EUROPEAN ROAD ASSESSMENT PROGRAMME
EuroRAP I (2003) TECHNICAL REPORT

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EUROPEAN ROAD ASSESSMENT PROGRAMME YEAR 1 TECHNICAL REPORT

Executive summary

Background and progress

The methodology for a European Road Assessment programme was developed and piloted during 2001 and 2002, based primarily on three national datasets (from Sweden, the Netherlands and Great Britain) plus some supporting data from Catalonia. The three main countries were chosen for the early development of the programme because they were known to have good safety records, and were likely to have good access to the data needed.

The work during the first full year of the programme has focussed on consolidating and extending the methodology, and on increasing the number of countries involved. Considerable progress has been made in both these areas.

The principles underpinning the programme and the ways in which the data can provide useful lessons have been debated at both national and European level. Dialogue has been prompted within individual countries between EuroRAP and road authorities. This debate has been extended in Sweden to the stage where a national road inspection programme is being launched. National conferences or workshops have been held in Britain, France and Italy, and are planned in Spain and the Netherlands for the early part of 2004 (see EuroRAP (2004) - Technical appendix)).

The programme has demonstrated that data from different time periods can be compared to provide an indication of the change in safety performance over time. This has mainly been demonstrated with data from Britain and the Netherlands. EuroRAP analysis has shown how safety has changed in different parts of the network, and different road types, within each country, and the extent to which the higher risk roads have been improved.

Methods have been developed for comparing safety performance between networks and between countries. These go beyond the standard simple comparison of average accident rates, to show how the distribution of accident rates across the network has changed. They also provide an indication of the extent to which the safety performance relates to infrastructure standard or to road user behaviour.

Potential links with existing engineering programmes have been clarified. The launch of the 2003 results in Britain was done in close consultation with the local and national highway authorities. The basis by which an improvement programme can progress from blackspot treatment to route management and then to assessing overall network quality is discussed.

The methodology for road inspections and scoring has been refined. Risk tables have been developed, based on speed limit and road design features, for the injury protection that the road provided in relation to three key accident types – head on collisions, single vehicles leaving the road, and side impacts at intersections. The system (the "Road Protection Score") has been trialled by scoring a sample of roads in seven different countries, and further development of the scoring system proposed.

The programme now provides a basis for a European safety monitor of road networks which the European Commission could use as part of a regular assessment of road safety performance of member states. Illustrations are provided in the report of the way in which the various risk indicators can be compared between countries, and the lessons that could be learnt from these comparisons. The outputs could show how changes in safety risks within the road network in each country are contributing towards the overall Commission target for casualty reduction.

Detailed results

Analyses have been made of fatal and serious accidents occurring on the EuroRAP network in each of Britain, Italy, the Netherlands, Spain and Sweden. The analyses that have been made reflect the nature of these networks and the extent of the data available.

Comparison of fatal and serious accident rate data sets in Britain and in the Netherlands show a reduction of 11% from 1997-99 to 1999-2001 in Britain and 22% from 1996-98 to 1999-2001 in the Netherlands. These two results are not directly comparable, but show an overall downward trend and demonstrate a new monitoring technique.

On motorways, in both countries, reductions in risk have generally been among the higher risk roads. Changes on other types of roads are spread more widely across the risk rate bands.

Motorways in Britain and the Netherlands are performing substantially better than other divided roads in these countries, whereas in Sweden and in Spain the difference is less marked. Standard 2-lane (single-carriageway – one lane each direction) roads perform much less well compared with motorways in all four countries, especially in Britain.

There is a wider spread of fatal and serious accident rate risk on Spanish motorways compared with those in Britain, the Netherlands and Sweden. This suggests that some Spanish motorways do not provide as safe an environment as others and not simply that there are differences in national driving characteristics (eg attitudes to speed and seat-belt wearing).

Comparisons can be made on the basis of collective risk based on the potential accident savings that could be achieved within the network in each country. On the EuroRAP network in Britain there are about 190 km of road where more than 2 fatal or serious accidents per km in 3 years could be saved if the accident rate were reduced to the group average for these roads. In Spain there are about 250 km.

Shortcomings have been identified in the quality of road accident and traffic data in Italy but a EuroRAP network similar to other countries has been developed. This has been used to map the number of fatal accidents per kilometre on state roads and motorways.

Accident rates on 833 British road sections were analysed in detail and published in lists of 13 “most improved roads” and 21 “persistently high risk roads” (see also The AA Motoring Trust, 2003).

The persistently high risk roads identified included wholly rural sections where median and roadside protection would be desirable, and lengths with lower speed limits and some roadside development where junction improvements and improved facilities for vulnerable road users would reduce accidents or severe injuries.

The Road Protection Score indicates the extent to which road design protects the user in the event of an accident occurring. The RPS allocates scores according to median and roadside protection and junction design. 60 routes from 7 countries have been analysed and scored using the RPS.

The scores show that:

- On many roads there is substantial scope to improve the potential for injury prevention. Accidents involving fatal injury will continue unless this is done.
- On average, single carriageway RPS scores are lower than divided (dual carriageway) roads. Single carriageways show more variability in their design and associated protection from injury.

- Many roads score poorly for run-off protection, reflecting the fact that fatal injuries are likely to occur unless barriers or very wide safety zones can be provided. There is considerable variability in run-off protection along individual routes.

- The lowest scoring roads score poorly for all three accident types – head-ons, single-vehicle run-offs and those at junctions.

- Most of the divided roads that have been assessed do not score the full four stars available, even though they are the safer roads in all highway networks. Scope remains to reduce serious injuries from accidents at uncontrolled junctions and from vehicle run-offs.

- On ordinary 2-lane roads, despite the lower speeds adopted, protection is often limited by narrow safety zones, poor access provision and by the lack of measures to limit the interaction of opposing traffic streams. Some good examples of median treatment of these roads can be seen in Sweden and the Netherlands.

There is a general need to find ways of providing better median, run-off and junction protection at reasonable costs if large-scale affordable networks are to be provided which cater for desired traffic speed without resulting in fatal or severe injury.

1 SUMMARY OF THE PILOT YEAR PROGRAMME

The report on the pilot year of the programme was published in May 2003 (Lynam et al, 2003). This report covered the setting up and piloting of a process for assessing the relative safety performance of European roads, which could be developed into a regular programme benchmarking the safety of roads being achieved in different countries.

1.1 Basic principles

The pilot report describes how the EuroRAP development work led to the definition of two new standard test protocols:

- a standard road inspection for safety features (the Road Protection Score or RPS);
- A process for measurement and mapping of the rate at which people are killed and seriously injured.

The work focussed on major roads outside built-up areas, because it is on these roads that most deaths in Europe occur.

An important aspect of the work was to develop partnerships between road user organisations and road providers, and to produce results that will be useful to the motoring public, policy makers, highway providers and operators alike.

1.2 Data collected

The pilot report provides information on accident data for Great Britain, Sweden, the Netherlands, and the region of Catalonia in Spain.

Preliminary risk rate maps, showing fatal and serious accidents per vehicle km, were produced for each of these four countries.

A set of four risk maps was demonstrated, using data from Great Britain. These showed how safety indicators based on accidents per km, accidents per vehicle km, and potential accident savings from reducing risk on roads with above the average risk for the group, all gave different insights into risk. These maps each gave useful information in building up the overall picture of safety performance of the network. The different maps also showed how the view of safety differed between the various stakeholders depending on their role in achieving a safe highway network.

1.3 Preliminary development of RPS

An initial protocol was developed for a procedure for "drive through" inspections of routes, and sample routes were inspected in Britain, Sweden, the Netherlands, and Germany.

1.4 Conclusions

It was concluded from the pilot phase that accident databases could be established that enabled comparative risk maps to be drawn for different countries, and provided useful information on the difference in risk rate between different road types. The route inspection protocol needed further refinement before it would give a sound basis for comparing between the protection from fatal or serious injury provided by different roads.

2 OBJECTIVES OF THE SECOND YEAR OF THE PROGRAMME

The four main objectives to the second year's programme are summarised below.

2.1 Development of principles (Section 3)

As the basic methodology is developed it is important to understand clearly what the results mean and how they can be used alongside current safety practice. Debate during this year has shown that it is easy to draw incorrect conclusions from the data emerging from the programme if they are used inappropriately. There is therefore a strong need to clarify the principles behind the programme. It is also important continually to test the assumptions behind the analyses and their potential application as the methodology is extended, and the programme is applied to new networks, and to areas with different current practice.

2.2 Extend risk mapping and accident analysis (Section 4)

The production of further risk maps was planned:

- to present updated data from Britain and the Netherlands;
- to provide maps for Spain, Italy and France.

Further work has also been done on developing accident risk distributions to reflect differences in network quality.

2.3 Refine RPS (Section 5)

The procedure for developing a road protection score has been extensively refined. Although the basic principles remain similar, the scoring regime has been modified to relate to road speed, and also given a more robust basis in relation to highway engineering principles. It remains however, a sufficiently simple technique to be achieved through visual inspection whilst still providing useful comparisons of network quality. It is now being trialled extensively in Sweden; sample inspections have also been completed in a total of seven countries.

2.4 Extend national coverage

Close collaboration has continued between the national data teams in Sweden, Netherlands and Britain. Similar teams have been developed in Spain, Italy, and France. Discussion has begun with teams in Northern Ireland, and in the Republic of Ireland, and initial work on accident data is also being considered in several other countries.

3 DEVELOPMENT OF PRINCIPLES

EuroRAP seeks to provide a benchmark which is understandable to both road users (individually and in groups) and road providers and managers. This requires identifying the risk to individual drivers when they use particular routes, but also recognising the factors that determine the overall policy on which roads warrant improvement and the safety levels to be targeted on these roads. Section 3.1 discusses these issues further.

EuroRAP analyses need to be seen as an integral part of the wider spectrum of road safety management techniques. Their interrelationship with these techniques, and the additional dimension they provide, needs to be clearly defined. Section 3.2 summarises some of the discussions on these issues with local highway engineers during this year. By focussing on a measure of safety across the whole network, the EuroRAP results provide a means by which the safety performance of a network can be monitored on a regular basis. Section 3.3 shows how this concept might be developed.

Focus for EuroRAP outcomes

- **What should the individual road user be aware of?**
- **What should the individual expect?**
- **What should society provide?**
- **What are the best solutions for both needs?**
- **How should risk be reduced?**

3.1 Looking more at individual and collective perspectives

For the individual road user, it is important to understand both the role of the infrastructure and the role of their own behaviour in determining the risk they face on the road. It is important to recognise that not all roads can be managed to the same risk level, but at the same time to seek to keep the risk within acceptable bounds for those roads with the highest levels of risk.

For the road provider, the most immediate need is to decide how best to improve the collective risk across the network, primarily in terms of how to spend available budgets most effectively. But EuroRAP introduces an additional focus that enables the provider to consider what quality of network, in terms of level of safety, should be planned for in future, and what investment would be needed to achieve this. An important part of this focus will be to take account fully of the maximum risk that road users might face on any part of the network.

Achieving low risk levels involves both the design and the management of the network. The chosen speed regime (design speeds and speed limits) is an important basis for both of these. But the planned outcome from a well-designed road system is only achieved if road users stay within the behavioural rules on which the system is based. Although education and enforcement agencies may take the lead in encouraging safe behaviour, the road provider and manager also have a role to play in influencing this behaviour on any particular road. Finally, different road users will experience different risks when travelling on any given road. Where these risks vary considerably or where they are exacerbated by the mix of road users, the road manager has the opportunity to intervene to lower risk, although sometimes at the potential expense of accessibility or mobility.

3.1.1 Ways of representing individual and collective risk

The simplest way to represent individual risk is in terms of accident outcome. Accident rates per vehicle km on any road can show the likelihood of a particular type of road user, on average, being involved in a road accident. Collective risk needs to reflect more broadly how risk is distributed between all road users, across the network. At the simplest level, it is shown by accident rate per km on each road, but these rates are largely influenced by the traffic flow on each road. To assess how best to improve collective risk, it is important to understand not just the present level of risk, but also the extent to which a lower level of risk can be achieved on any particular road at reasonable cost. Accident rates do not show the extent to which the behaviour of a specific road user might result in his risk being higher or lower than the average. They also do not show well the extent to which the road user can make a mistake, and recover from it without serious injury. This latter is better reflected by looking at the distribution of accident severities to that road user group on that road, although this still does not show the extent to which the higher severity has resulted from the behaviour of the road user.

EuroRAP aims to understand better the relative influence of road user behaviour and the protective quality of the road infrastructure. It therefore brings together historical accident risk and inspection of the apparent safety quality of the infrastructure. These need to be considered together. It would not be appropriate to improve the protection provided by the infrastructure in a way that encouraged less responsible behaviour, such as increased travel speeds or less awareness of risk, and thus resulted in little overall change in the casualty toll.

Individual and collective risk

EuroRAP data need to be presented in a way which shows both individual and collective risk, and the links between them

Risk Mapping	**Road Protection**
through different risk maps	**through use of different risk factors**

3.1.1.1 Risk mapping

The pilot year report introduced a set of four maps which showed different aspects of individual and collective risk. The two most relevant are the accident rate per vehicle km, showing the risk to individual drivers, and the assessment of potential accident savings, which forms the basis for considering investment decisions. The latter map only provides an indication of the number of accidents that might be saved if accident rates on all those routes with risk above the average, for roads of similar flow, were reduced to the average. This analysis needs to be extended to take account of the practical measures that could be applied and their cost, before investment decisions can be made. This is discussed further in 3.2 below.

Much use has been made of the maps of individual risk because they highlight areas of potential public concern, but it is important to use the two maps together to show how policy might best be influenced. If all fatal accidents could be eliminated, then the individual risk map might provide an agenda for action, but even then the timescale for action would be influenced by the relative savings that could be made on each road. In the more likely situation that only a proportion of fatal accidents can be eliminated in a foreseeable timescale, it is important to develop policies based on both viewpoints.

