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 manufacturers and road authorities.

Road Assessment Programmes (RAPs) are now active in more than 50 countries throughout Europe, Asia Pacific, North, Central and South America and Africa.

EuroRAP has shown that the risk of death or crippling injury can vary tenfold on different roads in the same country. The public, politicians and road engineers must be able to see clearly where the roads with unacceptably high risk are - and be guided to what can be done to put them right. Sometimes the cost of saving lives can be as little as the paint to provide clear road markings, so that drivers can read the road, or safety fencing to stop people being killed hitting the same trees or lamp-posts close to the roadside.

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

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To find out more about the international programme, visit www.irap.org.
You can also subscribe to ‘WrapUp’, the iRAP e-newsletter, by sending a message to icanhelp@irap.net.

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**Introduction**

EuroRAP is the regional programme currently active in more than 20 countries across Europe. It is a sister programme to AusRAP in Australia and similar programmes exist in New Zealand, the United States and are being developed in Africa, Latin America and Asia-Pacific.

iRAP, the International Road Assessment Programme, coordinates the work of these programmes and was established to help tackle the devastating social and economic cost of road crashes. Without intervention, the annual number of road deaths worldwide is projected to increase to some 2.4 million by 2030. The majority of these will occur in low-income and middle-income countries, which already suffer nine out of ten of the world’s road deaths. Almost half of those killed will be vulnerable road users – motorcyclists, bicyclists and pedestrians.¹

Large as the problem is, making roads safe is by no means an insurmountable challenge; the requisite research, technology and expertise to save lives already exists. Road safety engineering makes a direct contribution to the reduction of road death and injury. Well designed intersections, safe roadsides and appropriate road cross-sections can significantly decrease the risk of a crash occurring and the severity of crashes that do occur. Dedicated footpaths and bicycle paths can substantially cut the risk that pedestrians and cyclists will be killed or injured by avoiding the need for them to mix with motorised vehicles. Dedicated lanes for motorcyclists can minimise the risk of death and injury for this class of road user.

By building on the work of Road Assessment Programmes (RAP) in the developed world (EuroRAP, AusRAP and usRAP) and with the expertise of leading road safety research organisations worldwide, including ARRB Group (Australia), TRL (United Kingdom), the Midwest Research Institute (United States) and MIROS (Malaysia), four globally-consistent protocols to assess and improve the safety of roads have been developed (see Box 1).

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**Box 1: The protocols**

1. **Risk Maps** use detailed crash data to illustrate the actual number of deaths and injuries on a road network.
2. **Star Ratings** provide a simple and objective measure of the level of safety provided by a road’s design.
3. **Safer Roads Investment Plans** draw on approximately 70 proven road improvement options to generate affordable and economically sound infrastructure options for saving lives.
4. **Performance Tracking** enables the use of Star Ratings and Risk Maps to track road safety performance and establish policy positions.

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The focus of this report is on the second of these protocols, Star Ratings. The approach of Star Rating and subsequent development of Safer Roads Investment Plans represents a systematic approach to road infrastructure design and renewal based on research about where severe crashes are likely and predictable.

The Star Ratings and Safer Road Investment Plans are related by the detailed road condition report that is collected during inspections (Figure 2). This report provides an overview of the components in Figure 1; the components in Figure dark-green are currently only available within iRAP and are addressed in the report, *Safer Roads Investment Plans: The iRAP Methodology.* This report outlines how the inspection is carried out, the features that are recorded and how the Star Rating is achieved. Future developments within EuroRAP will enable the outputs shown in Figure 2.

**Figure 1** The EuroRAP road inspection, Star Rating

**Figure 2** To be incorporated into future EuroRAP software

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Star Ratings involve an inspection of road infrastructure elements that are known to have an impact on the likelihood of a crash and its severity. Between 1 and 5-stars are awarded depending on the level of safety which is ‘built-in’ to the road.

