Crash rate – Star Rating comparisons

Review of available evidence, May 2011

Key:
- 1-star
- 2-star
- 3-star
- 4-star

KSI accident rate 04-06

Motorways
Dual
Mixed
Single

Road Class

iRAP/EuroRAP Working Paper 504.2
Executive summary

This is a review of 11 studies that make comparisons between average crash rates, costs or severities and the Road Assessment Programme’s Star Rating or Road Protection Score (RPS). Work from Australia, Germany, Iceland, Italy, Netherlands, New Zealand, Spain, Sweden (two studies), the United Kingdom and the United States is included. Ongoing work in other countries will be added to this review in due course.

Different methodologies and approaches have been used to answer the question “How well does the Star Rating of roads for safety match actual crash data?”. This review includes comparisons of (i) Star Rating data with accelerometers in real world crashes, (ii) visual comparisons of crash rates and Star Rating maps and (iii) elements of seven studies correlating average crash rates or crash costs with the Star Rating or RPS. The most robust studies included here show decreasing average crash or cost rates associated with increasing Star Rating and vice versa. This indicates that the Star Rating and RPS is providing a valid measure of injury risk.

Different RPS models have been used in these assessments – all contain elements that assess the crash protection elements of the highway and the later models include factors that influence crash likelihood. Both types show evidence of the relationship with crash rates, but some of those with both crash protection and crash likelihood elements are also more substantial studies and show this to a greater extent.

There have been particularly good matches between the Star Rating and average crash rates or costs where data sets are large and the road sections on the routes being compared are relatively homogenous – those studies in Australia, New Zealand and the US illustrate this best.

The Star Rating or RPS is not a good predictor of crash rates for an individual road section – there is typically too much inherent variance in the crash data. Just as the crash data may not give a reliable true long-term picture of the safety of a road section, so too the RPS does not fully capture those infrastructure elements that lead to fatal and serious injury.

A small number of the studies cited here show very little correlation between average crash rates and the Star Rating/RPS. There is usually a good explanation for this, either in the way in which the data have been defined or assembled or the inability of the research design to separate statistical noise or confounding factors.

The overall relationship between average crash rate and Star Rating/RPS for any network will vary from country to country, dependent in part upon the mix of roads in that network. In some circumstances it is useful to know how average crash rates change from one Star Rating band to the next. Some analyses show a reduction of between a third and a half in average crash rates, notably when moving between 2-star and 3-star roads. This change in crash rates is often lower when moving from a 3-star to 4-star or 4-star to 5-star banding, and this in part reflects the nature of the relationship between crash rates, traffic volume and road standard.

Some considerations and recommendations have been offered for future comparisons and for the presentation of these studies.
About EuroRAP

The European Road Assessment Programme (EuroRAP) is a not-for-profit organisation dedicated to saving lives through safer roads. Its members are motoring organisations, national and regional road authorities, and experts who have been elected because of the special contribution they have made to EuroRAP.

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

- reduce death and serious injury on European roads rapidly through a programme of systematic testing of risk and identify major safety shortcomings which can be addressed by practical road improvement measures
- ensure assessment of risk lies at the heart of strategic decisions on route improvements, crash protection and standards of route management
- forge partnerships between those responsible for a safe roads system – motoring organisations, vehicle manufactures and road authorities.

Road Assessment Programmes (RAPs) are now active in more than 60 countries throughout Europe, Asia Pacific, North, Central and South America and Africa. These programmes provide independent, consistent safety ratings of roads across borders. The Road Assessment Programme has shown that the implementation of countermeasures at locations of high injury risk provide the potential for very high rates of economic return.

iRAP (the International Road Assessment Programme) is the umbrella organisation promoting the Road Assessment Programme worldwide, often in low- and middle-income countries, and developing the assessment tools required for this purpose.

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

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European Road Assessment Programme

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1. Why assess the crash rate-Star Rating/RPS relationship?
This is a working paper produced primarily for EuroRAP and iRAP members and those with whom they work. Production of this document was prompted initially by EuroRAP RPS (Road Protection Score) Group. It draws from a series of EuroRAP, iRAP and other working documents produced by Road Assessment Programme members and partners over recent years. It includes reviews of 11 studies that make comparisons between average crash rates, costs or severities and the Road Assessment Programme’s Star Rating or Road Protection Score (RPS). Most are unpublished studies and have been produced locally by different methods and in different formats and generally after Road Assessment Programme inspections have been completed in a country. Not all elements of the studies are shown here.

The Star Rating used by those involved in the Road Assessment Programme worldwide is derived from the Road Protection Score. This score was developed initially by EuroRAP to provide an estimate of likely fatal and serious injury outcomes when a crash occurs. That methodology was improved within the AusRAP programme to include a measure of crash likelihood and further developed by iRAP to provide the current iRAP Star Rating of the safety of roads where 1-star represents a poorly-scoring road, and 5-stars the best.

The Star Rating is often used when there are no crash data available to assess the safety of a road and therefore it is reasonable to ask how valid the Star Rating is as a measure of safety and how well it measures what it is designed to assess. To address these issues, where crash data are available, the fatal and serious crash rate per billion vehicle kilometre (or other measures) may be compared with measures of the RPS or the Star Rating. To demonstrate validity, the RPS or Star Rating needs to demonstrate a good indication of risk based on the observed road design features. This document therefore mainly focuses on comparing experience of matching RPS or Star Rating with crash rates.

2. The RPS models
The Road Assessment Programme ethos is one of continuous improvement and several RPS versions have been developed or tested over recent years:

- EuroRAP RPS1.0 – this is the original EuroRAP RPS. Only crash protection items (secondary safety elements) relating to car occupants are included. See Figure 1 for a list of these items. Section lengths can be based upon start and end points at which the character of the road changes or divided every 100m, the latter analysed using an online calculator developed in 2010. Data collection is typically completed whilst travelling the road and recorded via a touch-sensitive pad.

- EuroRAP RPS2.0 – this version of the model includes crash likelihood factors. It uses the car elements from the iRAP model and a multiplicative model, rating roads every 100m. Typically, data for RPS2.0 can be taken partly from a drive-through inspection and partly (or wholly) by retrospective assessment of the videos of the inspection route.