The risk maps provide information not only for road improvement policies, but also for the road user. Because of the map format, it is sometimes assumed that the main purpose is to inform the road user how best to modify his **route** to minimise risk. A much more important focus of the programme is to inform the road user how and where he needs to modify his **behaviour** to minimise risk - ie to enable him to recognise the sources of risk on different types of road. Alongside this should be the recognition that risk cannot be eliminated on all roads through infrastructure changes, and that the road user must take a share in the responsibility for a safe road system.

3.1.1.2 Road Protection scoring

The proposed procedure for scoring the quality of the road is also risk based – but in this case it identifies the potential risk that results from the way the infrastructure is designed and managed. A risk matrix approach has been taken which aims to separate the likelihood of the accident occurring from the injury consequences once it occurs. The matrix allows the risk from these two elements to be considered separately, but also for the combined effect to be estimated.

Within this approach the risk of severe injury to the individual if he makes a mistake can again be separated from the total risk. The design elements that relate to protecting the road user from injury – eg safety barriers, restrictions on unsafe manoeuvres, safety zones – all clearly influence this risk of injury. The initial scoring is being based primarily on these elements. Conceptually that approach is similar to the EuroNCAP approach of assessing how well the vehicle protects the occupant if an accident occurs.

The collective risk of serious accidents occurring, however, also needs to combine the likelihood of the accident occurring with the risk of injury. The factors that will affect this likelihood include traffic flow, road alignment, junction frequency etc. The risk matrix approach will provide a means in due course whereby these can be added to the scoring system. But driver behaviour is also often an important factor in the likelihood of the accident occurring, and to create a score for this, which properly isolates the influence that road design and management can have on behaviour as well as the more passive protection the infrastructure can have on injury outcome, requires more work.

3.1.2 Representing collective risk in relation to investment decisions

If infrastructure could be so designed as to virtually eliminate serious accidents, then the number of collisions would not be important. For some elements of design – eg providing a well-performing central barrier – the effect is virtually to remove one accident type (head on collisions). But in most cases, certainly in the foreseeable future, the best that can be targeted is a substantial reduction in the number of serious accidents. In this case it is important to demonstrate the value of the investment that is required to achieve this reduction, and to design a programme that prioritises the most cost-effective improvements. It is for this reason that the EuroRAP analysis needs to provide a firm basis for making these decisions, as well as simply highlighting where risk to the individual is high.

The two concepts – individual and collective risk – are interrelated. Safety engineers need to be aware of both objectives, and to recognise the need to keep risk within acceptable limits, even for minority users, as well using budgets effectively. Simply tracking the next most cost-efficient short term measure will not necessarily lead to the best use of resources, unless broader programme objectives are also defined and evaluated. The challenge for EuroRAP is to develop ways of combining the two objectives.

3.1.2.1 Accident cost density and accident targets

Accident cost density (ie weighting accidents of different severity by their cost value) is sometimes proposed as a basis for prioritising the potential benefits from road investment (BASt, 2003). While it has the advantage of bringing together all accident types into one value, it relies on agreed cost valuations for the different accident types. In general this can often be done within countries, but there is no agreed European basis on which to make these valuations that allows easy comparison between countries. The cost density approach is also claimed to be more comprehensive than using numbers of fatal and serious accidents, because it includes the much larger number of slight accidents.

However this does not add substantially to the robustness of the estimates - in British valuations, for example, fatal and serious accident costs make up 75% of total accident cost - and it does not focus so strongly as the use of simple accident numbers on the casualty reduction targets defined by most countries, and also by the European Union, that relate to numbers of fatalities and serious injuries only. The use of slight accident numbers also adds a further source of variation as a result of reporting differences between countries.

However it is straightforward to calculate cost density for routes from EuroRAP data if this is desired – including a value for the cost of slight accidents if those are to be included – and this may well be a useful approach within individual countries. But for comparative European purposes, agreed valuations of accident cost would still need to be developed.

3.1.2.2 Accident density threshold

A simple approach to combining both risk and potential accident reduction was used in launching the 2003 British results, reflecting parts of both individual and collective risk arguments. In this case roads were listed on the basis of their individual risk (rate per vehicle km), but only those roads with accident densities per km above a defined threshold were included. This ensured that there was a substantial potential saving in accident cost available from reducing the risk on the roads that were highlighted, but did not simply pick out all the roads that could be treated most cost-effectively.

3.1.2.3 Reference levels for improvement

Whether potential accident savings are estimated on the basis of cost density of all accidents or numbers of fatal and serious accidents (which are then valued), an assumption has to be made about the expected accident rate after improvement. When an individual road is being considered for improvement the engineer will estimate the cost of specific measures that are appropriate to improve the safety of that specific route. For a general assessment programme across many thousands of kms of road network, a more generalised approach is needed.

The approach used in EuroRAP is based on the distributions of accident rates among the routes being considered. Estimates of benefit can be related to ensuring that all roads are improved to, say, the mean risk rate or the lowest quartile rate of the distribution. Alternatively, estimates could be based on obtaining a certain percentage improvement for roads at every level within the distribution. This enables simple calculations to be made, and the consequences of alternative choices of target risk level to be assessed. It is also consistent with seeking solutions that are likely to be applied, and therefore costed, as mass action programmes.

An alternative approach (BASt, 2003) is to define a reference target design for the improved route, for which a risk rate is estimated. The advantage of this approach is a clear link with a target design. The disadvantages are that it is unclear how many reference designs might be needed to cover the range of roads within the networks of the countries contributing to EuroRAP, and the target design would not necessarily encourage an innovative approach to mass action solutions that are aimed to set upper bounds on risk levels.

3.1.3 Relevance of fatalities, fatal and serious accidents, slight accidents, severity ratios

EuroRAP has focused primarily on rates based on fatal and serious accidents because most casualty reduction targets relate to these accidents. But data on fatal accidents (or fatalities) and on all accidents provide important inputs to some of calculations below. Comparisons between countries are most easily done on the basis of fatalities, as these are recorded most consistently. Risk estimates for individual routes need larger numbers of accidents to provide consistent rates between years.

Where numbers allow we have made these comparisons on the basis of fatal and serious accidents, but for some countries we may need to use all injury accidents, or a weighted combination of all accident severities. For comparing accident outcome with the estimates of potential risk provided by the road protection score, we need to use severity ratios (ie the proportion of all injury accidents that are fatal or serious) to see how well the road is providing protection against the most severe accidents.

Within EuroRAP therefore we shall seek to assemble data for each of these accident severities, and use them appropriately in the different comparisons.

3.1.4 Contribution of infrastructure

EuroRAP seeks to assess the safety performance of the road infrastructure. At its simplest level this implies the basic road design and layout, but there are also many features which the safety engineer can add – particularly signs and marking – which will influence how the road user interprets that basic design. Where the road cannot be designed to a consistent standard throughout, it is important for the safety engineer to identify to the road user the potential variations in standard that might lead the user to misjudge the safety of the road. A comprehensive assessment process will include an assessment of how well this has been done.

An important tool for alerting the road user to different levels of risk is speed management. This may involve the use of a generally lower speed limit throughout a route to reflect its lower standard, or it may involve local speed control measures in the vicinity of a hazard. The road protection scoring procedure discussed later includes speed as an explicit variable.

3.1.5 Focus for acceptable risk

One aspect of the approach that EuroRAP is developing is aimed at a better understanding of what risks should be accepted within the road network. In industry, it is common for standards of health and safety to be set which put upper bounds on the risk that the work force should encounter. This approach is also common in other areas of transport – air and rail transport – and there is a growing awareness that road networks should be judged in a similar way. The emphasis of EuroRAP on risk to the individual as well as collective risk to all road users encourages this approach to be incorporated into road investment policies. It also provides a basis for the acceptable risk concept to be applied to individual roads and accident types.

3.1.6 Future network quality and investment

Current casualty targets envisage substantial reductions in fatal and serious accidents – typically reductions of up to 50% over ten years. Further reductions are likely to be sought in later periods. The basis for these targets is a recognition that risk rates need to be much lower before they are acceptable. But setting lower risk rates on their own does not provide a guide to what changes may be required within the road transport system to achieve these lower rates. Vehicle safety and unsocial and illegal behaviour can clearly be targeted, but there is also a need to define the quality of the future road network that is aspired to within these targets. EuroRAP provides a basis on which to assess both what risk levels are desired, and what changes to the road infrastructure are needed to provide these levels. Assessment at this strategic level should be aimed at a vision of that future network, and should define what investment is needed to achieve it, rather than limit the focus to how to spend available budgets most cost effectively.

3.2 Collaborating with highway authorities

EuroRAP seeks to support effective casualty reduction programmes mounted by highway authorities, but also to enable them to take a more strategic view of the safety of the road network and to consider longer term solutions. It also seeks to stimulate discussion about risk levels, and about the appropriate quality of the future road network and the investment required to achieve it.

EuroRAP approach

To provide information through

Risk rate mapping	**Road Protection Score (RPS)**
Accident rates	**Potential risk**
from national data	**through inspection**

Black spots → route management → route quality

3.2.1 Locus in relation to AIP (accident prevention and investigation), route management, safety audit

Traditionally road engineering safety programmes have started by focussing on improving individual high risk sites, and extended into measures aimed at route and area management. These approaches can be extended further by considering ways in which the quality of the network can be improved and overall risk levels reduced. The basis for considering route quality should be a strategic assessment of how safely the network should be expected to perform 10-15 years ahead. The approach to achieving this is likely to be a combination of mass action implementation of effective safety measures, and major upgrading of some parts of the network to a higher standard. Much can be done at relatively low cost but there is a limit to the extent to which old road designs can be improved by low cost measures.

Alternative policies may require speed management and restriction of access or of some movements at junctions. At the strategic level, safety objectives will need to be set alongside mobility and accessibility objectives, so it is important to be able quickly to assess the safety consequences of alternative policies.

The road inspection protocol being developed within EuroRAP has close links with current thinking on the development of safety audit principles. It is different from current safety audit procedures in that it does not seek to identify detailed deficiencies at a site. Standard procedures for safety audit are therefore not in conflict with EuroRAP procedures. But there is debate at present among auditors as to the potential value and methodology of auditing existing roads. If this were done, a more generalised procedure, along the lines of that proposed in EuroRAP, may be the most appropriate approach, although this could be modified and refined if the auditor wished to focus on specific aspects of the road design. Some auditors are also seeking a firmer basis on which to establish the links between the deficiencies identified by audit, and their potential for reducing accidents. The risk matrix approach proposed in EuroRAP is one way of doing this. These ideas were debated at an International conference on London in September 2003, at which EuroRAP was presented.

3.3 Role of EuroRAP as a safety monitor - tracking the level of overall safety and the performance of individual parts of the network

Comparison of accident rates within Europe is based on outputs from international databases such as CARE and IRTAD. Data submitted to these databases, particularly on traffic flows, is of variable quality and coverage. The statistics usually quoted from these databases only give a very broad brush picture of the comparative safety in different countries. From time to time there have been attempts to assemble data for the Trans European Road Network, but no definitive record exists.

EuroRAP provides an opportunity to produce a regular measure of safety performance on a consistent basis which shows in detail how risk is changing in different parts of the road network in different countries, and also shows the potential for improvement in a way that can be linked to specific programmes. It also shows how infrastructure improvements in each country could contribute to the EU target for casualty reduction. The EuroRAP analyses will seek both to provide better understanding of the factors affecting the safety performance of different roads and how their safety might be improved, and also to provide a regular monitor of the level of safety across those countries contributing data to the programme.

3.3.1 Use of frequency distributions

The main tools envisaged at present to provide comparative performance indicators are frequency distributions of the range of risks across the network in each country and of the potential for accident reduction resulting from that risk. These go beyond simple averages to show which parts of the network should be targeted for improvement, and illustrate the effects of both improving the mean risk on all roads and reducing the variation in performance between different routes. Sections 4.5.4 and 4.5.5 illustrate how these distributions might be presented.

4 EXTENSION TO RISK MAPPING

4.1 National results up to 2001

Data for substantial road networks are now available from five countries - Sweden, Britain, the Netherlands, Spain, and Italy - and data for France are expected to be available during 2004. Risk maps for the first four of these countries are shown in Fig 2 and are presented in fuller form in the overall report to the European Commission. Maps for Italy are shown in section 4.3.

The following sections provide a comparative overview of the data collected in these countries.

4.1.1 Networks and traffic flows

The aim in each country has been to cover a network of interurban roads on which at least 30% of national fatalities occurred. This usually means the national road network plus a wider network of routes on the next tier down. These latter roads are defined in different ways in different countries, but usually comprise mainly single carriageway two lane roads. They are a particular target because they often have substantially higher accident rates (per vehicle km) than the higher tier roads, but still carry substantial flows, and therefore contribute substantially to the national death toll.

Figure 1 shows the networks included in the four main countries. The exception to the general rule that the majority of the network length is single carriageway is the Netherlands, where the national network is high quality, being mostly divided roads, and carries a large proportion of the interurban traffic, resulting in the 30% target for fatalities being achieved on that network alone. To enable comparisons with Dutch roads of lower flows, a sample of routes on the provincial network is being targeted separately.

The data being compiled for Italy cover a network of 15,944 kms. Of this, 39% is autostrada and the remainder state roads; the proportion of the state roads that are divided carriageway is not yet documented.