The safest roads (4- and 5-star) have road safety features that are appropriate for the prevailing traffic speeds. Road infrastructure elements on a safe road might include separation of opposing traffic by a wide median or barrier, good line-marking and intersection design, wide lanes and sealed (paved) shoulders, roadsides free of unprotected hazards such as poles.

The least safe roads (1- and 2-star) do not have road safety features that are appropriate for the prevailing traffic speeds. EuroRAP analyses show that these are often single-carriageway roads with relatively high posted speed limits, with frequent curves and intersections, narrow lanes, gravel shoulders, poor line markings, hidden intersections and unprotected roadside hazards such as trees, poles and steep embankments close to the side of the road.

**Road Inspections**

EuroRAP Star Ratings are based on a detailed visual inspection of a road’s infrastructure elements. EuroRAP currently uses two types of road inspections:

- drive-through inspections – partial collection of data during drive-through, partial rating retrospectively from video
- video-based inspections – retrospective rating of all data

The type of inspection conducted depends on the availability of technology, the complexity of the road network and the degree to which a project is focused on building the capacity of road safety stakeholder organisations.

Part of the EuroRAP process includes the accreditation of those who will be conducting inspections. The accreditation relates both to the individuals who are conducting the process and to the equipment (vehicle, camera, hardware and software) that is being used.³ Accreditation is tailored to the two inspection systems being used (Figure 3).

Figure 3 The EuroRAP accreditation process for drive-through inspections

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³ Further details are available in the iRAP accreditation document (iRAP303).
Drive-through inspections

Drive-through inspections involve at least two people: one driving a vehicle and a passenger recording road infrastructure elements as they travel. Several systems have been accredited, one of which is shown in Figure 4. This type of inspection needs high levels of technical competence. All inspectors must be accredited by EuroRAP. This system requires the inspector to record as the vehicle drives through at or just below the speed limit. It is often used in situations where the road network is not overly complex or it is difficult or time-consuming to import a vehicle that is equipped for video-based inspections.

The RAP Inspection Device (RAPID) equipment shown here includes a video camera, touch-sensitive laptop (see Figure 4) and Global Positioning System (GPS) antenna. Generally only the high-level road infrastructure elements are recorded during the drive-through inspection, with additional data being added later. The video is also used retrospectively as a means of quality checking and assurance.

Video-based inspections

Video-based inspections differ from drive-through inspections because data is first collected by video and this is later used by raters to record road infrastructure elements.

The videos are recorded with a specially equipped survey vehicle (see Figure 5) that records images of a road at intervals of 5–10 metres using an array of cameras aligned to pick up panoramic views (such as forward, side-left, side-right, and often, rear). The main forward view can be calibrated to later allow measurements of key road infrastructure elements. The vehicle is also equipped with GPS that enables the video images to be assigned to precise locations on the road network. The vehicles can drive along the road at normal operating speeds while collecting this information.
After the video data is collected, raters undertake desktop inspections of road infrastructure elements by conducting a virtual drive-through of the network.

The raters use specialised software to make accurate measurements of elements such as lane widths, shoulder widths and distance between the road edge and fixed hazards, such as trees and large poles (Figure 6).

Figure 5  Specially equipped vehicles video the road network

Figure 6  Raters are trained to use tailored software to rate road infrastructure elements
Although the drive-through inspections involve a continuous record of road infrastructure elements, and the video-based inspection records video images at 5-10 metre intervals, the actual results are produced for 100 metre sections of road. At the completion of each type of inspection, it will actually be possible to produce a detailed condition report that summarizes many roadway characteristics for the EuroRAP network. The report will contain information such as the proportion of the network that has paved shoulders and number of locations that have adequate Delineation (see Figure 7). This data will then form the basis of Star Ratings.