- EuroRAP RPS1.5 – this is a more limited interim version of RPS2.0 which includes fewer likelihood items and fewer categories for each item than the planned fully extended RPS. It is based on the items and categories included on the British tablet during Stage I of the work with the Highways
Agency in England (see Castle et al (2007)). It extended the data collected to a level utilising most of the available space on the tablet and the capacity of the inspectors to collect this in-car.

- RPS iRAP – this includes assessments for four separate modes (car, motorcycle, pedal cycle and pedestrian), and requires some or all of the data to be obtained retrospectively by rating the inspection videos. Data have been collected in more than 20 countries using versions 2.1 and 2.2 of this model. See Figure 2 for the car occupant example of the elements in this model.

- The Australian and New Zealand models reported on here have most of the same core characteristics of the iRAP version but incorporate variations requested by local professionals to suit local custom, practice and needs.

All of these models use measures of risk than can be collected from a drive-through inspection or can be augmented by retrospective coding of a video recording. All but EuroRAP RPS1.0 are translated into a Star Rating of 1-5 stars. The EuroRAP RPS1.0 operates on 1-4 stars.

3. Why the crash rate-Star Rating/RPS relationship may be imprecise

If all other factors are consistent, the RPS scores should give a good indication of the relative numbers of killed and seriously injured casualties to expect on different road sections. But, with EuroRAP RPS1.0 for example, even without natural variance in crash rates, the scores will not match the number of killed and seriously injured (KSIs) where:

- the likelihood of an accident occurring varies between roads of the same type (because EuroRAP RPS1.0 only measures secondary safety and the extent to which the road protects once the accident has occurred (and therefore no measure of the likelihood of a crash happening)

Further, even when the model being used does measure the likelihood of a crash occurring, the match between crash data and RPS will be poor where:

- the number of fatal and serious crashes is small and there is substantial variation in crash totals from one potential comparison period to another
- those involved in the accident are not complying with the behavioural design “envelope” for the road ie being belted and driving within legal speed and drink drive limits (Inappropriate speeds within the limit might still be adopted – for example, on bends.)
- the cars involved in crashes have less than an NCAP 4-star rating
- those injured are unduly frail
- there are a substantial number of accidents resulting in injuries to road users other than car occupants (and if these crashes to other road users are not excluded from the analyses)
- the car occupant accident pattern is dominated by types other than those that are modelled – ie run-off, junction or frontal car to car impacts
- there is substantial under-reporting of fatal and serious crashes or there is miscoding of their location
the traffic flows on which the crash rates are based are substantially inaccurate

Although the RPS does not capture all aspects of risk, it can potentially be a better indicator of the influence of road design on the risk of serious injury than total accident numbers because it highlights some of the risks arising directly from road design rather than from road-user behaviour.

**Figure 1: EuroRAP Version 1.0 elements**
4. How to assess the crash rate-Star Rating/RPS relationship

Several methods have been used to compare the RPS and crash data:

- In the most basic of situations, the crash rate for a single section of road has been compared with the Road Protection Score for that road section. For many sections (and even those of the 10-20km lengths often involved in the route analyses of the RAP) and as indicated in section 3, this is unlikely to provide a precise match because large variance in the average measures associated with crashes mean that the number of crashes on any given road section will vary substantially even during the 3-year time periods often used to make such comparisons.
Other, visual, comparisons are possible and some are presented here. Typically, they compare a Star Rating map side-by-side with a Risk Rate Map and show that overall there is lower risk on roads that have higher Star Ratings and vice versa.

Lynam (2010) has reviewed crash rate-Star Rating/RPS comparisons and reports, and much of what follows in this section and section 5 is taken from that report: “The validity of the results obtained has been investigated in various ways. An initial approach was to look at roads in Sweden that were assessed as 4-star – which in principle should have no fatal accidents – and see if this was indeed the case. To do this it is necessary to isolate the fatal accidents that only involve cars, specifically those that are rated as 4-star in NCAP, and where no traffic violation such as speeding or non-wearing of seatbelts is involved. When this is done, there are relatively few situations where fatal accidents occur on four star roads (Lynam et al, 2007).”

Assessments of the secondary safety (crash protection) characteristics of the road have been made and the Star Rating compared with potential injury severity measured by accelerometer pulses. Stigson et al (2009 and 2010) have investigated differences in crash pulses from on-board recorders in accidents on roads with different infrastructure ratings. That work showed that changes in velocity were typically greater on those roads rated as less than 4-star – the lower-rated roads being less forgiving (Figures 3 and 4).

**Figure 3: Average change of velocity in crashes on four-star and less-than-four-star roads**
Lynam comments “More direct validation has been attempted by comparison between Star Ratings and observed accident data. To do this, average fatal and serious accident rates are calculated for roads obtaining different Star Ratings, with the aim of showing that the higher star roads have lower accident rates. Comparisons across whole networks including a range of road types typically show a strong relationship between Star Rating and accident rate, but this is heavily driven by the low rates and high ratings to be expected on motorways compared with the higher rates and lower Star Ratings to be expected on single carriageway roads.

“Much more convincing comparisons are provided by looking for relationships within road type groups. The range of rating and accident rate within a road group is much less than across all road types but fairly strong relationships can still be seen in the Swedish data (Lynam et al, 2007 – see the excerpt at section 9.1 of this report) and the British data (Castle et al, 2007; Martin et al, 2009 – section 9.2).” (The chart below, taken from an unpublished draft report by SWOV (2010) shows the type of relationship that might be targeted, whereby a decrease in one star is associated with a reduction in the average crash rate. Note in particular that the crash rate shown in the histograms is an average and that the crash rate for each for each star rating will vary about this mean. See Figures 15-18.)
The relationships can further be seen within comparisons for individual accident types. The British comparisons show similar linkages for subsets of the road network as well as for the Highways Agency network as a whole, and the whole primary road network. However it is noted that roads with higher flows among the British data typically have both lower accident rates and high ratings than those with lower flows. It is unclear whether this is a confounding factor in the comparisons, and the extent that this trend reflects the higher flow roads having been improved more because of the higher cost effectiveness of improvements on these roads. (see section 9.2)

Similarly analyses of EuroRAP data from Germany (see section 9.5) and early work in the Netherlands have failed to identify any clear link between ratings and accident rates, although more recent work in the Netherlands has pointed to the structure of the data set as being a shortcoming (see section 9.1 for details of more successful linking work in the Netherlands)

Some factors have been identified that might explain this difference between the outcomes in the different countries. These factors include differences in the nature of the road sections being grouped (a lack of homogeneity), low numbers of sections being compared in each category, low numbers of severe crashes on each road section, and pre-definition of crash types in a way that is not directly compatible with the risk types being assessed in the Road Protection Score. More comparative analyses are being pursued.
5. Validation of the iRAP model

Lynam (2010) outlines the work done thus far: “The aim of the iRAP programme is to show the general shape and size of potential improvement programmes for the low and middle income countries. Ratings can be used to identify individual road sections that appear to warrant improvements but these should be tested by ground inspections. The improvement programmes proposed for the four initial trial countries were generally recognised as plausible by local safety engineers (iRAP, 2008).