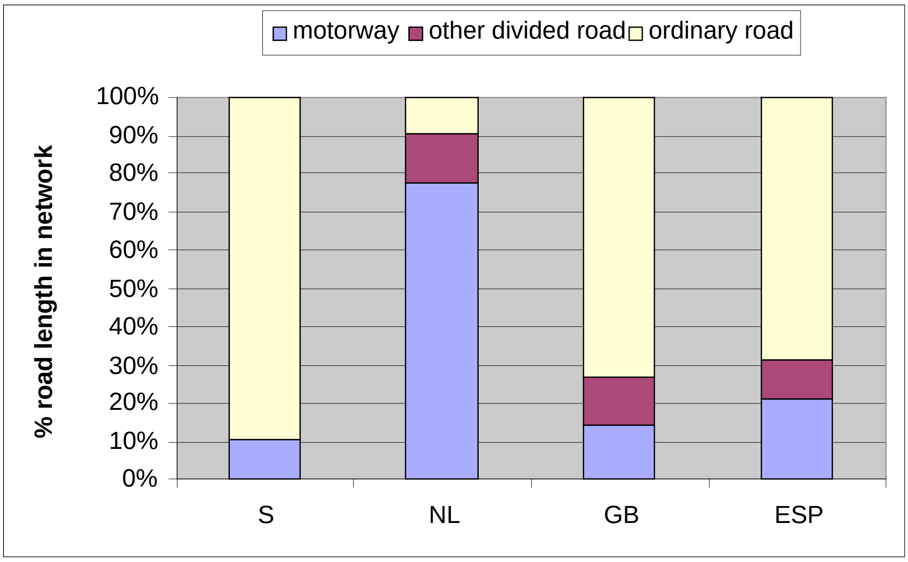
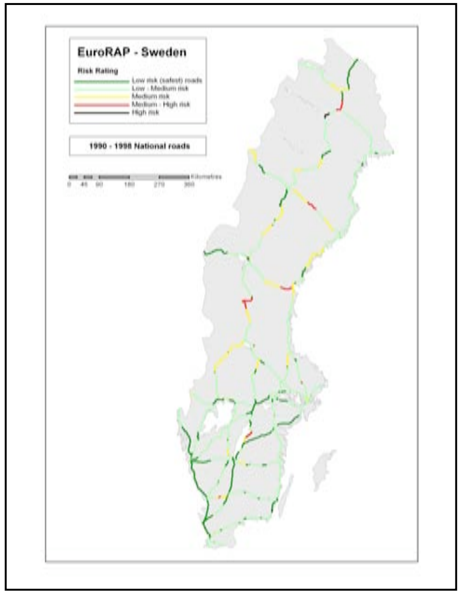


Figure 1. Types of road included in EuroRAP networks in each country



Sweden

Great Britain

Netherlands

Spain

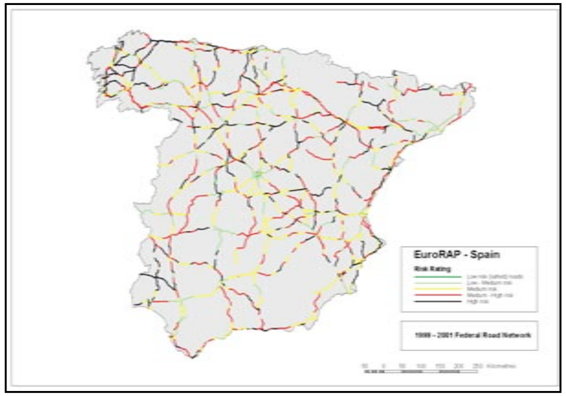


Figure 2 Risk rate maps (fatal and serious accidents per vehicle km) for Sweden, Great Britain, the Netherlands and Spain (revised provisional data)

Traffic flows

Traffic flows vary considerably between the countries analysed, both in terms of overall averages across the whole network and in distribution of traffic between the different parts of the network and the different road types. This emphasises the need both to have traffic data at a fairly detailed level, and to take account of these differences when making comparisons between countries.

	GB	NL *	SV	ESP
Motorway	86.5	66.0	17.1	26.6
Other divided roads	36.6	33.6		34.4
Mixed design roads	20.6	25.5		
Two lane roads	10.5	12.7 *		7.8
Four lane roads			16.6	
Two lane roads 9-13m.			8.5	
Two lane roads <9m.			3.5	
Overall	28.7	47.3 *	9.5	14.4

* Very little of the Dutch network is undivided roads

Table 1 Traffic flows (Annual Average Daily Traffic Flow – thousands of vehicles) on different types of road in different countries on the EuroRAP networks (2000)

Table 1 shows that traffic flows on motorways are highest in Britain and relatively low in Sweden and in Spain. Flows on other (non-motorway) divided roads are similar in Britain Spain and the Netherlands. Flows on the small sample of 2 lane roads in Netherlands are unlikely to be representative of wider network of Dutch 2 lane roads.

4.1.2 Summary of link structure in EuroRAP network

The EuroRAP route structure for each country is based on simple rules aimed at keeping as consistent a design as possible within any route section while at the same time extending the section far enough to give sufficient accident numbers to minimise variation between years.

However the extent to which this can be achieved varies within the road networks in different countries. A further requirement has been for the section to retain the same road number throughout its length to ensure easy identification when extracting accident data. Sections with small accident numbers are likely to result in considerable variation in accident rate between years. Where a section comprises a short length between two major junctions, accident rates may also be unrepresentative of average rates for longer route lengths, since junction accidents will make a major contribution to the rate. The extent to which section lengths and accident numbers per section vary in the different countries is illustrated in Tables 2 and 3.

There are a large number of short links with very small accident numbers in the Swedish network in particular and further aggregation will be attempted. The other networks generally only have a small minority of very short links and often a substantial number of links are over 30kms in order to achieve sufficient accident numbers. The average length is typically around 20kms. The most common numbers of accidents per year are in the bands 3-10 per year (ie approximately 10-30 in the 3 year period, although there is a slightly higher proportion of Spanish routes with less than 10 accidents in the 3 year period). Again the Swedish network is the exception. The Italian data includes all injury accidents, and easily meets the requirements for minimum numbers of accidents per route.

Length (km)	S	GB	NL	ESP	I
0-3	31.4	1.2	7.1	6.8	0.0
3-5	6.3	5.2	5.2	3.9	0.3
5-10	12.1	15.3	10.3	6.8	4.8
10-15	7.2	13.3	17.4	32.7	8.8
15-20	5.6	12.8	14.8	17.3	17.3
20-25	6.1	12.1	11.6	10.3	18.3
25-30	6.1	8.2	9.7	6.2	14..9
>30	25.2	31.9	23.9	16.1	35.6
Total no of links	430	843	155	1182	590
Average length	19.8	26.8	20.9	18.1	26.9

Table 2 Percentage distribution of route link lengths in networks in different countries

Annual number of accidents* per link	S Fatal and serious	GB Fatal and serious	NL Fatal and serious	ESP Fatal and serious	I All injury
0	29	0	6	2	1
0.1 – 1.0	27	2	4	6	2
1.0 – 3.0	30	13	6	31	5
3.0 – 5.0	7	15	25	22	6
5.0 – 10.0	3	38	42	24	14
10.0 – 15.0	2	20	8	8	15
15.0 – 20.0	0	8	8	4	10
20.0 – 25.0	0	3	1	2	7
>25	0	1	0	1	40
Average annual number of accidents	675	6,890	961	6,372	21,426

* Averaged over three years (typically 1999-2001)

Table 3 Percentage distribution of annual numbers of fatal and serious accidents per link (Italian figures represent all injury accidents)

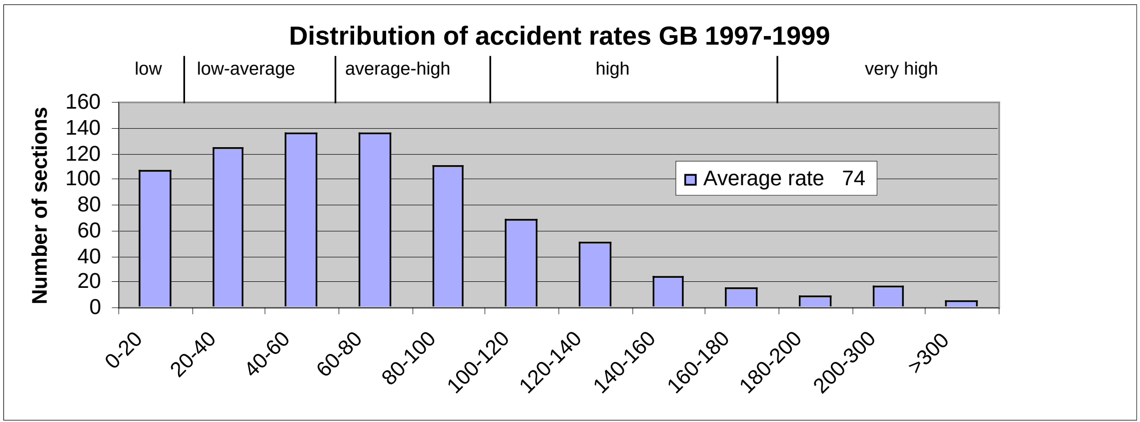
4.2 Comparing between years

By collecting similar data at regular time intervals for the same road network in a country, EuroRAP provides the capability to demonstrate the changes in risk occurring within the networks over time. In practice the EuroRAP networks need to be modified slightly for each time period, as new road links are constructed or as some roads are moved between national and regional control. However this effect is small with only a few percent of the network length changing even over three years.

4.2.1 Overall distribution (GB and NL)

During this year, data from a second time period were analysed for two of the countries (Britain and Netherlands) included in the pilot year. For Britain, the second period covered the three year period 1999-2001, which overlapped by one year with the earlier period (1997-1999). For the Netherlands, the new period, 1999-2001, represented a fully new dataset compared with the earlier period (1996-1998). In both cases, the average fatal and serious accident rate for the later period showed a reduction compared with the earlier period. In Britain, the reduction over the two year change was 11%, while in Netherlands, over three years, it was 22%.

The simple overall average change in accident rate does not give any information about how this has been achieved. A more useful way of comparing accident rates across the networks between time periods is to compare the distributions of accident rates across all the links in the network The comparative distributions for the two years in Britain are shown in Figure 3.



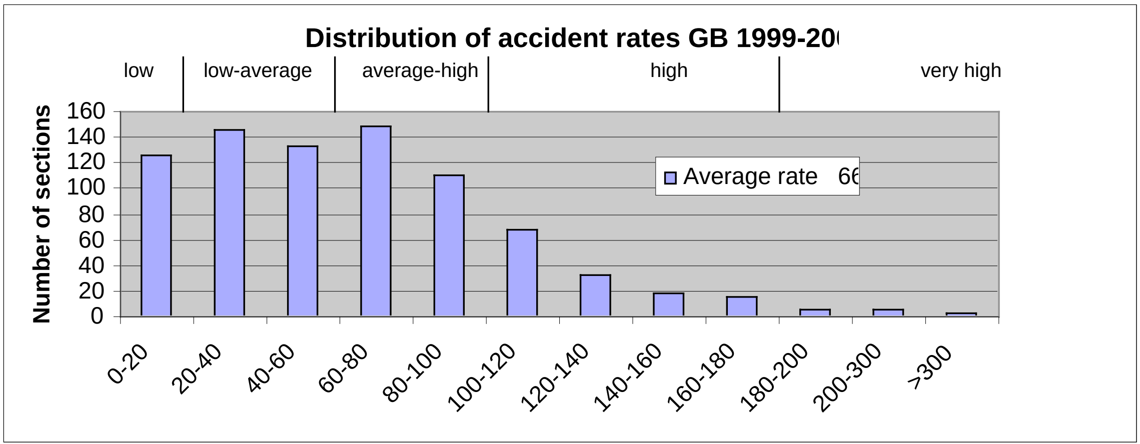


Figure 3 Comparison of risk rates distribution over time in Great Britain

4.2.2 *Variation by risk band and by road type*

Figure 4a below shows the percentage change in the number of route kms with accident rates in each risk band. Ideally as risk rates are reduced, the number of route kms in the highest risk bands will reduce. Those in the less high risk bands, will vary due to two effects – the number will reduce where routes previously in these bands now have lower risk, but the number will increase as routes which previously had higher risk now fall in this band after improvement.

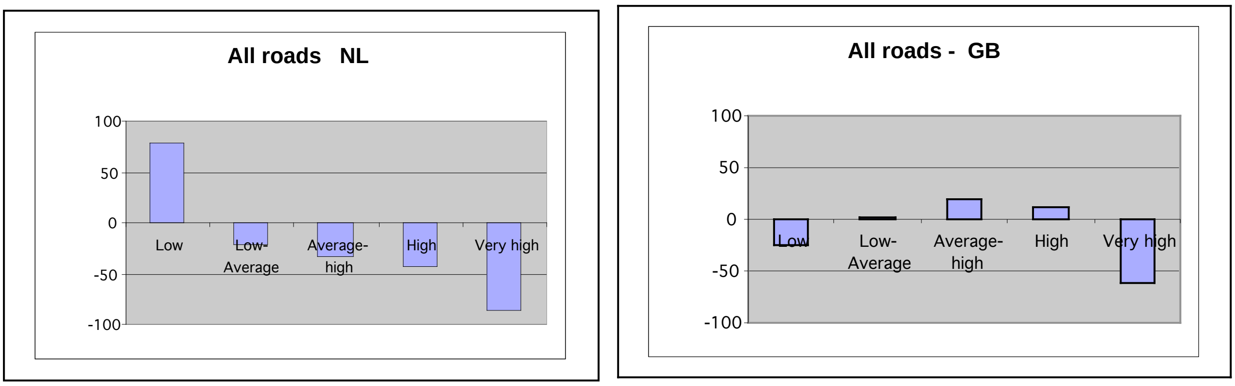


Figure 4a Percentage changes over time in numbers of kms for whole network by risk bands

The Dutch data show a fairly consistent pattern, but the British data show some reduction in the lowest risk band as well as in the highest risk band.

Similar comparisons can be made between sub-groups of routes of either the same road type or similar flow levels. Figure 4b shows the differences between years for both GB and NL in rates for different road types. The total route length reduces as the data are disaggregated into these sub-groups, so the results can be expected to be more volatile. They suggest significant percentage reductions on motorways, but the picture for two lane roads is more difficult to interpret.