![Figure 7](A sample of a detailed road condition report)

### Road infrastructure elements

A road’s Star Rating is based on an inspection of infrastructure elements that are known from extensive research to influence the likelihood of crashes occurring and the severity of those crashes that do occur. The focus of the Star Ratings is on the infrastructure elements which influence the most common and severe types of crash on roads for car occupants (this is discussed later in the Road Protection Scores section of this report). Each road infrastructure element is assigned to one of a number of categories by the raters according to its condition. For example, delineation on a section of road is assigned to one of two categories:

- **adequate**, where signs warning of hazards, and centre and edge markings are generally present, visible and easy to interpret
- **poor**, where signs warning of hazards, or centre and edge markings are absent or in poor condition over long lengths.

The number and definition of road design elements and categories for each road infrastructure element was determined by reference to the existing knowledge and practice and current research on levels of crash risk.
associated with road infrastructure. Figures 8 is an example of how an inspector and rater would categorise road infrastructure elements on a road.

**Figure 8** Road design element categories for infrastructure elements on a section of road.
Road Protection Score

Following the inspections of the road infrastructure elements, the Road Protection Score (RPS) is calculated for each 100 metre section of road using software currently in preparation (see Box 2). The RPS is a relative and objective measure of the likelihood of a crash occurring and its severity, based on an assessment of a road’s infrastructure elements. The RPS forms the basis for generating the Star Ratings (and, in turn it will eventually be possible to generate Safer Roads Investment Plan).

The EuroRAP RPS2.0 model assesses the protection afforded to car occupants by elements of the road in the event of a crash and the likelihood of a crash occurring. The RPS draws extensively on contemporary research on the relative risk associated with road infrastructure.

An important aspect of the models with EuroRAP and it’s other programmes that shaped the development of the RPS is that it must be globally consistent, enabling application in numerous countries, even when detailed, historic crash data is not available. It is also designed to provide a foundation for predicting the number of deaths and serious injuries that are likely to occur on a road network. This forms the basis for estimating the number of deaths and serious injuries and hence determining the countermeasures that might be applied.4

These infrastructure details required the development of a comprehensive model that:

- accounts for a significant proportion of crash types
- applies detailed relative risk factors.

4 For more information, see Safer Roads Investments Plans: The iRAP Methodology. Available at http://www.irap.org/library.asp.
Each of these aspects of the RPS model is discussed in the following sections.

Crash types

The EuroRAP RPS is based on an assessment of the road infrastructure elements that influence the main types of crashes for car occupants.

- Run-off road
- Head-on
- Intersections

These crash types provide a systematic framework for assessing the majority of fatal crashes that occur. For example, the three crash types listed above account for approximately 80 per cent of car occupant deaths on major rural roads.

Risk factors

There are several ‘risk factors’ that influence the likelihood of a crash occurring and its severity. These include behavioural factors such as drink driving and seat belt wearing, vehicle factors such as the fitment of seat belts and airbags and road infrastructure elements, such as lane widths and intersection layout. EuroRAP’s primary focus is the infrastructure risk factors.

Road crash deaths and injuries can be mitigated by reducing the likelihood that a crash will occur. For example, other things being equal, the likelihood of serious crashes occurring at curves, especially those
with inadequate delineation, is higher than on straight sections of road.\textsuperscript{5} Hence, the likelihood that a crash will occur can be reduced by straightening bends and/or improving the markings.

In the event that a crash does occur, the severity can be reduced by the provision of road infrastructure elements that protect road users by reducing the kinetic energy of the crash to a tolerable level. Intervention to improve the protection afforded to road users by improved road infrastructure might not reduce the number of crashes, but it will reduce the severity of injury of each crash.

Drawing on publicly available evidence and research, EuroRAP has developed a series of factors that relate road infrastructure categories with the relative likelihood of crashes and their severity. These factors are then incorporated as variables in the equations discussed in the RPS Equation section of this report.

**Crash likelihood factors**

As an example of a likelihood risk factor, the relationship between delineation and the likelihood of car occupants being killed or seriously injured in a crash is shown below in Table 1. It indicates that the relative risk of death or serious injury on a rural road is 20 per cent greater when the delineation is poor, all other things being equal.