“To date there has been less work aimed at validating the risk models directly. One main reason for this is the lack of good accident data from the countries in which iRAP has been applied, which means that accident rate/rating comparisons of the type made for EuroRAP have not been possible. A paper by Harwood et al. on the application of iRAP to a sample of US roads has found some evidence of a relationship between Star Ratings and crash rates, and further work is continuing (see section 10.2 for the final published work – Harwood et al. (2010)). The structure of the data set in the US may be conducive to demonstrating the relationship – it includes larger and longer samples of road sections than some other data sets, and road sections that are relatively homogenous compared with Europe in design and layout. Martin et al (2009) show some results for Britain of applying a partially extended EuroRAP model in a similar format to the iRAP car occupant risk model. The relationship between accident rate and Star Rating is less strong than that for the basic (protection elements only) EuroRAP ratings, but this may result from this model not fully representing all iRAP parameters.

“An alternative approach to assessing the models is to look at their internal consistency and at the typical accident type patterns that their application produces. Extensive review of the initial results from the iRAP analyses, while indicating some improvements that could be made to both the models and to the risk factor values, failed to reveal any major inconsistencies in the results obtained.

“The iRAP ratings are spread over 5 bands, so that the best roads are now rated as 5 star. This is consistent with the bands used in AusRAP, and with the rating range used more generally, eg for hotels etc. EuroRAP initially followed the EuroNCAP practice of using 4 stars, but that has subsequently been extended to 5 stars to enable additional features to be captured.”

6. Assembling the data

The average crash rate (or crash cost) may be calculated for roads sections of similar type and with the same Star Rating. In assembling the data it is necessary to understand that:

- A substantial number of different kinds of relatively homogenous road sections is required to make any worthwhile comparison.
- These road sections must have sufficient fatal and serious crashes on each section to make comparisons. This may mean using a five-year time period rather than the three-year used in many studies.

- The road sections will typically be divided into (i) motorways (ii) non-motorway dual carriageways (iii) single carriageways and (iv) other roads.

- The requirement for these roads to be relatively homogenous within their categories is because it is necessary to demonstrate a comparison of like-with-like – if there are substantial differences in the high-level design features of the roads other than in those features captured by the RPS that contribute to injury outcome, then these features should have been captured in the RPS.

- Any comparison between roads of different types of road must ensure that there are enough road sections in each of the types being compared (eg motorway, single or dual carriageway).

- Because the comparison of crash is being made between roads of different Star Ratings in each road category, it is also necessary to have a substantial number of road sections within each Star Rating group.

- The most successful matches of crash rate and RPS have shown that it is necessary to have a substantial number of such road sections in each Star Rating group. More specific advice can be provided on this and matched to particular local circumstances.

- Not only must there be a satisfactory number of road sections, each of these road sections must be of sufficient length or have sufficient fatal and serious crashes to reflect the long term average for crashes on that particular road section.

- Be aware that, if disaggregating by crash type and comparing the RPS/Star Rating component (eg head-on, run-off or intersection), with crashes of only that kind, that the number of crashes available for the comparison will of course be smaller than the total number of crashes for each section and that this will add variance to the exercise.

It is unusual for all the criteria listed above to be met in any study. The results that have been achieved in comparisons thus far reflect the increased variation that is introduced when dealing with smaller than ideal road numbers within some of the histogram bars shown here and the very small crash numbers on these road sections.

1 “Other roads” often include a variety of road designs and it is unusual to find a strong relationship between crash rate and RPS on these roads. Note also that when making comparisons between crash data and RPS score, it should be considered whether urban road sections should be excluded. Similarly, roads with a low average speed limit should be checked to see whether they are in fact urban in nature.
Ideally, to compare crash rates with RPS, only the fatal and serious crashes relating to the elements in the RAP model should be included – run-off head-on and intersection crashes. The closest comparison is likely to be achieved when considering only car occupant fatalities, but it is unlikely that there will be sufficient quantities of data for these collisions (i.e. it is highly unlikely that there are 20 collisions that are fatal for car occupants on each road section), so serious injuries will probably need to be included, and often crash data for all motorised vehicles taken into account.

7. Visual comparisons from maps

7.1. England

These Star Rating data are for the English motorway and trunk road network and were collected in 2007-08. The crash data are fatal and serious crashes and for 2005-07. Quantitative analysis is presented in a subsequent section. Those familiar with the English motorway network will identify it in the Risk Rate Map as mainly those sections of continuous green. Those sections in the Star Rating map that are not green are typically those with low-scoring run-off protection. Away from the motorway network the matching of colours is less precise but there are nevertheless many long sections with identical colours on the two maps.

Figure 6: Risk Rate Mapping (left) and Star Rating (right) in England
7.2. Iceland

These Star Rating data are for the national road network in Iceland – principally the major road encircling this country. Again, many of those sections scoring poorly in the Star Rating (mainly 2-star in EuroRAP RPS1.0) also feature in the high crash rates (black and red sections). Similarly, those scoring better on the Star Rating also score well in crash rates. This analysis also identifies another potential difficulty in making RPS-crash rate comparisons in circumstances where the spread of Star Rating is insufficient to make a useful comparison. Here, the bulk of the Star Rating is categorised as either 2-star or 3-star, with very little distribution in either 1-star or 4-star. Other comparative maps are presented in the Appendix.