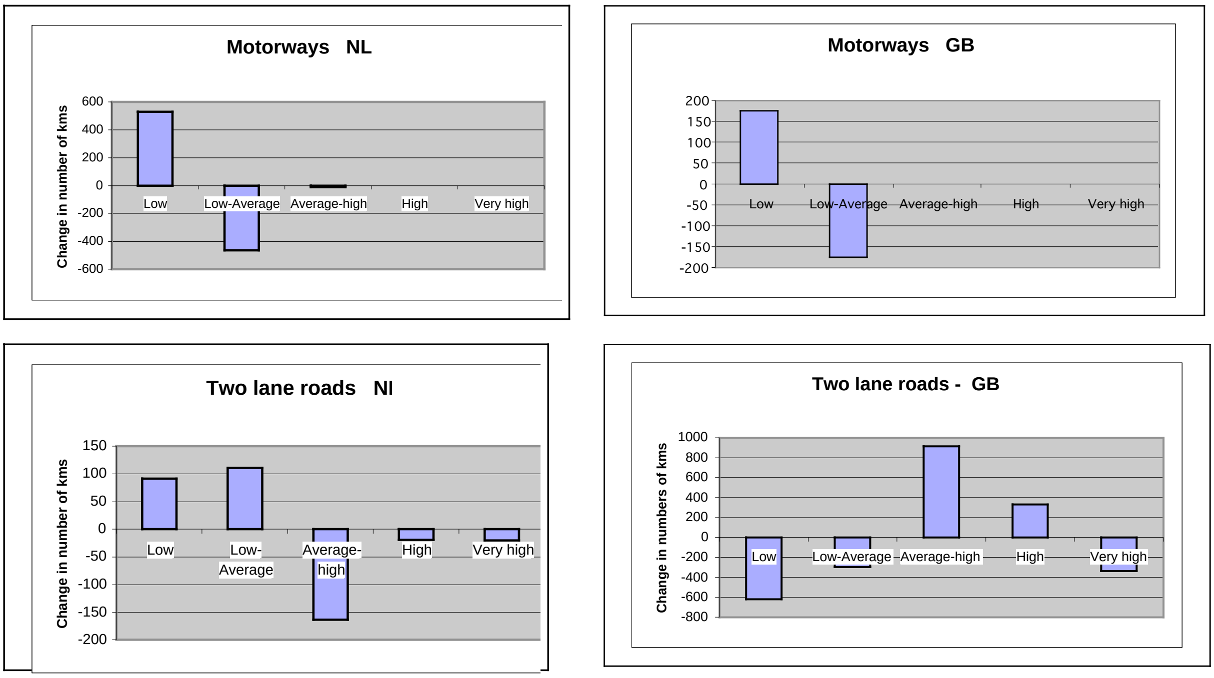


Figure 4b Variation over time in numbers of kms of different road types by risk bands

4.2.3 Highlighting particular routes

At a more detailed level, rates for individual routes can be compared between the two time periods. An extensive analysis of the British data was made at this level, and the results formed the basis for the second launch of the EuroRAP data in Britain in September 2003. The route structure targeted in EuroRAP was planned to try to maximise the chance of identifying rates for individual routes that would minimise the effect of chance variation due to small accident numbers when compared over three year periods. However, although a target of 20 accidents per link was achieved for a substantial part of the network there still remained many links with far fewer accidents (as discussed in 4.1.2 above). Therefore it can be expected that there will be considerable random variability between time periods in the estimates of accident rates for individual links. A methodology was developed to establish which changes in accident rate could be regarded with confidence as reflecting real long-term changes in safety performance.

4.2.3.1 Methodology for identifying routes with real changes

Over time, changes in accident rate per vehicle km may occur on individual links due to both changes in vehicle flows and to changes in number of accidents. The latter will occur potentially from three sources:

- The overall change in accident trends resulting from national or area wide policies (eg vehicle safety improvements, general changes in driver behaviour);
- Random variation in accident numbers around a true long term accident rate - for example “regression to the mean” effects suggests that routes which in any one year had rates higher than their true long term rate will tend to lower rates in the next time period, and vice versa;
- Real changes in long term accident rate due to real improvements in safety on the link.

Figure 5 shows the distribution of changes in accident numbers between the two time periods for all 833 links in the British network.

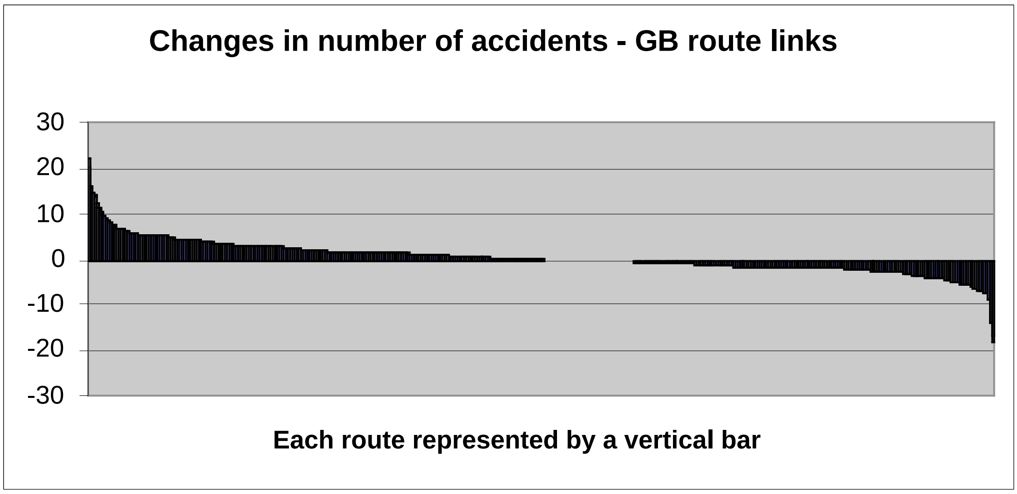


Figure 5 Changes in numbers of accidents between two time periods for individual links in GB network

As expected, numbers of accidents had increased on some links and decreased on others, but for the majority of links the change in numbers had been small. To assess on which links these changes represented a significant change in both accident rate and accident number, it was necessary to screen the results using a high level of significance. Fig 6 shows the links which appear to have a significantly lower rate based on a 5% significance test. But in effect each paired comparison represents one test, and therefore for 833 tests a 5% significant test might still have yielded many false positives (ie links meeting the significance test but where differences occurred by chance).

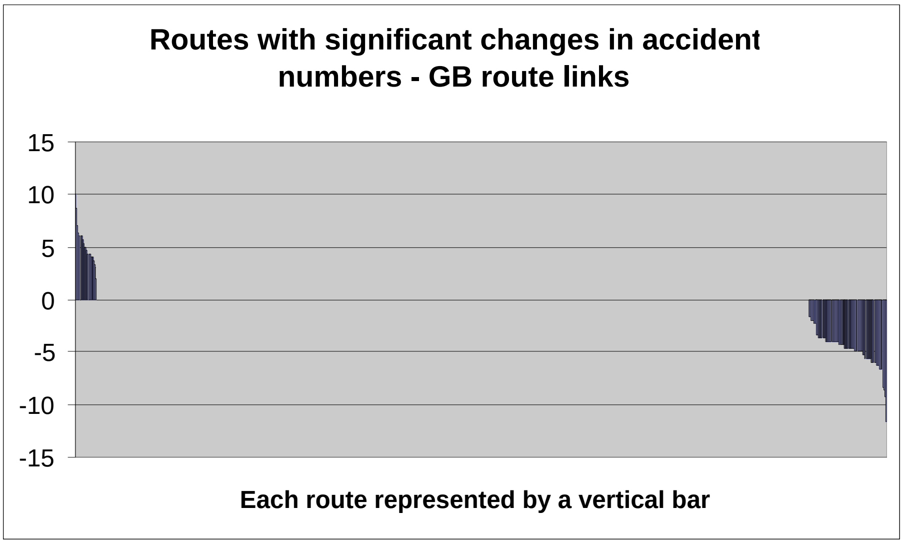


Figure 6 Links on which accident numbers differed at 5% significance level

To be more confident in identifying real changes, the test of significance was increased to 1% and then 0.1%. At each higher level more links were screened out, so that less than ten links with reduced accident rates and one link with increased accident rate were left at the highest significance level used.

The single link with an apparent increased accident rate at the highest significance level was a motorway link; no reason could be identified for safety on this link to have worsened. The remainder of the links with increased accident rates at lower levels of significance were also considered to have occurred largely by chance. To investigate further the links where accident rate reductions appeared most likely to be real, the twenty five links with the most significant reductions were circulated to the highway authorities responsible for their management, asking for evidence of any work that had been carried out to improve them.

4.2.3.2 Working with highway authorities to understand changes

A good response was obtained from many highway authorities to this request for information. Over the same period, general discussions were held with the national body representing the highway authorities to help interpret the results and consider ways of presenting them that would be useful to local engineers.

From the comparison of the two time periods, two groups of links were identified. Those where accident rates had reduced significantly, and those which were consistently high risk in both time periods. For the former the local engineers were asked to provide information on the safety related measures that had been applied to these roads that might have influenced the accident rate during the period. For the routes with consistently high risk, the engineers were asked what they thought were the persistent problems on these routes, and what measures they had applied recently to try to reduce risk.

4.2.3.3 Improved and continuing high risk routes

The results are summarised in the Tables 4 and 5.

Britain's most improved roads

Road	From - To	Region	Length (km)	Carriageway type	Fatal & serious accidents 97-99	Fatal & serious accidents 99-01	Percentage of fatal and serious accidents saved	Engineering measures aimed at cutting: Head-on collisions	Single-vehicle run-offs	Accidents at junctions	Accidents involving pedestrians/cyclists
A134	Thetford – A10	East	38	Single	23	9	61		✓		✓
M73	M73 J1 – J3	Scotland	10	Motorway	18	7	61			✓	
A682	A56 – A646 Burnley	North West	11	Mixed	28	13	54	✓	✓		
A45	Coventry Ring Road – M42 J6	W Mids	20	Dual	48	23	52			✓	✓
A6	Leicester – Derby	E Mids	37	Mixed	69	34	51	✓	✓	✓	✓
A299	Faversham – A253 Monkon	South East	29	Dual	34	17	50	✓	✓	✓	
A523	Macclesfield – Hazel Grove	North West	14	Mixed	34	17	50	✓	✓	✓	✓
A75	Gretna Green – Dumfries	Scotland	40	Single	28	14	50	✓	✓	✓	
A243	A3 Hook – M25 J9	London	10	Mixed	40	21	48			✓	
A638	Adwick Le Street – Crofton	North East	19	Single	29	15	48	✓	✓	✓	
A12	Lowestoft – Gt Yarmouth	East	16	Mixed	39	21	46			✓	✓
A91	Stirling – Kinross	Scotland	41	Single	41	23	44		✓		
A90	Dundee – Aberdeen	Scotland	101	Dual	85	57	33			✓	

Table 4 Routes in Britain with greatest reduction in numbers of fatal and serious accidents per vehicle km between 1997-99 and 1999-01

Britain's persistently high risk roads†

Road	From - To	Region	Length (km)	Carriageway type	Fatal & serious accidents 97-99	Fatal & serious accidents 99-01	Predominant accident types involve:	
A537	Macclesfield – Buxton*	North West	13	Single	35	35	Head-ons	
A534	Welsh boundary – Nantwich*	North West	24	Single	33	32	Run-offs	
A682	M65 J13 – A65 Long Preston*	North West	24	Single	25	24	Head-ons	Run-offs
A54	Congleton – Buxton*	North West	24	Single	24	18	Head-ons/run-offs/junctions	
A631	Gainsborough – A1103*	E Mids	24	Mixed	23	21	Junctions	
A683	A6 – Kirkby Lonsdale*	North West	24	Single	28	23	Junctions	
A61	Barnsley – Wakefield*	Y & Humber	10	Single	13	17	Junctions	
A1101	Outwell (A1122) – Long Sutton (A17)*	East	21	Mixed	22	25	Head-ons	
A44	Leominster – Worcester*	W Mids	37	Single	39	34	Junctions	
A53	Leek – Buxton*	W Mids	20	Single	20	18	Junctions	
A5	Daventry – Rugby (A428)	W Mids/E Mids	16	Mixed	23	18	Junctions	
A70	Cumnock – Ayr*	Scotland	21	Single	25	20	Junctions	
A59	Skipton – Harrogate*	Y & Humber	30	Single	48	42	Junctions	Head-ons
A28	Ashford – Margate*	South East	47	Mixed	104	93	Junctions	Pedestrians/cyclists
A436	A417 Little Witcombe – A40 Shipton*	South West	10	Single	10	10	Head-ons	Junctions
A170	Thirsk – Scarborough*	Y & Humber	70	Single	64	57	Junctions	
A60	Mansfield – Worksop*	E Mids	20	Single	44	36	Junctions	
A71	Kilmarnock – M74 J8*	Scotland	39	Single	39	38	Head-ons	
A6	Derby – Buxton	E Mids	56	Single	97	89	Junctions	
A660	Leeds – Otley	Y & Humber	20	Mixed	59	55	Pedestrians/cyclists	Junctions
A43	Corby – Stamford	E Mids	23	Single	35	26	Head-ons	Junctions

Table 5 Routes in Britain with persistently high numbers of fatal and serious accidents per vehicle km over the whole period 1997-2001

Routes with very short lengths or with small numbers of accidents are known to be more prone to variability in accident rate in different years. These were therefore filtered out and excluded from the list of routes with highest risk. The list also excluded routes where the density of fatal and serious accidents was at less than one per km over the three year period. This ensured that the routes highlighted were mainly ones where it might be expected that cost effective improvements were most likely to be achievable.

The rates listed for these links include accidents involving all vehicles, but it was noted that for some of the highest risk links, an appreciable part of the risk arose because of accidents involving a specific road user group such as motorcyclists. Further analysis of these data enables a clearer picture to be developed of the differing role of the infrastructure on these routes to different road users. The data also allow those routes which present a particularly risky environment for specific groups to be highlighted.

More detailed investigation of the causes of risk on these routes is also useful to indicate the type of safety measures that would be needed. The routes in Table 5 include both wholly rural sections, where the dominance of head-on and run-off accidents show the need for improvements to the median and the roadside protection, and sections which include substantial lengths with lower speed limits and some roadside development. In the latter sections, junction improvements and improved facilities for vulnerable road users are likely to be desirable.

4.3 Dealing with sparser data

Not all countries have accident data available that allows such extensive analysis. In some situations, such as Sweden, a relatively small number of accidents spread over a large road network means that site specific or even route specific issues are difficult to identify from three years of accident data. Here statistical assumptions about accident rate variation between years are also sometimes needed to give plausible estimates of accident rates for individual routes.
In other countries, such as Italy, accident reporting is variable in both quality and quantity leading to an uncertain basis from which to derive comparative rates.

