,35 for bicyclists. So, as a result of maintenance remedies only, the Star Rating was significantly increased for all road users (3 stars for vehicle occupants and motorcycles, and 2 stars for bicyclists).
CONCLUSIONS

In this example the Star Rating is used to illustrate how the safety of part of a network can be assessed when maintenance measures are implemented. It shows how it is not necessary to rely entirely upon crash data to demonstrate a potential safety improvement.

The maintenance carried out improved the road safety status substantially, with the Star Ratings increased by one or two stars.

The maintenance-only remedies implemented are considered effective.
2.15 D15 – Spain A-376 Highway (CH. 24+000, Seville)

INTRODUCTION

The information detailed in this Case Study has been provided by DGT. The road A-376 is located in the South of Spain and connects the cities of Seville and Utrera. The road authority in charge is “Junta de Andalucía”, which is part of the Regional Government of Andalusia (Spain).

A-376 has two lanes in each direction at the most part of the road. The case study is located at the end of the road where the road has just one lane per direction near Utrera (2 km of length), and the Annual Average Daily Traffic (AADT) in 2018 was 6,468 vehicles. Figure 1 shows the divided and undivided (2 km of length) carriageway road location. Figure 2 provides an aerial view of the roundabout located at the CH.24+000.

![Figure 92. Location of A-376 road Case Study](image)

![Figure 93. Aerial view of A-376 road Case Study](image)
MAINTENANCE REMEDIES
The road authority carried out different maintenance remedies at A-376 CH.24+000. This case study is located near a roundabout located in the Northwest of Utrera. It was a road stretch with a sharp curve where the surface had deteriorated.

The remedies carried out were: (i) re-surfacing and providing better delineation and (ii) improving a traffic calming measure (rumble strips placed perpendicular to the direction of travel).

The investment budget of the two remedies were 200,000 €/km and 2,000 €/km (including all the cross section), respectively.

Figures 3 and 4 show the road before and after the maintenance (re-surfacing and with better delineation and the traffic calming measure). The construction works were carried out in 2018.

As may be seen in Figure 94, a traffic sign was present, warning of the bad road condition. Figure 95 shows the road condition after the re-surface and traffic calming measures were carried out.

ROAD ASSESSMENT
The Star Rating Score (SRS – a measurement of the component parts of the risk where the higher the score, the higher the risk) has been analysed for 100 meters of section before and after the maintenance works (CH.24+000).

Before the maintenance remedies at CH.24+000 (Figure 5), the Star Rating Score was 18.51 for vehicle occupants, 28.28 for motorcycles and not applicable for pedestrians or bicyclists (the road was not assessed for the latter road users). The Star Rating (the simplified assessment of risk where the higher the number of stars, the safer the road) was 2 stars for vehicles occupant and 1 star for motorcycles.

Figure 94. A-376 CH.24+000 (2018)

Figure 95. A-376 CH.24+000 (2019)
After the completion of the maintenance works at CH.24+000 (Figure 6), the Star Rating Score was 6.66 for vehicle occupants, 8.19 for motorcycles, and not applicable for pedestrians and bicyclists. So, due to maintenance remedies only, the Star Rating was increased for all road users (3 stars for vehicles occupants and 3 stars for motorcycles).

ASSESSMENT OF CRASH DATA

The following Chart shows the type of injuries variation (fatality, serious and slight) between the years 2009-2019 for just 2 km length of A-376 that includes CH.24+000.
Chart 1 shows that, although the time period is short, there were no reported fatalities and serious injuries after the maintenance implementation (in 2018 and 2019).

The traffic calming countermeasures encouraged drivers to slow down approaching the. Drivers tended to adapt their speed to the new road condition and speeds are more uniform.

Chart 2 shows the head-on crashes at the road section. The blue points represent the number of crashes and the trend (blue dashed line) has been fitted as a polynomial regression. Chart 2 may suggest a trend of the head-on crashes decreasing, with between zero and two crashes per year, although note that the number of crashes is relatively small in recent years and the “after” time period is short.

![Chart 2. Head-on crashes (2009-2019)](chart2.png)

**CONCLUSIONS**

In this example the Star Rating is used to illustrate how the safety of part of a network can be assessed when maintenance measures are implemented. The maintenance carried out improved the road safety status substantially, with the Star Ratings increased by one or two stars.

The maintenance-only remedies implemented are considered effective, with both Star Ratings and crash data pointing to improvement after the completion of maintenance.
2.16  D16 – Spain A-8005 Road (CH. 7+300, CH. 26+500 Seville)

INTRODUCTION

The information detailed in this Case Study has been provided by DGT.