Figure 7: Risk Rate Mapping (top) and Star Rating (EuroRAP RPS1.0 -- foot) in Iceland
8. Quantitative comparisons of average crash rate vs Star Rating/RPS

The EuroRAP RPS Group has identified that different approaches have been used to assess crash rate and RPS. Several studies have matched 100m RPS data (or Star Rating) to crash rates over that same 100m section, whereas others have matched average Star Rating or RPS over longer lengths to crash rates over longer lengths of route. Both methods are relating observed risk to estimated risk, with the latter method providing an average or “smoothed” value over the longer length. Schematically, Puerto (2010) has explained an idealised process that could be used when comparing either 100m or longer lengths.

**Figure 8: Comparing lengths of crash data and Star Rating/RPS data**

- **CRASH DATA**
  - Select either crash density or risk rate
  - Take out non-car accidents
  - Separate data into crash types – Head-on, Run-off and Intersection
  - Take out crashes involving non 4-star car, speeding, non use of seatbelt etc

- **RPS DATA**
  - For each 100m section (or longer lengths)
  - Match RPS data with each risk map section
  - Plot graph for all carriageway types (aggregated) and then for each of: all motorways, all dual carriageways and all single carriageways
9. Country and regional quantitative comparisons using the RPS model with only the crash protection element

This section shows selected results from some comparisons of Star Ratings using EuroRAP RPS1.0\(^2\) and crash rates.

9.1. Sweden

These notes are taken substantially from an unpublished report to Vagverket by VTI (2007).

“The purpose of this study was to verify RPS (Road Protection Score) by comparing the Star Rating with accident data. The Star Rating for each road link is compared with KSI divided by million kilometres travelled for that road link. Let’s call the term for KSI divided by million kilometres travelled for KSI-quota\(^3\). Seat-belt usage and actual speed needs consideration so the quota is reduced because of these two parameters. In both these cases a model is used and not individual accident data.

The scores for vulnerable road users are excluded in this study. Only accidents with passenger cars involved were considered. The accident data used is from a three year period, from 2003 to 2005. The total road length is 8969 km including:

- Single carriage way 6576 km
- Motorway 1429 km
- 2+1 roads 811 km
- 4-lane roads 110 km
- Other roads 43 km

There is an overall correlation between the RPS and the KSI-quota with all studied road links put together. Links with higher EuroRAP scores have a lower KSI-quota than low scoring links. Bars with checked pattern are based on less than a hundred million kilometres travelled.

- The purpose has been to study RPS by comparing the Star Rating with KSI (killed an seriously injured) divided by million km’s travelled. (the Swedish term is DSS-kvot).
- The match between accident data and RPS road network has been done by SWECO.
- The analysis has been done by VTI, The Swedish research institute in road transport.
- The graphs in this presentation has been prepared by VTI.

\(^2\) Figure 14 shows a comparison using RPS1.5, a pilot version including some trial likelihood elements

\(^3\) KSI_quota – the crashes involving killed and seriously injured casualties divided by traffic
### Table 1: Disaggregation of road, crash and traffic variables by road type

<table>
<thead>
<tr>
<th>Road type</th>
<th>Length [km]</th>
<th>Million km's travelled</th>
<th>Accidents</th>
<th>No of road links With kai =0</th>
<th>ksl</th>
<th>reduced</th>
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<tbody>
<tr>
<td>Single carriage</td>
<td>6 576</td>
<td>30 249</td>
<td>833</td>
<td>3096</td>
<td>2434</td>
<td>1359</td>
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<tr>
<td>Motorway 2+1</td>
<td>1 429</td>
<td>34 600</td>
<td>389</td>
<td>1217</td>
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<td>561</td>
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<td>4-lane</td>
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<td>6 901</td>
<td>60</td>
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<td>92</td>
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<td>331</td>
<td>11</td>
<td>107</td>
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<td>15</td>
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<tr>
<td><strong>Total</strong></td>
<td>8 969</td>
<td>74 548</td>
<td>1385</td>
<td>5429</td>
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### Table 2: Disaggregation of road type by Star Rating

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<th>3</th>
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<td>125</td>
<td>21</td>
<td>5</td>
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<tr>
<td>Single carr w VÅG-90</td>
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<td>630</td>
<td>362</td>
<td>27</td>
<td>1030</td>
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<td>Single carr w-70</td>
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<td>212</td>
<td>289</td>
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<td>507</td>
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<td>Single carr w-50</td>
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<td>332</td>
<td></td>
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<tr>
<td>Single carr w VÅG-30</td>
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<td>Motorway 110</td>
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<td>316</td>
<td>505</td>
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<td>2+1-1-110</td>
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<td>76</td>
<td>127</td>
<td></td>
<td>215</td>
<td></td>
</tr>
<tr>
<td>2+1-70</td>
<td>11</td>
<td>63</td>
<td></td>
<td></td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>2+1-50</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4-lane-110</td>
<td>1</td>
<td>7</td>
<td>10</td>
<td></td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>4-lane-90</td>
<td>3</td>
<td>29</td>
<td>9</td>
<td></td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>4-lane-70</td>
<td>2</td>
<td>13</td>
<td>80</td>
<td></td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>4-lane-50</td>
<td>2</td>
<td>12</td>
<td>39</td>
<td></td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>Single carr w mix speed</td>
<td>2</td>
<td>472</td>
<td>422</td>
<td>91</td>
<td>987</td>
<td></td>
</tr>
<tr>
<td>Motorway mix speed</td>
<td>2</td>
<td>32</td>
<td>48</td>
<td></td>
<td>82</td>
<td></td>
</tr>
<tr>
<td>2+1 mix speed</td>
<td>2</td>
<td>67</td>
<td>81</td>
<td></td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>4-lane mix speed</td>
<td>5</td>
<td>32</td>
<td>42</td>
<td></td>
<td>79</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>19</td>
<td>1266</td>
<td>1932</td>
<td>2140</td>
<td>5429</td>
<td></td>
</tr>
</tbody>
</table>
Figure 9: KSI-quota crash rate (all accidents) by Star Rating and road type

The KSI-quota varies more between road types – especially if the road has a divided carriageway or not – than between different EuroRAP scores. A result of this is that undivided roads with high EuroRAP score have significantly higher KSI-quota than divided roads (motorway and 2+1 roads) with a low score. In addition there is a clear difference in KSI-quota for 2+1 roads depending on the speed limit. With high speed comes higher KSI-quota.