4.3.1 Data availability and definition in Italy

Between the two periods (1998-2000 and 1999-2001) examined there was an apparent increase in the numbers of accidents on the EuroRAP routes in Italy. But it is suspected that this is influenced by the greater attention given to accident reporting over this period leading to a higher rate of reporting and recording accidents. Until a stable reporting system is achieved therefore, it will not be meaningful to make comparisons between time periods.

For some 30% of accidents that are currently reported, no detailed location of the accident is given. The accident is assigned to a road number and a province but not to a specific location on the road. An estimate of the accident numbers associated with a defined road link can be made by, for example, allocating the unlocated accidents in the same proportion as located accidents on any particular road within a province.

Injury severity level is only recorded within the Italian data as fatal or "other injuries". It is not therefore possible to estimate fatal and serious accident risk rates for the Italian road links. Comparisons can be made, at link level on the basis on all injury accidents, and at national level for different road types in terms of fatal accident rates.

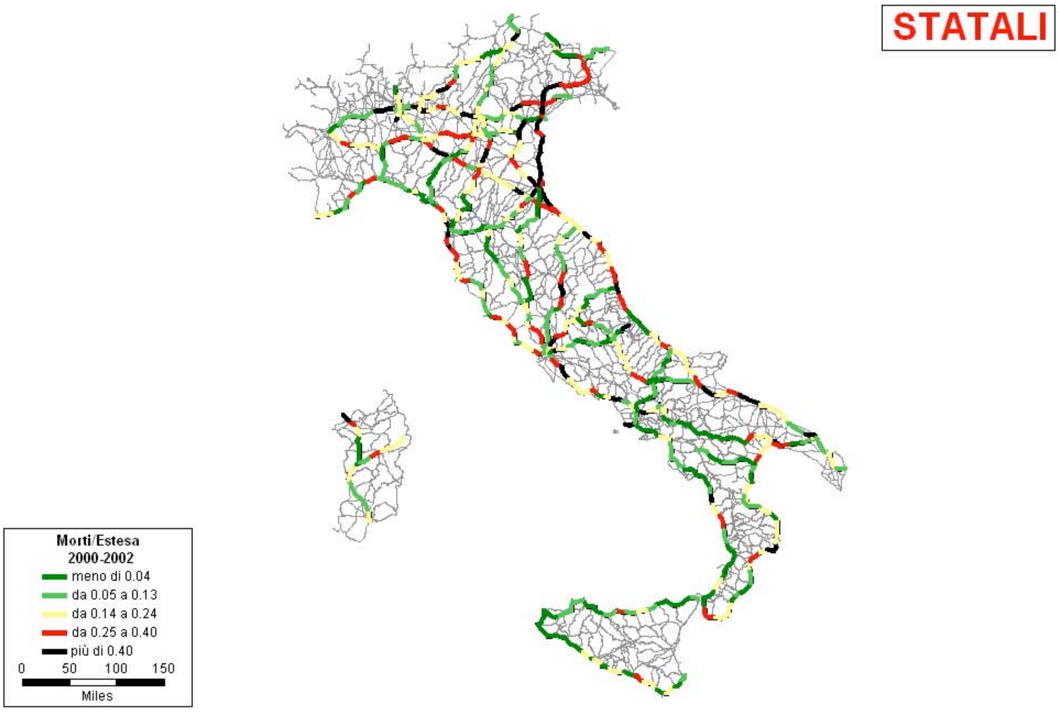
Data on traffic flows is also lacking at present for the Italian network. Some data are available for motorway flows, and this has been used to map accident rates per vehicle km for those roads. On other roads risk rates are currently calculated as accidents per km. This shows the relative density of accidents between roads, but does not indicate whether the higher densities are due to greater traffic flows, or to less safe roads.

Figure 7 shows the rates for deaths per km for the Italian network.

4.3.2 Repeatability of risk rates

A different issue arises with data from the Swedish network. Here the density of accidents is relatively low on most roads due to the low traffic flows, and the long distances between conflict points such as junctions. Long term accident rates can therefore only be developed with confidence from data over many years. But these estimates do not show very effectively the benefits of recent changes to the infrastructure. There is also little to be learned from frequent updating of these data.

A similar problem, although perhaps not to the same extent, is likely to arise with other countries which have relatively low traffic flows and accident numbers. During the next year, this issue may need to be dealt with in Northern Ireland and the Republic of Ireland. An alternative to creating either very long links or using all injury accidents rather than just fatal and serious injuries is to calculate average rates over a longer time period. All these approaches however will result in a reduced ability to carry out analysis in relation to short route lengths.



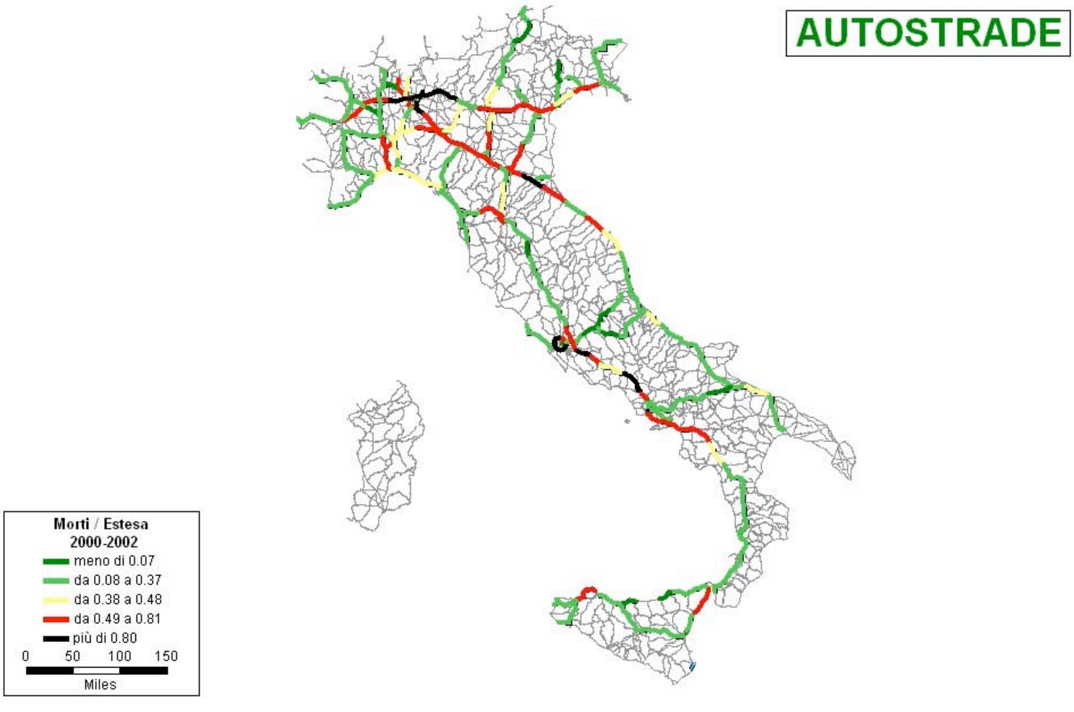


Figure 7 Deaths per km for Italian State roads (Statali) and motorways (Autostrade)

4.4 Comparing within countries

4.4.1 Factors affecting comparison

EuroRAP provides a means by which the safety performance of different routes within a country can be compared. Differences in accident rates can be expected for roads carrying different flows and for roads built to different standards. The main interest therefore is in comparing performance of roads fulfilling the same traffic function within the country. Some roads can be expected to have higher risk rates where they pass through difficult terrain or suffer worse than average weather conditions. But generally high risk rates will indicate that roads could be improved. Roads which pass through more developed areas should have designs and speed management regimes which allow the greater potential risk to be accommodated without an increase in actual risk. The data may also allow variations in risk to be identified between networks managed by different authorities or between roads used by drivers in different regions who might exhibit different driving behaviour.

4.4.2 Accident rates by road type and road management

The variation in average fatal and serious accident rates between different road types has already been illustrated in the pilot report for the first three countries investigated. To these can be added data from the national road network in Spain.

The highest rates per km and lowest rates per vehicle km occur as expected on the motorways. Fatal and serious accident rates per km on 2 lane single carriageway roads are typically a third lower than those on motorways, while the rates per vehicle km on the 2 lane roads are up to five times higher than those on motorways. Where data are available for multilane roads (eg Sweden), rates per km for 4 lane roads are more than double those on 2 lane roads, although rates per vehicle km are slightly lower. Rates per vehicle km for two lane roads are high relative to other road types in Britain partly reflecting the greater incidence of built up areas along these routes in Britain.

These results are illustrated in Tables 6 and 13. In Table 6 rates per vehicle km on each road type, in each country, are shown as a proportion of the average rate for non-motorway divided roads. Presentation in this format shows the countries where motorways appear to be performing substantially better in terms of rate per vehicle km than other divided roads, and the extent to which non-divided roads perform less well, on this measure, than divided roads.

	GB	NL	S	ESP
Motorway	0.4	0.4	0.7	0.9
Other divided	1	1	1	1
4 lane roads			1.6	
Wide 2 lane roads			1.8	
Standard 2 lane roads	2.3	1.6	1.7	1.8

Table 6 Fatal and serious accident rates per vehicle km as a proportion of the rate for non-motorway divided roads in each country

4.4.2.1 Speed limit

One factor that could influence performance is the speed limit adopted. However the use of a lower limit will often be in response to an anticipated accident problem if the higher limit were to be used, so it is not likely that major differences will be seen in the data, or that these can be assumed to represent primarily the influence of the different speed limits.

As an example Table 7 compares the rates for motorways in the Netherlands. Overall average rates appear to differ with a rate of 14.1 for motorways with 120km/h limit compared with a rate of 12.6 for motorways with a 100km/h limit. At face value this could suggest that the speed limit was effective in reducing the accident rate. However Table 7 shows a more complicated picture. Motorways with 100km/h limit are typically in urban areas where flows are higher, and Table 7 shows that rates tend to reduce with flow.

Speed limit	Flow (AADT)	Accident Rate per vehicle km
100 km/h	<50,000	13.95
	50,000 – 100,000	12.09
	>100,000	13.01
120 km/h	<50,000	18.64
	50,000 – 100,000	13.14
	>100,000	11.13

Table 7 Accident rate for motorways by speed limit and flow – Netherlands (1999-2001)

4.4.3 Conclusion

EuroRAP provides a sound basis for comparing the performance of roads within each country that is capable of reflecting differences in traffic function, road type and speed management regimes. This can include tracking changes in the safety of the network as a whole over time, highlighting well and poorly performing routes in any particular time period, and comparing the relative performance of different road types within the network.

4.5 Comparing between countries

An important part of the programme is to understand differences in accident risk between different countries. As part of the "within country" comparisons we have already investigated how the relative variation in accidents for different road types varies between different countries. To look in more detail at differences in absolute accident rates, two issues need to be considered. First, the accident reporting and recording systems differ between countries. There is reasonable consistency in reporting fatalities, and agreed ways exist to correct for differences in reporting criteria. Section 4.5.1 looks at comparisons on this basis. When non-fatal accidents are also included, more substantial differences in reporting systems need to be recognised; section 4.5.2 discusses ways of doing this. There are also differences in the extent to which traffic flow data are collected, and section 4.5.3 looks at comparisons based only on accident density.

Secondly, the comparisons between countries reflect both differences in infrastructure design and management and differences in driving behaviour. In sections 4.5.4 and 4.5.5 comparisons are made based on indicators of both individual risk and collective risk. For these the concept of the distribution of risk rates across the network is introduced, as a means of indicating whether differences arise mainly due to a similar shaped risk distribution around a different mean value or a spread of risk rates over a much wider set of values. It is likely that the former implies a difference in rates arising mainly from behavioural differences, while the latter implies a wider variation in infrastructure standards.

4.5.1 Fatality rates

Most countries record a very high proportion of the road deaths that occur. The main difference in reporting systems relates to the "time to die", ie the period over which the death is still regarded as being caused by the road accident. Most countries now assume a 30 day period after the road accident during which fatalities are assumed to be the result of the road accident, and corrections can be made for countries (eg Spain in Table below) where fatalities are recorded over a shorter period. Average rates for fatal accidents per vehicle km for different road types for different countries are shown in Table 8.

	GB	NL	S	ESP
Motorway	1.9	1.7	1.7	11.3
Other divided	5.0	7.7	**	11.3
Standard 2 lane roads	12.4	11*	7.7	23.2

* based on only a small sample   ** data not available separately on fatalities

Table 8 Fatal accidents per billion vehicle kms by country and road type

These show fairly consistent rates for Britain, Netherlands, and Sweden across all the road types. The "other divided" category includes roads with both segregated and non-segregated junctions, and the proportions of these differs between countries. These roads are also generally only 2x2 lane. The numbers of lanes on motorways also differs between countries, being generally 2x3 in Britain, but less in some other countries.

The variation in fatality rates between road types for each country in Table 8 differs slightly from the ratios of fatal and serious accident rates shown in Table 6. This is not due to differences in general reporting rates between the countries, as Table 6 relates only to ratios within each country, and Table 8 compares absolute rates that should reflect consistent reporting practice. The differences appear to arise due to real differences between the relative proportions of serious accidents on the different road types within each country. This either reflects real differences in injury patterns between the different roads within each country, or differences in reporting rates for the different road types within some of the countries.

4.5.2 Fatality / F&S rate factors by road type

Many countries use a definition of serious injury that is based on at least one night being spent in a hospital. Practice will still vary between countries as to whether casualties are detained in hospital for particular injury types. Britain is most out of line with this definition, using "serious injury" to denote a wider range of injuries. Only about half the casualties recorded as "serious" in Britain are detained overnight in hospital. In addition, there are likely to be substantial differences between countries in the extent to which accidents involving serious injury are attended by the police and recorded in the accidents statistics.