<table>
<thead>
<tr>
<th>Delineation</th>
<th>Relative Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adequate</td>
<td>1.00</td>
</tr>
<tr>
<td>Poor</td>
<td>1.20</td>
</tr>
</tbody>
</table>


\textsuperscript{5} See the iRAP Road Safety Toolkit for example: \url{http://www.irap.net/toolkit/default.asp?p=treatment&ds=1&i=56}
Figure 9  Car occupant risk and the likelihood of death or serious injury on a rural road

*The likelihood of a run-off road crash involving a car occupant is relatively high on roads with poor delineation (risk factor = 1.20)*

*The likelihood of a run-off road crash involving a car occupant is relatively low on roads with good delineation (risk factor = 1.00)*

Crash severity factors

Road signs, trees, poles and ditches can cause severe injury on impact, especially where speeds are high. But well-sited safety barriers can be very effective in reducing injury, as illustrated below in Table 3. The table shows that the relative risk for safety barriers is 1.75, while the relative risk for deep drainage ditches is almost three times higher, at 5.00. This reflects research that shows that barriers help prevent death and injury by absorbing impact energies and containing and redirecting errant vehicles.

Table 2  Sample of car occupant risk factors for the condition of roadsides

<table>
<thead>
<tr>
<th>Category</th>
<th>Risk Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety barrier</td>
<td>1.75</td>
</tr>
<tr>
<td>Distance to rigid object 7-10m</td>
<td>3.80*</td>
</tr>
<tr>
<td>Deep drainage ditches</td>
<td>5.00</td>
</tr>
<tr>
<td>Cliff</td>
<td>10.00</td>
</tr>
</tbody>
</table>

* to be confirmed

Figure 10 below illustrates a safety barrier (relatively low risk) and a steep embankment (relatively high risk).

Photo (right) courtesy of RIOH, Beijing.
Safety barriers help reduce the kinetic energy of a run-off road crash for car occupants (risk factor = 1.75)

Steep embankments represent a severe roadside hazard for car occupants involved in a run-off road crash (risk factor = 5.00)

Research underpinning the likelihood and severity risk factors used in the model is cited throughout the Road Safety Toolkit (see Box 3) provided by iRAP. Risk factors have been developed for car occupants, and in time will be developed for other road-users.

**Box 3: Road Safety Toolkit**

Building on decades of research into causes and prevention of serious injury on the roads, the Road Safety Toolkit offers engineers and planners a free resource on the cost and life-saving potential of more than 35 safety countermeasures.

In addition to advice on countermeasures, which range from basic linemarking to complete highway duplication, the Toolkit helps engineers and planners tailor safety plans for all road users, including cars, cyclists, pedestrians, heavy vehicles, motorcyclists and public transport vehicles, and for various road crash types, such as head-ons, intersections, lane-changes, manoeuvring, rear-end and run-off road.

The Road Safety Toolkit is the result of collaboration between iRAP, the Global Transport Knowledge Partnership (GTKP) and ARRB. The Road Safety Toolkit can be accessed at [www.irap.org/toolkit](http://www.irap.org/toolkit).
Crash-type calibration factors

To ensure a true reflection of the typical crash types and proportions along a road network, the EuroRAP RPS2.0 model applies a “crash-type calibration factor”. These factors have been based on an analysis of the fatality proportions associated with each crash type along generic road types. The factors take into account typical crash mixes in rural, semi-urban and urban areas.