The KSI-quota was calculated for head-on, run-off and intersection accidents only. The comparison was done for the total Star Rating and also for the EuroRAP score broken down into the three accident types above. Charts for these three accident scenarios can be seen below.
Figure 10: KSI-quota crash rate (run-off) by Star Rating and road type

Figure 11: KSI-quota crash rate (head-on) by Star Rating and road type
The Swedish Transport Authority added the following comments (Torsten Bergh, personal communication, 2010):

“Star Rating for middle section should have a clear statistic relationship with presence of middle barrier. In the report they found a higher dead/seriously injured quota on 2+1 roads with middle barrier with speed limit 110 kph than the speed limit 90 kph. If the crossing section is added the differences are less, but still vary a lot.

Crossing section points are difficult to understand how they are set, and there is no correlation found as the point does not recognise traffic flow.

Dead/seriously injured quota varies more between road type than Star Rating bounds, i.e. that roads without middle barrier and high EuroRAP scoring has a higher dead/seriously injured quota than roads with middle barrier and low EuroRAP scoring.”

9.2. England

ADAC inspected 5,200km of Highways Agency road between November 2007 and January 2008 and had previously inspected 2,700km in a pilot. The project was managed and the research analysed by TRL. Relationships were analysed by crash types. See Figures 13 and 14 for details.
Figures 13 shows decreasing crash rates (KSI – fatal and serious crashes involving those killed and seriously injured) with increasing Star Rating using EuroRAP RPS1.0 and, on the following page, Figure 14 shows a less uniform pattern using the pilot RPS1.5 model which included some trial likelihood elements.

Figure 13: Average accident rate by road type and Star Rating in England using RPS1.0
Figure 14: Average accident rate by road type and Star Rating in England using RPS1.5

Run-off + head-on + junction accidents

Head-on accidents

Junction accidents

Run-off accidents

Key: 1-star 2-star 3-star 4-star
9.3. Netherlands – Utrecht

A report from SWOV to ANWB showed “...that the casualty risk is lower on sections of road with 4 stars for the entire section of road than for sections of road with a total of 3 stars. Moreover, the casualty risk for occupants of motor vehicles on sections of road with a total of 3 stars is once again lower than for sections of road with a 2-star rating. However, the differences are not statistically significant...”

The absence of a statistically significant result may be due in part to the size of the sample and the underlying assembly of the data.

Again, to be able to make a useful comparison of different roads and scores it is necessary to have a sufficiently large sample of roads within each of the categories to be analysed and a sufficiently large number of fatal and serious crashes that have occurred within each category.

The charts in the SWOV analysis move in the “right direction”, with increasing crash rates being associated with decreasing Star Rating for different crash types. Extracts from the SWOV report have been provided (Louwerse (2011) – personal communication) below and expand upon these points.

Table 3: Disaggregation of variables by Star Rating

<table>
<thead>
<tr>
<th></th>
<th>2 star roads</th>
<th>3 star roads</th>
<th>4 star roads</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road sections (#)</td>
<td>32</td>
<td>482</td>
<td>87</td>
<td>601</td>
</tr>
<tr>
<td>Total road length in</td>
<td>127</td>
<td>165</td>
<td>22</td>
<td>314</td>
</tr>
<tr>
<td>kilometres</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic performance in</td>
<td>1663,72</td>
<td>2497,79</td>
<td>420,59</td>
<td>4564,10</td>
</tr>
<tr>
<td>million vehicle kilometres</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serious casualties</td>
<td>63</td>
<td>89</td>
<td>6</td>
<td>158</td>
</tr>
<tr>
<td>Casualty rate (serious</td>
<td>0,038</td>
<td>0,036</td>
<td>0,015</td>
<td>0,035</td>
</tr>
<tr>
<td>casualties per million</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>vehicle kilometres)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 15: Weighted average of the casualty rate for road sections with 2, 3 or 4 star with respect to the RPS for the total. The error bars indicate +/- 1 times the standard error (p-value of difference between 2 and 3 stars is 0.8, 2 and 4 stars 0.2 and 3 and 4 stars 0.2).

Figure 15 shows that the casualty rate decreases with the number of stars. The casualty rate at 4 stars is considerably lower than at 2 and 3 stars, but the differences are not statistically significant (p>0.05).

Figure 16: Weighted average of the casualty rate for road sections with 2, 3 or 4 star with respect to the RPS for run-off crashes. The error bars indicate +/- 1 times the standard error (p-value of difference between 2 and 3 stars is 0.5, 2 and 4 stars 0.2 and 3 and 4 stars 0.6).
The decline in the weighted average of the casualty rate in a rising Star Rating is not statistically significant (p>0.05). The decrease in the casualty rate is too low and the dispersion around the weighted average is too large. The small number of roadside accidents in the sample (47) is partly to blame here.

**Figure 17:** Weighted average of the casualty rate for single carriageway road sections with 2 or 4 star with respect to the RPS for head-on crashes. The error bars indicate +/- 1 times the standard error (p-value of difference between 2 and 4 stars is 0.13)

The casualty rate is significantly lower at 4 stars than at 2 stars (p >0.10).

**Figure 18:** Weighted average of the casualty rate for road sections with 1, 2, 3 or 4 star with respect to the RPS for side impact crashes at junctions. The error bars indicate +/- 1 times the standard error (p-value of difference between 1 and 3 stars is 0.16, 1 and 4 stars 0.006 and 2 and 4 stars 0.03)
The difference in the weighted casualty rate between junctions with 1 star and 4 stars (p <0.01) and between junctions with 2 and 4 star (p <0.05) was statistically significant.

9.4. Spain – Murcia

In Spain, RPS was compared to Risk Rate Mapping for the 952km of the Murcia region. Motorcycles, HGVs (trucks) and pedestrians were excluded from the analysis, although overall AADT was used since motorcycle and HGV figures could not be excluded from that information. The analysts reported that data were unreliable due to a large proportion of urban road sections, small sample size for 1-star and 2-star roads (see table below), unreliability of data recorded for collision type (it not being possible to remove crashes not modelled by the RPS). Head-on risk matched better with head-on Star Rating than either run-off or intersection crashes matching, although the 1-star section (possibly because it is a sample of only five sections) does not match well.