The resulting variation between countries can be seen by comparing the ratios of fatal plus serious accidents to fatal accidents in each country. At aggregate level, it is often not necessary to use the serious accident data to compare between road or road user types, as sufficiently large numbers of fatal accidents occur to provide robust comparisons. However on individual routes, it is likely that there will be only a small number of fatal accidents, and it is necessary to work with numbers of fatal and serious accidents to provide reliable comparisons. The ratios in Table 9 provide a basis for this comparison, and "adjustment" factors to bring the rates for other countries in line with those based on the British ratios are given in Table 10. The use of this adjustment factor assumes that the proportion of fatal accidents to fatal and serious accidents is constant for the group of roads being considered and is stable over time. In practice Table 9 suggests that in some countries different ratios are needed for different types of road; this may reflect differences between the roads in both the types of accident occurring and the level reporting of non-fatal accidents.

	GB	NL	S	ESP
Motorway	6.5	8.2	9.3	4.4
Other divided	(7.3)	5.0		5.1
Standard 2 lane roads	6.5	5.5	5.2	4.4
All roads	6.5	7.5		4.4

Table 9 Ratio of fatal and serious accidents to fatal accidents for different road types in different countries

	GB	NL	S (based on casualty ratio)	ESP
Motorway	1.0	0.7	0.6	1.5
Other divided	1.0	1.5		1.4
Standard 2 lane roads	1.0		1.25	1.5
All roads	1.0	0.8	0.9	1.5

Table 10 Adjustment factors to bring the ratios in line with British ratios

The effect of applying these ratios can be seen in Tables 11 and 12, results in Table 12 having been adjusted using the ratios in Table 10.

	GB	NL	S	ESP
National "A" roads	44.4	54.5	57.7	82.2
Other (regional) "A" roads	75.9			
Motorways	12.4	14.0	15.8	50.2
Dual cway; grade sep.	28.1	] 38.5	23.9	] 57.2
Dual cway; at grade	43.2	]		]
Multilane single cways			38.0	
Wide single cways			39.4	
Single cways	80.0	(61)	40.4	101.9

Table 11: Reported fatal and serious accident rates per vehicle km 1999-2001.

<table>
<tr><th></th><th>GB</th><th>NL</th><th>S</th><th>ESP</th></tr>
<tr><td>National "A" roads</td><td>44</td><td>45</td><td>52</td><td>123</td></tr>
<tr><td>Other (regional) "A" roads</td><td>76</td><td></td><td></td><td></td></tr>
<tr><td>Motorways</td><td>12</td><td>10</td><td>11</td><td>75</td></tr>
<tr><td>Dual cway; grade sep.</td><td>28</td><td rowspan="2">(57)</td><td>24</td><td rowspan="2">82</td></tr>
<tr><td>Dual cway; at grade</td><td>43</td><td></td></tr>
<tr><td>Multilane single cways</td><td></td><td></td><td>48</td><td></td></tr>
<tr><td>Wide single cways</td><td></td><td></td><td>49</td><td></td></tr>
<tr><td>Single cways</td><td>80</td><td>(72)</td><td>50</td><td>151</td></tr>
</table>

Table 12: Fatal and serious accident rates, adjusted for reporting differences relative to British rates (parentheses signify small samples).

Risk maps are initially drawn for each country based on the actual numbers of accidents in that country. A further set of risk maps can be developed in which the rates in each country are "adjusted" on the basis of the ratios in Table 10; these would then show route rates in the different countries with a common risk scale. But it is likely that map based information will be most relevant for comparing within each country. The adjustment to a common risk scale is therefore probably more relevant to the risk rate distributions discussed in 4.5.4 and 4.5.5 below to enable these to be used as comparative indicators of national performance.

4.5.3 Accident density and risk

Comparisons can also be made of accident density (ie number of accidents per km) As a first order comparison, accident densities reflect differences in traffic flow levels. In order to learn more from these data therefore, accident densities have been compared by road type (Table 13), and then further divided by flow class and road type (Tables 14 and 15).

<table>
<tr><th></th><th>GB
Fatal and serious</th><th>NL
Fatal and serious</th><th>S
Fatal and serious</th><th>ESP
Fatal and serious</th><th>I
All accidents</th></tr>
<tr><td>Motorway</td><td>0.36</td><td>0.32</td><td>0.36</td><td>0.38</td><td>1.90</td></tr>
<tr><td>Dual cways</td><td>0.42</td><td>0.39</td><td>0.26</td><td>0.64</td><td rowspan="3">0.70</td></tr>
<tr><td>Mixed cways</td><td>0.35</td><td>0.25</td><td></td><td></td></tr>
<tr><td>Single cways</td><td>0.25</td><td>0.33</td><td>0.21</td><td>0.25</td></tr>
<tr><td>4 lane roads</td><td></td><td></td><td>0.67</td><td></td><td></td></tr>
<tr><td>Single (2 lane) 9-13m.</td><td></td><td></td><td>0.29</td><td></td><td></td></tr>
<tr><td>Single (2 lane) <9m.</td><td></td><td></td><td>0.10</td><td></td><td></td></tr>
<tr><td>Overall</td><td>0.30</td><td>0.32</td><td>0.24</td><td>0.32</td><td>1.05</td></tr>
</table>

Table 13 Accident rate per km (Fatal and serious injury accidents, except Italy – all injury accidents)

For non-motorways, the carriageway type is not specified in the Italian data. The data-set specifies the number of lanes and the carriageway width. These values seem to indicate that most of the non-motorways in the data are single carriageway roads.

The values for the densities in Table 13 are calculated as the sum of all the annual fatal and serious accidents within a certain road-type-group, divided by the sum of the length of all the sections within that group (instead of the average value of the density of all separate sections). This means that bias caused by short sections (with low accident numbers per section) is avoided.

Table 13 suggests that:

- the overall values for fatal and serious accident rates are reasonably comparable, with the exception of Sweden, which shows a lower accident density on non-motorway roads;
- rates for motorways are generally comparable (Netherlands rate is slightly lower);
- rates for dual carriageway roads in Sweden are considerably lower than in Britain and the Netherlands but rates in Spain are considerably higher;
- rates for single carriageway roads are generally comparable, although the rate in the Netherlands is somewhat higher;
- Swedish 4-lane single carriageway roads have a considerably higher accident density than other single carriageway roads in any of the countries.

It is not clear whether differences are caused by differences in flow or by other factors (including design factors). For instance, the fact that Sweden shows lower overall accident densities could indicate that the difference may be caused by flow differences (since traffic volumes in Sweden are generally lower than in other countries).

This last example is demonstrated in Table 14, in which accident densities for all road types (overall) are listed by flow category:

Flow (AADT)	**GB**	**NL**	**S**	**ESP**
<5,000	0.14	-	0.10	0.12
5,000-10,000	0.23	0.27	0.28	0.25
10,000-20,000	0.33	0.28	0.33	0.43
20,000-40,000	0.39	0.27	0.55	0.58
40,000-100,000	0.38	0.33	1.17	0.82
>100,000	0.60	0.64	-	1.30

Table 14 Accident densities by traffic flow (all road types combined)

The accident densities for Sweden in this table are more in line with GB and NL (even higher for the higher volumes), demonstrating that the low overall value seen in Table 13 was probably caused by a large number of sections with very low volumes.

It is interesting that the Spanish values seem to be in line with GB, NL and SV for the lower volumes, but are considerably higher for the higher volumes. This could be caused by a more extensive use of single and mainly dual carriageway roads by large flows (due to a less extensive motorway network); this difference is shown in Table 15 for single carriageway roads.

Flow	GB	NL	SV	ESP
<5,000	0.14		0.11	0.12
5,000-10,000	0.23	0.29	0.29	0.26
10,000-20,000	0.35	0.35	0.48	0.49
20,000-40,000	0.46	0.59	0.38	0.77
40,000-100,000				0.61

Table 15 Fatal and serious accident rates per km for single carriageway roads by flow group

Accident densities for each road type separately, divided into a number of flow categories, probably give a good basis for comparison.

Making the comparisons per flow category seems to provide a rough equivalent of comparing accident rates per vehicle km. A major difference however is that categorising links by flow in this way requires less reliable flow information than calculating accident rates (which are much more sensitive to relatively small changes in estimated flows).

For countries that do not have reliable flow data, this could be a workable solution.

4.5.4 Individual risk

The variation in individual risk between countries is best represented by comparing the distributions of accidents per vehicle km. This can be done at two levels:

- comparing the risk distributions between countries for roads of the same type – this enables the overall risk for that road type to be compared between countries;
- comparing the risk distribution for all the roads in the selected network with those in a similar network in another country – this shows not only how the risk varies for a particular road type but also the extent to which the network is made up of roads of different types.

Examples of the former are given below. The differences in average risk for different road types, corrected for difference in reporting practice, have already been shown in Table 12. The use of the risk distribution here enables us to look at another characteristic of the risk within different countries for the same road type – the extent to most roads of the same type within a country operate at similar risk levels. This is easily illustrated by the graphs below (Figs 8 and 9) – first for motorways, and second for 2 lane single carriageways. The colour bars in the graphs are used to highlight the different risk bands and are consistent with the colours used for the risk bands in the risk maps.

Where most roads are built and operated to a consistent standard within a country, the spread of risk on this type of road within that country will be relatively narrow. There will still remain some variation – partly due to random distribution of accidents, and partly due to factors such as some of the roads being in areas where topography or weather conditions are more extreme. But in most cases the risk for individual routes will be close to the mean For these illustrations, the actual rates have been used without correcting for reporting, as it is the relative distribution, not the absolute values, that is being demonstrated.

In the examples below for motorways (Fig 8), it can be seen that rates for NL, GB and to a slightly lesser extent S motorways are all fairly tightly bunched, whereas the rates for Spanish motorways are much more widely spread. The mean accident rate may be higher on the Spanish motorways due to differences in national driving characteristics (eg seat belt wearing, speeding etc). This would give rise to a greater spread in rates even if the variance around the mean was the same as in other countries.

A wide spread of rates can be seen for all countries for two lane roads (Fig 9) but again mean accident rates vary, and are all much higher than those for motorways.

To put these distributions on a more consistent comparative basis, the fatal and serious accident rates can be plotted as a proportion of the average rate for the group within each country. Using this normalised rate within each country also removes differences related to the proportions of fatal and serious accidents compared with fatal accidents in each country. Figs 10 and 11 show the result when the data are compared on this basis. These suggest that there remains greater variance within the distribution of the Spanish rates for both motorways and 2 lane roads although the real variance is less than that suggested by the simple plots (Figs 8 and 9), and there is also variation between the variances of the distributions for the other countries. These distributions need to be investigated further to understand the influence of the network link structure on the distribution of rates. Rates for links shorter than 5kms are excluded from these comparisons to remove one source of potential variance.

This suggests that some roads do not provide as safe an environment as others, and highlights the need to try to bring risk on these road networks within a narrower risk range.