Speed factors

The RPS model includes a speed factor in both the likelihood and protection components of the equations (see the RPS Equation section of the report). In relation to likelihood, the speed risk factors were determined by computing the ratio of the square of the speed on a test section to the square of the speed limit for a base case. For the severity component, speed risk factors were determined by computing the ratio of the speed on a test section to the square of the speed limit for a base case. When combined, these factors give an overall effect of risk varying with the cube of the ratio of the speeds, as illustrated below in Figure 11. It shows that the relative risk for a road with speed of 120km/h is nearly 30 times higher than a road with speed limit of 40km/h. Evidence from research literature identifies this relationship for the variation of fatal and serious crashes with speed.⁸

Figure 11   Relative risk factors for speed

![Relative risk factors for speed](image)

RPS scores are based on traffic ‘operating speeds’, which are defined as being the greater of the following: the legal speed limit or the 85th percentile speed, rounded to the nearest 10km/h.

⁸ See for example http://www.erso.eu/knowledge/content/20_speed/speed_and_accident_risk.htm.
The Road Protection Score Equation

The structure of the car occupant, Road Protection Score (RPS) equations is shown in Figure 12. The Car occupant RPS is the sum of RPS for the relevant crash types, which are in turn a function of likelihood, severity and crash-type calibration factors.

The RPS is a unit-less measurement and is calculated for each road user for each 100 metre section of road. A high score equates with a high level of risk, and a low score equates with a low level of risk.

Figure 12  Car occupant RPS equation
Star Ratings

Road Protection Scores (RPS) are calculated for each 100 metre section of road. The EuroRAP software will enable these to be plotted in a chart, with the distance in kilometres from the start of a road plotted on the horizontal axis and the RPS is plotted on the vertical axis. An example of a RPS chart for car occupants is shown in left side of Figure 13. It illustrates that as a car occupant moves along the road, the risk they face changes constantly as the road infrastructure elements vary (noting that as the RPS increases, so does risk).

To generate Star Ratings, each RPS is allocated to one of five Star Rating bands. The Star Rating system reflects the typical international practice of recognising the best performing category as 5-star (green) and the worst as 1-star (black). In the chart at the left side of Figure 13 green sections of road are 5-stars, yellow sections are 4-star, orange sections are 3-stars, red sections are 2-star and black sections are 1-star.

The right side of Figure 13 shows the Star Ratings for the same road, but in map form planned to be available through the EuroRAP software. As Star Ratings for 100 metre sections provide excessive detail for a large-scale map, the Star Ratings are ‘smoothed’ in the production of the maps. The “risk worm” in the chart to the left of the map (in Figure 13) shows the detail of the risk.

Figure 13  Car occupant Road Protection Scores (RPS) and Star Ratings

In principle, a 5-star road is one where the probability of a crash and death or serious injury is very low. The exact upper and lower RPS thresholds for the Star Ratings were set following significant sensitivity testing to determine how RPS vary with changes in road infrastructure elements. Figure 14 provides an illustration of the way in which the RPS for car occupant head-on crashes varies according to median-type and speed. It shows that a safety barrier will gain a 5-star rating (green) at all speeds, whereas the RPS associated with a median and centreline only increases rapidly as speed increases, such that Star Ratings decrease.
In circumstances where highways are dual divided carriageway, the RPS is calculated for both directions. The map in Figure 15 illustrates car occupant Star Ratings in Serbia.
Figure 15  Car occupant Star Ratings in Serbia
Conclusion

Star Ratings are based on road inspection data and provide a simple and objective measure of the level of safety which is ‘built-in’ to the road for car occupants. Five-star roads are the safest, while one-star roads are the least safe.

Importantly, Star Ratings can be completed without reference to detailed crash data, which in some countries often unavailable or unreliable. When this information is available it may be used to support and validate the RPS.

Protecting against human error, and recognising that mistakes are an intrinsic part of human behaviour, is fundamental to the now widely supported ‘safe system’ approach to road safety. Safe road infrastructure has significant potential to complement efforts to improve behaviour of road users and the safety of vehicles by minimising the chances of a crashes occurring and the severity of those that do occur.

The EuroRAP Star Rating protocol will continue to be developed in the future as new research on road infrastructure risk factors is completed and published.