The analysts report that correlation was difficult due to:

- Many peri-urban stretches where road design and speed limit are not aligned.
- Little sample size for 1 and 2 star roads.
- Accident types not clear in database.
- Lack of detailed stepwise methodology (assessment may have differed in S or UK)

![Figure 19: Overall risk vs Star Rating](image-url)
Table 4: Disaggregation of variables by Star Rating (overall crashes and risk)

<table>
<thead>
<tr>
<th>RPS</th>
<th>N</th>
<th>Length</th>
<th>VehKm</th>
<th>AccTotal</th>
<th>AccKSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>9</td>
<td>81.7</td>
<td>183,908,248</td>
<td>23.8</td>
</tr>
<tr>
<td>2</td>
<td>67</td>
<td>728.4</td>
<td>1,378,851,077</td>
<td>190.8</td>
<td>76.8</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>142.0</td>
<td>679,803,095</td>
<td>74.0</td>
<td>25.3</td>
</tr>
<tr>
<td>Total</td>
<td>96</td>
<td>952.2</td>
<td>2,242,552,410</td>
<td>288.5</td>
<td>111.5</td>
</tr>
</tbody>
</table>

Figure 20: Head-on risk vs Star Rating (head-on)

Table 5: Disaggregation of variables by Star Rating (head-on crashes and risk)

<table>
<thead>
<tr>
<th>RPS</th>
<th>N</th>
<th>Length</th>
<th>VehKm</th>
<th>AccTotal</th>
<th>AccKSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>69.8</td>
<td>89,863,785</td>
<td>2.5</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>45</td>
<td>470.2</td>
<td>776,992,957</td>
<td>52.0</td>
<td>22.0</td>
</tr>
<tr>
<td>3</td>
<td>31</td>
<td>258.5</td>
<td>624,124,089</td>
<td>19.3</td>
<td>9.8</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>153.6</td>
<td>751,581,580</td>
<td>19.8</td>
<td>7.5</td>
</tr>
<tr>
<td>Total</td>
<td>96</td>
<td>952.2</td>
<td>2,242,562,410</td>
<td>93.5</td>
<td>40.3</td>
</tr>
</tbody>
</table>

*Note that in both figures the horizontal line refers to the overall mean crash rate.
9.5. Germany

The results below are from work in Bavaria and Rheinland-Pfalz. Disappointingly, they show little correlation between crash rate and Star Rating. A number of factors were noted by the researchers as contributing to this lack of fit, among them:

- Pre-defined crash data that did not exactly match the character of the crashes modelled in the RPS.
- Localised speed limits at junctions – the rating convention scores such locations well by virtue of the low limit even though infrastructure and compliance with the limit may have suggested that the risk is higher.
- There was limited ability to define urban areas.
- Many road sections were rated at the posted speed limit of 70 km/h although it was noted that compliance with this limit was notably poor and the underlying relationship with crash rate and RPS would therefore have been weakened.

In the charts below the following abbreviations are used:

- U(SP) – killed and seriously injured
- BAB — motorway
- B – single carriageway federal roads
- St – single carriageway state roads
Figure 21: Bavaria Crash Rate by Star Rating

Figure 22: Rheinland-Pfalz Crash Rate by Star Rating
10. Country and regional quantitative comparisons using the RPS models with both crash protection and likelihood elements

Section 2 describes the models being used in the comparisons being made here.

10.1. Australia

Collision cost per billion vehicle kilometre (BVKM) may be calculated by multiplying the number of collisions by their relative recovery cost and then calculating the collision cost per BVKM. This places more of a weighting on fatal collisions whereas individual risk makes no distinction between fatalities and injuries. This may provide a closer correlation between RPS and Risk Rate and is the methodology adopted by AusRAP (see AusRAP (2008)).

AusRAP plotted average crash cost against Star Rating for the state of Queensland. Over 5,300 carriageway kilometres were assessed, in homogeneous sections ranging from 200 metres to 20 kilometres in length. The roads were predominantly sigh-speed roads in open rural settings, ranging from coastal hinterland to arid outback environments. The process for this study was as follows:

- Source traffic volume & crash data for 5-yr period (1999-2004)
- Aggregate RPS data into meaningful section lengths
- Assign data to homogeneous road sections defined by RPS results
- Source crash cost data: ($2,038,182 fatal, $500,741 serious injury, $29,598 minor injury based on Queensland Main Roads data – other available data include BTRE, ARRB)
- Calculate average crash cost for road sections
- Calculate vehicle km travelled for each road section
- Calculate crash cost per vehicle km for each road section
- Analyse & review relationship between RPS & crash cost data.
- Comparisons were made as follows:
  - Crash cost per VKT by Star Rating
  - Crash cost per VKT by raw RPS (data classed 0-2, 2-4, 4-6 etc)
  - Component RPS – run-off RPS
  - Component RPS – head-on RPS
  - Component RPS – junction RPS
  - Graphs shown as RPS cumulative road length (%) against risk/cost etc
European Road Assessment Programme

As a form of model validation, it is expected that the crash costs per vehicle kilometre travelled will increase on roads with a lower Star Rating. For example, it would be expected that a road with a 1- or 2-Star Rating would have more crashes than a road with a 3- or 4-Star Rating.

This would provide knowledge of the crash cost savings that can be achieved through improvements in road infrastructure, thereby allowing clubs and authorities to understand the economic benefits to be achieved from improving the Star Rating of roads.

The results showed good correlation as a result of large road network coverage and use of crash cost figures instead of individual risk. Note that using crash cost takes into account collision severity as well as frequency.

The primary analysis of average crash costs per kilometre travelled and the Star Ratings revealed the following result:

- Average crash costs of $0.027 per kilometre travelled on 4 star roads
- Average crash costs of $0.050 per kilometre travelled on 3 star roads, and
- Average crash costs of $0.101 per kilometre travelled on 2 star roads.