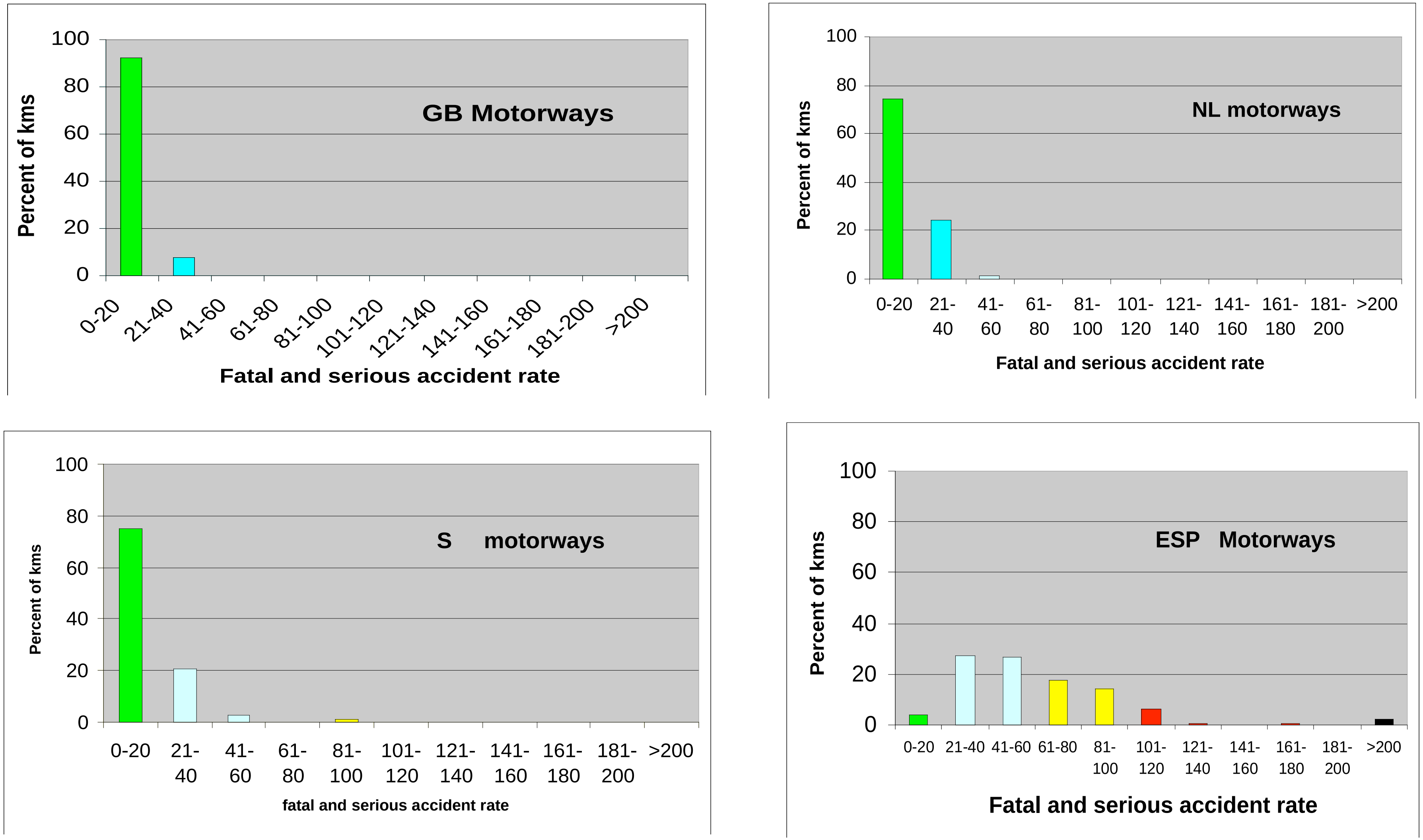
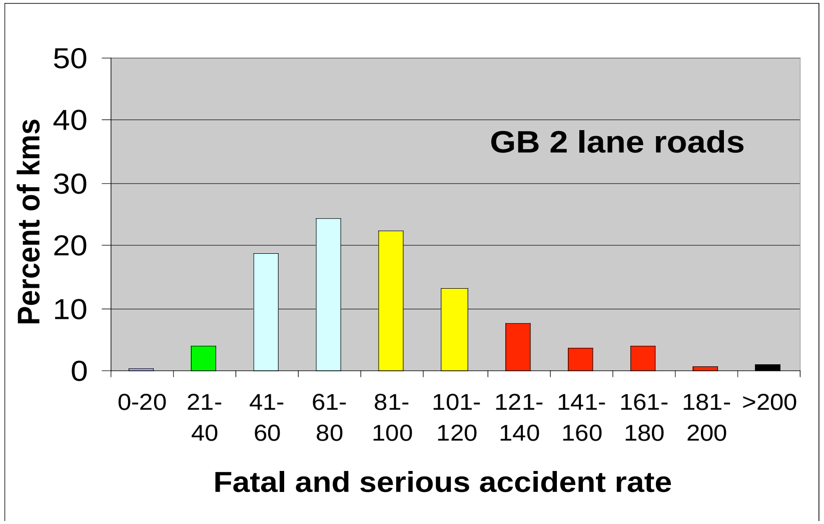
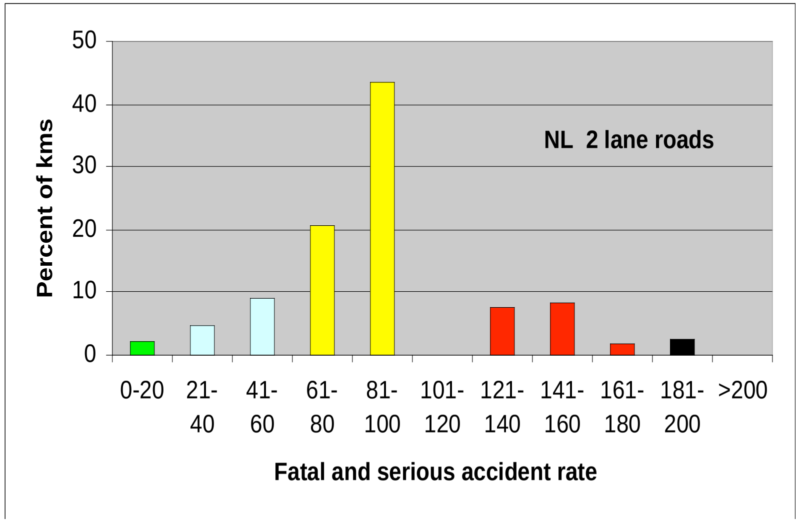
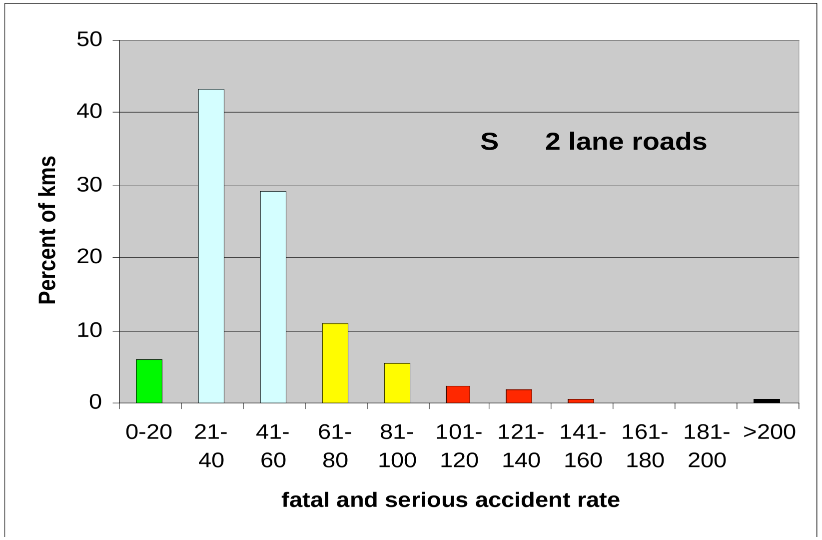


Fig 8 Distribution of fatal and serious accident rates for motorways for different countries







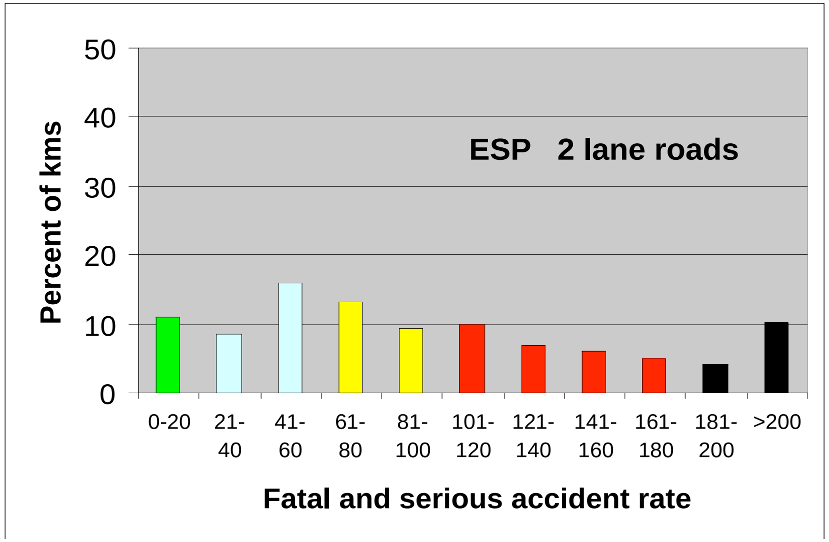


Fig 9 Distributions of fatal and serious accident rates for 2 lane roads for different countries

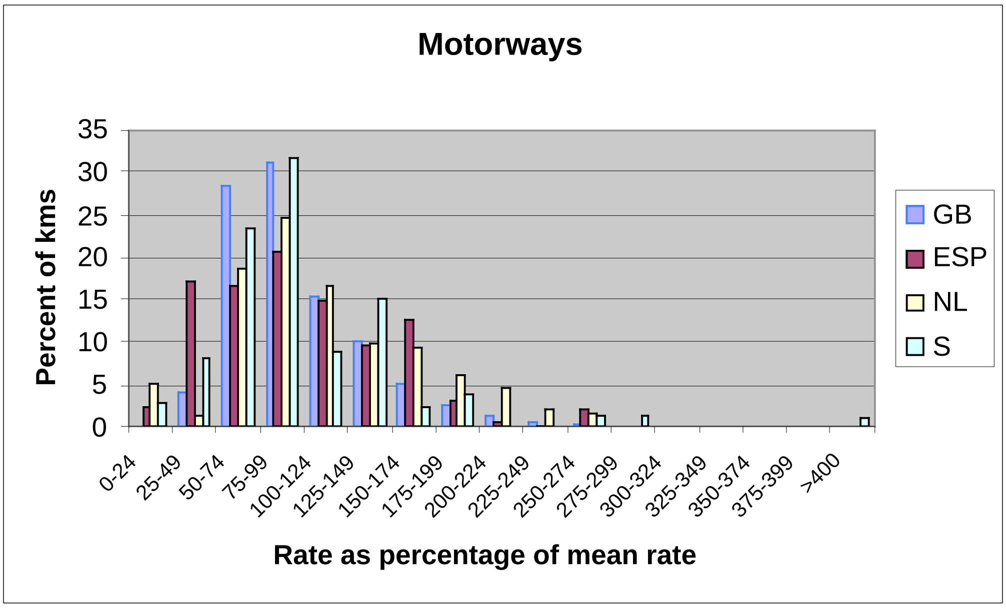
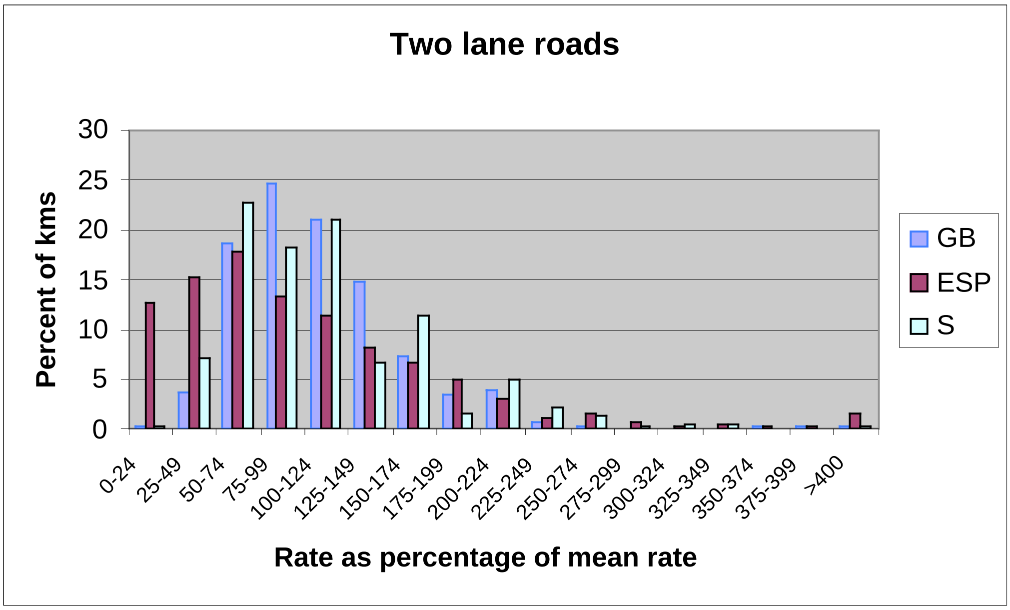


Figure 10 Comparison between countries of distribution of accident rates per vehicle km as a proportion of the mean rate for the country - motorways

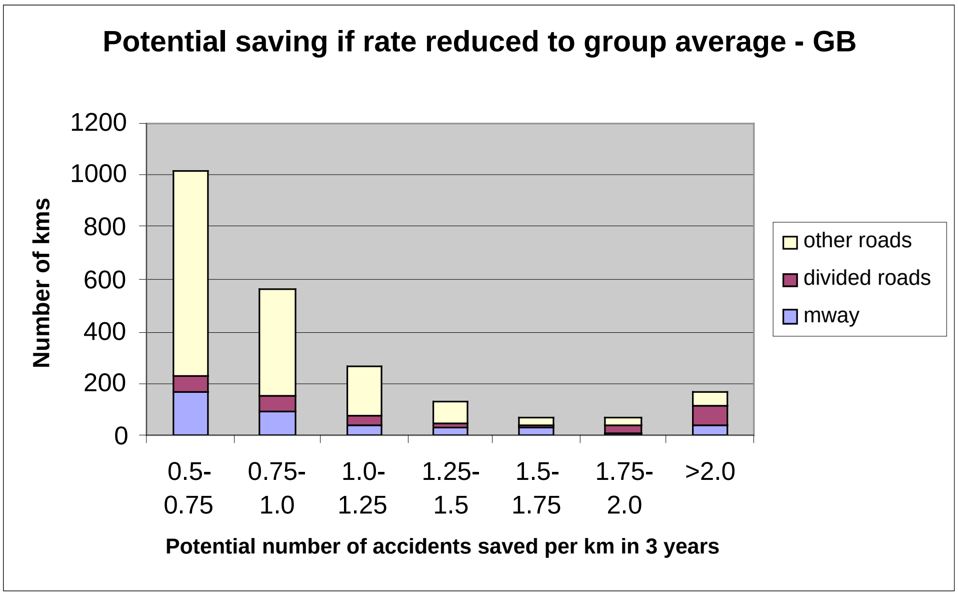


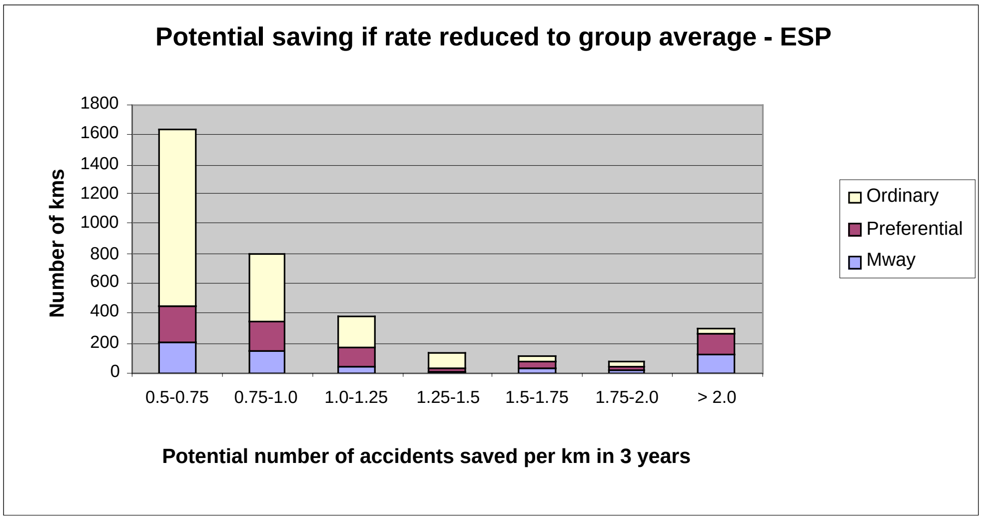
Data for the Netherlands are not included as there is only a small length of undivided roads in the national network

Figure 11 Comparison between countries of distribution of accident rates per vehicle km as a proportion of the mean rate for the country – 2 lane roads

4.5.5 *Collective risk*

Comparisons can also be made between countries on the basis of collective risk. This comparison again relies on comparing distributions, but in this case distributions based on the range of potential accident savings that could be achieved within the network in each country. For this, an assumption is needed of the extent to which roads might be improved in each country, and for this the issues described in section 3.1.2 need to be considered. The illustrative charts in Fig 12 make two assumptions – first that estimates of potential accident savings will be made separately for each of a defined set of road groups, and second that the standard that might be achieved within each group is equivalent to the current *average* value of the risk distribution for that group. The average rate values that are used as the target rate in the examples below are the averages for four separate groups – motorways, and all other roads divided into three AADT flow groups (0-10,000, 10,000-20,000, and over 20,000 vehicles per day respectively). Based on comparison with these target rates, the figures below indicate the numbers of accidents that might be saved on each current road type. The use of flow groups is discussed further in 4.5.6 below.