The road A-8005 is located in the Southwest of Spain and connects Seville city and different towns. The road authority in charge is “Junta de Andalucía”, which is part of the Regional Government of Andalusia (Spain).

A-8005 is an undivided road with one lane per direction, moderate speed limits and sharp curves. The Annual Average Daily Traffic (AADT) in 2018 was 7,152 vehicles. Figure 1 shows the case study location and Figure 2 provides an aerial view.

![Figure 98. Location of A-8005 CH.7+300 road Case Study](image1)

![Figure 99. Aerial view of A-8005 road Case Study](image2)
MAINTENANCE REMEDIES

Between 2008 and 2012 the road authority carried out different maintenance remedies along the A-8005. One of these measures was implementation traffic calming measures at the roundabout approaches.

Figure 100 show the situation at CH.26+500 before (2008) and after (2012) the maintenance implementation (traffic calming and central hatching).

![Figure 100. A-8005 CH.26+500 (2008) and A-8005 CH.26+500 (2012) “before” and “after”](image)

Additionally, road lining improvement was carried out in 2015 as part of improving the road condition. This maintenance measure was carried out by “Junta de Andalucía” Regional Government and the investment budget was around 2,000 €/km (including all the cross section).

Figures 4 and 5 show the road improving lining in the CH.7+300 and CH.28+300, before and after maintenance (in Figures 4 and 5 some time after implementation and therefore after some deterioration).

![Figure 101. A-8005 CH.7+300 (2014) and A-8005 CH.7+300 (2016) “before” and “after”](image)

![Figure 102. A-8005 CH.28+300 (2012) and A-8005 CH.28+300 (2016) “before” and “after”](image)

The road authority maintenance remedies on the A-8005 also included traffic calming and central hatching.
ROAD ASSESSMENT
The Star Rating Score (SRS – a measurement of the component parts of the risk where the higher the score, the higher the risk) has been analyzed for 100 meters of section before and after the maintenance works, in both cases (CH.7+300 and CH.26+500).

Before the maintenance remedies at CH.26+500 (Figure 6), the Star Rating Score was 7.5 for vehicle occupants, 8.74 for motorcycles and 28.11 for bicyclists. The road was not assessed for pedestrians. The Star Rating (the simplified assessment of risk where the higher the number of stars, the safer the road) was 3 stars for vehicles occupant, motorcycles and bicyclists.

After the completion of the maintenance works at CH.26+500 (Figure 7), the Star Rating Score was 6.06 for vehicle occupants, 7.07 for motorcycles, not applicable for pedestrians and 17.94 for bicyclists. The Star Rating remained the same as before maintenance measures implementation.

Before the maintenance remedies at CH.7+300 (Figure 8), the Star Rating Score was 5.69 for vehicle occupants, 7.92 for motorcycles, not applicable for pedestrians and 58.22 for bicyclists. The Star Rating (the simplified assessment of risk where the higher the number of stars, the safer the road) was 3 stars for vehicles occupant and motorcycles and 2 stars for bicyclists.
After the completion of the maintenance works at CH.7+300 (Figure 9), the Star Rating Score was 3.7 for vehicle occupants, 4.95 for motorcycles, not applicable for pedestrians and 31.22 for bicyclists. So, due to maintenance remedies only, the Star Rating was increased for vehicle occupants and motorcycles, to 4 stars, while the Star Rating for bicyclists remained 2-star but had almost a halving in the SRS.

Figure 106. Star Rating Score: A-8005 CH.7+300 (After maintenance)

ASSESSMENT OF CRASH DATA

Charts 1 and 2 show the type of injuries variation (fatality, serious and slight) between the years 2009-2019 for the sections of A-8005 that include the above-mentioned points of interventions.

The crash numbers are small and there is considerable variation but there is some evidence of a reduction of fatalities and serious injuries after 2016, the years after 2015 when the A-8005 CH.7+300 maintenance occurred.

Similarly, Chart 4 is shows that no fatal or serious injuries have been recorded in the last 6 years, at A-8005 CH.24+000-29+400.
Chart 3 shows the head-on and run-off crashes at the A-8005 road between CH.0+000 and CH.29+400. The blue points represent the number of crashes and the trend (blue dashed line) has been fitted as a polynomial regression. The trend of the head-on and run-off crashes is downward.

**CONCLUSIONS**

In this example the Star Rating is used to illustrate how the safety of part of a network can be assessed when maintenance measures are implemented. The maintenance carried out improved the road safety status substantially, and the Star Ratings in all but one example were increased by one or two stars.

The number of severe injuries has decreased after the maintenance on these road stretches. No fatal or serious injuries have been reported since 2016.
The maintenance only remedies implemented are considered effective, with both Star Ratings and crash data pointing to improvement after the completion of maintenance.