The analysis provides a strong indication of the improvement in crash costs that can be expected as a road network improves from two star to three star to four star and ultimately a five star road, with ratings moving substantially in the “right direction” – decreasing crash costs with increasing Star Rating.
Figure 23: Crash Cost per VKT by Star Rating

Figure 24: Crash Cost per VKT by RPS
10.2. USA

In Iowa and Washington, Star Ratings have been compared with corresponding crash rates. Approximately 4,800 kms of rural and urban roads of various types were scored using the RPS-method of the US Road Assessment Program (usRAP), this the car-component of the iRAP model. Fatal and serious crash data were determined for 100m road segments (insofar as it is possible to allocate such data precisely) and sections aggregated by road type, area type and posted speed limit.

Harwood et. al. (2010) concluded that there is strong evidence (statistically significant at p < 0.05) that the crash rate decreases with increasing Star Rating values (for vehicle-occupant crashes as a whole) single carriageway roads of type 1x2 and 1x4 (two-lane undivided highways, four-lane undivided highways) and double lane roads of type 2x2 (four-lane divided non-freeways).

This statistically significant relationship (p < 0.05) was also found for run-off road crashes on single carriageway roads type 1x2 and double lane roads type 2x3 (six-lane divided freeways) and junction crashes on single carriageway roads type 1x2 and 1x4. For head-on crashes is a statistically significant relationship (p < 0.05) also demonstrated on single carriageway road type 1x2, in Iowa. For this type of road in Washington the same relationship has been found, but less strongly (p < 0.10).

The good correspondence of the RPS and crash rates with the US data is likely to be due to a result of the large size of the samples being assessed and because of the homogeneity of the road design in the US. However, the latter leads to the conclusion, according to Harwood et al. (2010), that in general relationships could not be clearly demonstrated for freeways because the design characteristics of freeways are to a large extent uniform, which means that not enough different star classes could be identified.

More work needs to be done to understand the importance of: the sample sizes in this process; the number of road sections being compared in each of the histogram bars (crash rate by Star Rating) presented by Harwood et al.; the length of the road sections in each comparison; the number of severe crashes per road section and in each histogram bar and the statistically confounding influence of differing speed limits within samples.
10.2.1. Iowa

Figure 25: Two-lane undivided road: crash rate vs Star Rating

Figure 26: Four-lane undivided road: crash rate vs Star Rating
10.2.2. Washington

Figure 27: Two-lane undivided road: crash rate vs Star Rating

Figure 28: Four-lane undivided road: crash rate vs Star Rating
10.3. New Zealand

The charts below show the matches achieved with the KiwiPAP model and the New Zealand data on which they were based. This analysis has been based on the KiwiRAP results produced for the June 2010 release of KiwiRAP, covering around 10,000km of the rural New Zealand State Highway network, which was based on a combination of video rating and high speed geometry data for 100m road sections. Reported injury crash data for the five years 2004-2008 have been matched with the Star Ratings for comparison.

The histogram in Figure 29 below shows a consistent pattern of crash rate decreasing with increasing Star Rating.

The regression line in Figure 30 has an R-squared value of 0.87 (between Star Ratings of 1.0 and 5.0 for which the cubic trendline applies), meaning that about 87% of the injury crash rate is explained by the Star Rating.
These relationships have been established by grouping rated 100m road sections by Star Rating. For each Star Rating category, the reported injury crash rate (per 100 million vehicle kilometres travelled) is calculated by summing the reported injury crashes that occurred on the grouped road sections and dividing by the vehicle kilometres travelled on those road sections. For example, in Figure 30 all 100m road sections with a Star Rating of 2.1 are grouped together, and all sections with a Star Rating of 2.2 are grouped etc.

When the 100m rated data is smoothed over a 5km section length, and the same analysis performed, similar results are obtained, as shown in Figures 31 and 32 below.
Figure 31: Reported injury crash rates associated with each Star Rating category, based on 5km Star Rating data for rated rural state highways.

Figure 32: Reported injury crash rates associated with each 1/10th Star Rating category, based on 5km Star Rating data for rated rural state highways.

There were no 1* or 5* roads over a 5km length for the June 2010 release of KiwiRAP.
10.4. Italy

In Italy, despite pressure from ACI and from EuroRAP itself, there is little or no publicly-available traffic data to use as the denominator in crash rate maps (smaller map, below left). The crash density map (smaller map, below right), shows a range of crash densities, the highest rate (black) on the ring road circling Rome. There is insufficient data to make a good comparison of Star Rating and crash rate and the comparison of maps (comparing map top left with the larger RPS2.0) does not provide evidence of correlation.

Figure 33: Risk per billion veh kms (2005-07)  
Figure 34: Crash density per km (2007-2009)

Figure 35: Star Rating using EuroRAP RPS2.0
The figure below compares crash density and Star Rating. It is noticeable that the crash density on the 3-star roads is relatively high. Many 3-star sections are motorways, carry high flows and therefore have high crash densities. Indeed, 65% of 3-star roads are motorways and 75% of crashes occur on 3-star roads.

Figure 36: Crashes per kilometre (2005-2007) by EuroRAP2.0 Star Rating
11. The extent of crash rate differences between Star Ratings

For those studies that do show a reduction in crash rates with increasing Star Rating, it is often useful to record the extent of this difference.

Note that very few studies completed thus far have a sufficiently large number of 1-star and 5-star roads to provide consistent results for groups of roads with these characteristics and that the four-point star scale used in the EuroRAP work cannot be directly compared with the five-point star scale used in iRAP. Nevertheless, some broad conclusions may be reached on the relative differences in crash rates on roads with differing Star Ratings:

- When using aggregated data for a network, some studies show a reduction of about a third to a half in fatal and serious crash rate (New Zealand, Sweden) or crash cost (Australia) when moving from 2-star to 3-star bands. This can be, for example, the difference between moving from a single carriageway to a low quality dual carriageway.

- The relative change in crash rate from one Star Rating to another will depend upon the characteristics and mix of the road types included in the aggregation. Comparing the networks of one country to another will not provide a consistent picture because of variation in the mix of road types.

- In Sweden, the reductions in crash rates when moving from 1-star to 2-star and 3-star to 4-star were of a similar order of magnitude to the change from 2-star to 3-star (a reduction of about a third to a half).

- Differences in crash rates between 3-star and 4-star roads, and between 4-star and 5-star roads can be less substantial. This picture emerges in parts of the US data when disaggregated by road type.

- When roads are disaggregated by road type, the decrease in crash rate with Star Rating is generally lower (see for, example, the data from England).

- The crash rate-traffic volume relationship shows higher crash rates on roads with lower traffic volume (and roads carrying lower volumes are typically of a lower standard) and this may explain in part the lower differentiation in crash rates between, for example, 3-star, 4-star and 5-star roads.

12. Conclusions

The most robust studies show decreasing average crash rates or crash costs associated with increasing Star Rating and vice versa. This indicates that the Star Rating and RPS is providing a valid measure of injury risk.

Different models have been used in these comparisons. There are good examples of the Star Rating-crash rate relationship from models that include elements of both crash protection and crash likelihood and from the model with only crash protection elements.
There have been particularly good matches between the Star Rating and average crash rates or costs where data sets are large and the road sections on the routes being compared are relatively homogenous.

The overall relationship between average crash rate and Star Rating/RPS for any network will vary from country to country, dependent in part upon the mix of roads in that network. There is variation between studies, but some show a crash rate reduction in the region of a third to a half when increasing the Star Rating by one star, notably when moving from a 2-star to 3-star rating. This reduction is often less when moving between higher Star Ratings.

13. References


SWOV (2011) report to ANWB on EuroRAP RPS1.0.
European Road Assessment Programme


Unpublished report from VTI to Vagverket (Swedish National Road Administration), February 2007 available to EuroRAP members on request.

14. Acknowledgements

This working paper combines the efforts of those involved in the International Road Assessment Programme worldwide and in particular those who have submitted or conducted the comparison studies cited here. Only a limited amount of the data available has been included. The sources include material from:

Australia -- Royal Automobile Club of Queensland (RACQ), AusRAP Technical Working Group and the Australian Automobile Association (AAA). Other assistance provided by Greg Smith.

Germany – Juergen Berlitz and Dr Christoph Hecht (ADAC)

Iceland – Olafur Gudmundsson (FIB) and Mrs. Audur Th. Arnadottir - Icelandic Road Administration

Italy – Lucia Pennisi, Francesco Mazzone, Enrico Pagliari and Chiusolo Katia (ACI)

Netherlands – Robert Louwerse (SWOV), Richard van den Hout, Frank Twiss and Ferry Smith (ANWB), Erik Wahle and Martijn te Wierik (Mobycon) and Peter Mak (RWS Safety Department)

New Zealand – Colin Brodie (New Zealand Transport Agency), Gina Waibl and Fergus Tate (MWH Global, New Zealand)

Spain – Lluis Puerto and Jose Tirone (RACC)

Sweden – Niklas Stavegård (Motormännens Riksforbund), Matts Belin and Torsten Bergh (Road Transport Authority), Ulf Brüde and Urban Björketun (VTI, Swedish National Road and Transport Research Institute), Helena Stigson (Folksam)

United Kingdom – Jennifer Martin and Lynne Crinson (TRL)

United States of America – Doug Harwood (Midwest Research Institute) and Peter Kissinger (AAA Foundation)

Substantial formative work in assessing the crash rate-Star Rating relationship was conducted by TRL and in particular by David Lynam.
Appendix I: other example maps
The maps shown here from Murcia, Slovakia and Germany show comparisons between crash data and RPS, but are generally a poorer match than others and for some of the reasons described in the body of this report. They are nevertheless presented here as a part of evidence collected thus far.

Murcia

Figure 37: Comparison of Risk Rate Mapping and Star Rating (EuroRAP RPS1.0): Murcia region

RISK RATE MAPPING OF MURCIA REGION 2004-07

STAR RATING MAPPING OF MURCIA REGION 2008
Slovakia

Figure 38: Comparison of Risk Rate Mapping and Star Rating (EuroRAP RPS 2.0): Slovakia
Figure 39: Comparison of Risk Rate Mapping and Star Rating (EuroRAP RPS1.0): Germany
**Appendix II: using the comparison**

The Star Rating/RPS shows where road design features are likely to result in higher risk of fatal and serious injuries and may identify sites where lower design standards are likely to lead to increased risk but where few accidents have yet occurred. These locations will not be highlighted by collision figures as needing priority countermeasure treatment, so in this case the use of RPS in addition to crash data can provide a more detailed focus for the implementation of mass action programmes.

Roads which have a high Risk Rating and low Star Rating should be prioritised for investment and road safety action plans. Roads with a low Risk Rating and high Star Rating present little or no danger to the road user so should be low on the priority list. Roads either with a high Risk Rating and high Star Rating, or a low Risk Rating and low Star Rating, typically require further investigation. These may also be sites where there should be a review of either speed management or speed limit policy. Some examples from Italy are provided at the end of this section, the number in each cell representing the kilometre length in each category.

**Figure 40: Risk Rate Mapping and Star Rating action matrix**

<table>
<thead>
<tr>
<th>RISK RATING</th>
<th>Low</th>
<th>Low-Medium</th>
<th>Medium</th>
<th>Medium-High</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Star</td>
<td>No action required</td>
<td></td>
<td></td>
<td>Investigation required</td>
<td></td>
</tr>
<tr>
<td>3 Star</td>
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<td></td>
</tr>
<tr>
<td>2 Star</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Priority action required</td>
</tr>
<tr>
<td>1 Star</td>
<td>Investigation required</td>
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www.eurorap.org

Crash rate – Star Rating comparisons
Figures 41 and 42: Risk Rate Mapping and Star Rating action matrix in use in Italy

### RISK RATING (SINGLE Carriageway)

<table>
<thead>
<tr>
<th>RISK &gt;</th>
<th>4 star</th>
<th>3 star</th>
<th>2 star</th>
<th>1 star</th>
<th>Low</th>
<th>Low-Medium</th>
<th>Medium</th>
<th>Medium-High</th>
<th>High</th>
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<tbody>
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<td>8</td>
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<td></td>
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</table>

**SS1 Aurelia (length = 64 Km)**

- Investigation required!
- Priority action required!

### RISK RATING (DUAL Carriageway)

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<th>3 star</th>
<th>Low-Medium</th>
<th>Medium</th>
<th>Medium-High</th>
<th>High</th>
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<tbody>
<tr>
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</tbody>
</table>

**A1 Rome-Naples (length = 227 Km)**

- NO action required
- Priority action required