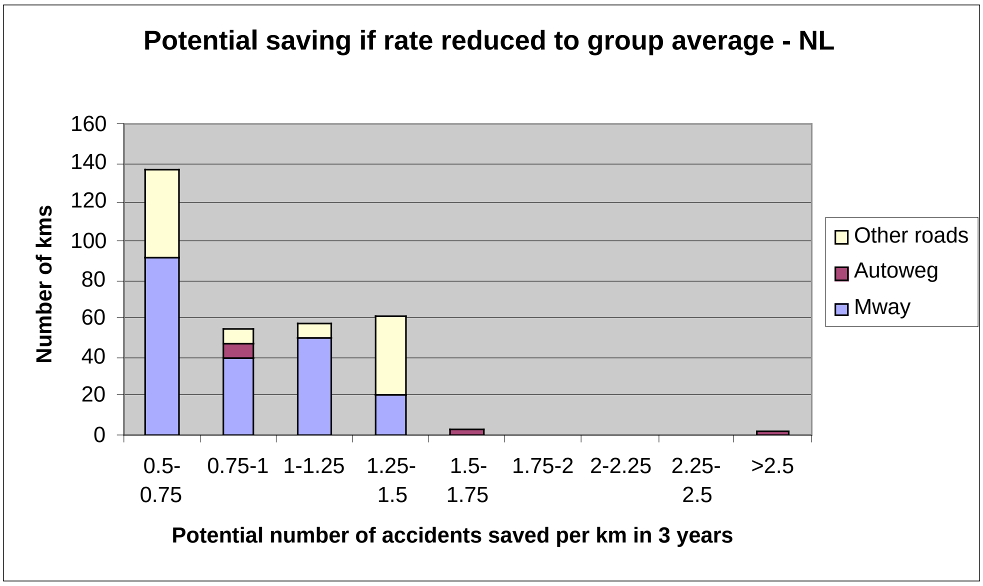


Figure 12 Road lengths in Britain, Spain and the Netherlands with potential for saving given number of accidents per km

These graphs are illustrative of the methodology that can be used. Further work is required to decide an appropriate "target" rate for each country against which to assess the potential total accident savings that might reasonably be sought in each country in a specific timescale. However, when such a rate is decided, a computation similar to those above can easily be made from the distribution of risk rates already established.

4.5.6 Taking flow bands into account

In both of the comparisons in 4.5.4 and 4.5.5, it is important to consider the effect of traffic flow. Risk rates per vehicle km are not linear with traffic flow, and therefore it can be expected that a road with a higher flow will have a lower fatal and serious accident rate per vehicle km even where the standard of the road is the same. We know that not only are average traffic flows different in different countries, but also the distribution of traffic between road types differs. This is taken into account in the comparisons of collective risk by comparing roads within flow bands, but further investigation of the influence of this on the comparisons may be necessary as different measures will be appropriate at different flow levels. Similarly, inclusion of traffic flow bands when comparing individual risk is also likely to give a more accurate picture of the role of infrastructure in influencing risk.

4.5.7 Conclusions

Providing adjustments are made to allow for the difference between countries in defining and reporting serious accidents, useful comparisons can be made between countries of the relative distributions of risk across their main road networks. These can be expressed in terms of accident rates per vehicle km, showing the risk to individual road users, or in terms of potential numbers of accidents that could be saved if the risk was reduced. To use these analyses to develop cost effective programmes for road improvement requires further work on considering how best to represent the accident savings in cost terms and how best to define the reductions in risk to be targeted, and the cost of achieving these changes. This can be done at national level, but there is at present no consensus between countries on the valuation of accident savings at European level.

4.6 Influence of different accident types

Accidents can be grouped according to whether they represent the four main accident types which comprise the majority of all rural road accidents – head on collisions, single vehicles running off the road, impacts at junctions, and impacts involving pedestrians or cyclists. These four types also form the basis of the road protection assessment described in section 5 below. The way in which these accident types can be identified depends on the accident report coding system. For example, in some systems (eg Britain) accidents occurring at intersections are coded separately. In other systems they need to be selected as those accidents involving side impacts. Similarly, head on accidents can be partly identified by selecting those impacts where each vehicle's first point of contact was the front of the vehicle, but this will usually also need qualifying by combining with angles and directions of impact.

An analysis of this type has been made for the British data, and enabled those links for which risks were higher than average, to be inspected to see which accident types were over-represented. This again formed part of the data provided with the results launched in Britain in 2003 (section 4.2.3.3). If accident data include a record of the road user involved, it is possible to identify whether the higher risk on different road types within the network or on specific routes is related to a particular road user group.

4.7 Inclusion of lower speed sections through small urban areas

The initial maps drawn for Britain focussed only on the inter-urban road sections with higher speed limits (50mph or above). This gives a network which is more consistent in terms of roads designed for high speed travel. But excluding linking sections along these routes, where for reasons typically of higher levels of roadside development lower speed limits have been introduced, gives a false impression of the overall risk along the route. For the report published in May 2003, therefore, overall risk rates for the whole route were quoted. This provides a better indication of the extent to which travel along the route is affected by sections with lower speed limit, but it also introduces road sections that have a different local function, and creates route links with more mixed design. Ideally the data from the sections with roadside development would be treated separately in the analyses from those without this development. But it is often not possible to isolate the data for these sections, and where this is possible the number of accidents on a short developed section may not be high even though the accident rate per vehicle km is inflated compared with the undeveloped sections.

The importance of this issue differs between different networks. In Sweden, all but the smallest developments are generally bypassed. In Netherlands, the network being analysed at present is built to a high standard and is largely separated from the neighbouring networks except at well designed junctions. In Britain and in Spain, however, the mixture of developed and undeveloped sections is much greater, particularly for the 2 lane single carriageway roads. In Britain, the average fatal and serious accident rate is some 25% higher on these roads if accidents on these lower speed sections are included. In the Spanish state road network, these "through town" sections are identified separately, and they only comprise some 2% of the total fatal and serious accidents on the State road network, and 3-4% of those on the 2 lane roads.

4.8 Extending outside national interurban roads

The starting point for EuroRAP was the national road networks in each country. But in several countries we are already extending the coverage of the network to include lower category roads. This is partly to include a network which represents a substantial proportion of fatal accidents in that country, but it also gives some insight into the risk rates on the lower category roads in comparison with the national network. This information is important because it can be used to emphasise that in terms of route choice, it is still often better to stay on the national network even where it is poor quality relative to the rest of the national network, rather than transfer to the lower category road. It also shows whether the problems and solutions to achieve improved safety may need to differ on these roads from those on the national network.

4.8.1 GB non-national roads

In Britain only about 20% of the national total of vehicle kms of travel occurs on the motorway network. This is very different for example from the Netherlands where 40% of national vehicle kms occur on the much denser motorway network. Although in Britain the national road network also includes a large network of non-motorway roads, a substantial proportion of the interurban traffic is carried on regional roads. Table 16 shows how the accident rates on these roads compare with those on the national network – for roads of similar type, and for roads with similar flow levels. The rates on regionally managed roads are consistently higher for the higher design standard roads, but for ordinary two lane roads the rates are similar.

AADT flow	**Divided roads – grade separated junctions**	**Divided roads - at grade junctions**	**Divided roads – mixed junctions**	**Mixed roads - divided and undivided**	**Ordinary undivided roads**
5-20,000	-	-	-	1.4	1.2
20-50,000	2.5	1.7	1.7	1.5	1.0

Minimum of ten routes in each group compared

Table 16 Ratio of risk rates (fatal and serious accidents per vehicle km) on regional roads and national roads in Britain

4.8.2 Catalonia non-State roads

The network of roads examined in Catalonia included both State roads and non-State roads. There are motorways, "preferential roads", and ordinary roads in each category. Again a comparison can be made by flow band (Table 17). There is less difference than in GB between the rates for the roads managed by the different authorities. The highest quality high flow roads have lower rates where managed by the state, but for some other combinations of design type and flow rate, the accident rates on the provincial roads are lower than those on the state roads.

AADT Flow	**Motorway**	**Preferential roads – undivided with at-grade junctions**	**Ordinary roads undivided with at-grade junctions**
0-5,000	-	-	1.6
5-20,000	0.6	0.8	1.0
20-50,000	1.6	-	-
> 50,000	1.6	-	-

Minimum of five routes in each group compared

Table 17 Ratio of risk rates (fatal and serious accidents per vehicle km) on provincial roads and State roads in Catalonia

4.8.3 Dutch provincial roads

Data for non-national roads are compiled by some individual Dutch provinces on a fairly detailed basis, but so far the accident data, traffic data and road inventory data are still on separate databases and with the resources available to the programme we have found it impossible to combine these into a database that will provide route data for these roads in a form suitable for EuroRAP analysis. It is understood that a programme is in place to produce combined databases but this is unlikely to be completed before 2006.

4.9 Desirability of extending to other countries

The future EuroRAP programme anticipates expanding the database to additional European countries. In due course it is desirable to include all the countries of Europe within the programme.

At a technical level, it will be useful to expand the coverage to include:

- Countries with different average accident rates;
- Countries with different levels of safety strategy;
- Countries where infrastructure and behaviour influences provide differing effects on the national accident total.

In this way, the methodology for comparing between countries can be tested more fully to ensure that it correctly picks up these differences, and the influences of different ranges of factors can be explored more extensively. In particular, it would be of interest to bring some central European countries into the programme, to assess their data systems, and to investigate the programmes best suited to improving their infrastructure.

5 REFINING ROAD PROTECTION SCORE

A scoring system was developed in the pilot year which defined four levels of "design" for the roadside features mainly affecting each of the four main accident types associated with rural roads. The aim of this process was to help understand how deficiencies in the road infrastructure contributed to the variation in accident rates identified through analysis of the accident databases.

During 2003, this scoring system has been given more prominence in the overall assessment process, and therefore a more robust scoring system has been sought, underpinned by estimates of risk differences between the design levels. Initially this has focussed on the passive safety of the roads, ie the ability of the infrastructure to limit injury severity when accidents occur. But a conceptual framework for the system has been sought which will allow future development to encompass also the influence of design on the likelihood of accidents occurring.

Developing the approach

- **Stage 1: Recording current design in relation to broad safety principles**
- **Stage 2: Developing risk tables for injury consequences related to different design choices**
- **Stage 3: Extending risk tables to include probability of accidents occurring as well as potential injury outcome**

5.1 Purpose and use – mass action, with maps, interpret sources of risk

The scoring system is designed to assess routes which might be up to 50kms in length. Its purpose is not to highlight local sites of inflated risk but to assess the overall standard of the route. The route lengths are chosen to cover road sections that are largely built to the same general standard, but they still include considerable variation in design particularly where they pass through built up areas. The scoring system is therefore built up by weighted combination of scores for shorter sections. The deficiencies that lower overall scores will highlight will be general to the route or to large parts of it, and therefore likely to be susceptible to mass action measures applied either consistently over long lengths of the route or regularly at particular types of site along the route.

As currently presented, a high (safer) score will not necessarily reflect a low accident rate as only part of the risk is being scored. But it should demonstrate that for a given number of accidents, a lower proportion of them will result in fatal or serious injury. The highest protection score reflects a situation where few or no fatal injuries should occur. The protection score should therefore be used in conjunction with the information from the accident database to fully understand the safety performance of the road.

5.2 Risk assessment approach

The use of a risk matrix is a technique commonly used in risk assessment . It enables total risk to be seen as the combination of the likelihood of an event (accident) occurring, and the resulting potential consequence (injury severity). Total risk can be reduced by reducing the effect of either factor alone, or of both together, as shown in Figure 13.

To use this approach in the RPS, we need to define the component factors which contribute to the variables on each axis, and assign them a risk relative to each other.

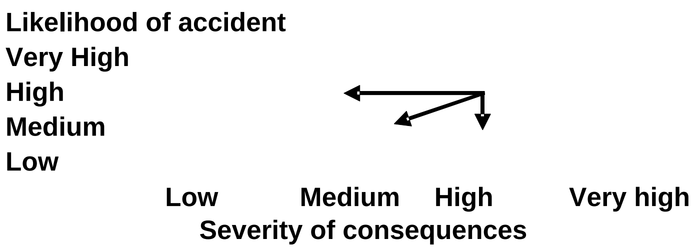


Figure 13 Risk matrix

Separating out the risk into two major components in this way is a useful approach as primarily only the injury consequences are to be targeted in the first version of the RPS, but it does also bring with it difficulties of interpretation which are discussed below.

5.3 Potential factors

The factors used for the RPS need to be identifiable through visual inspection. The areas of the roads that are assessed are those corresponding to the four accident types (head on collisions, single vehicles leaving the road, intersection accidents, and accidents involving vulnerable road users) that, together, have been shown to be associated with the majority of fatal and serious accidents on rural roads. These same areas can be identified and inspected for all types of road (Figure 14).

There also needs to be some direct evidence of the effect of these road features on accident rates, on which to give the features individual risk scores. Although it is desirable to separate the factors into groups representing accident likelihood and injury consequences, this is not straightforward as some design features clearly influence both components. For example, one effective means of reducing both the number and severity of accidents resulting from leaving the road is to provide a hardened area at the road edge outside the normal running lane.

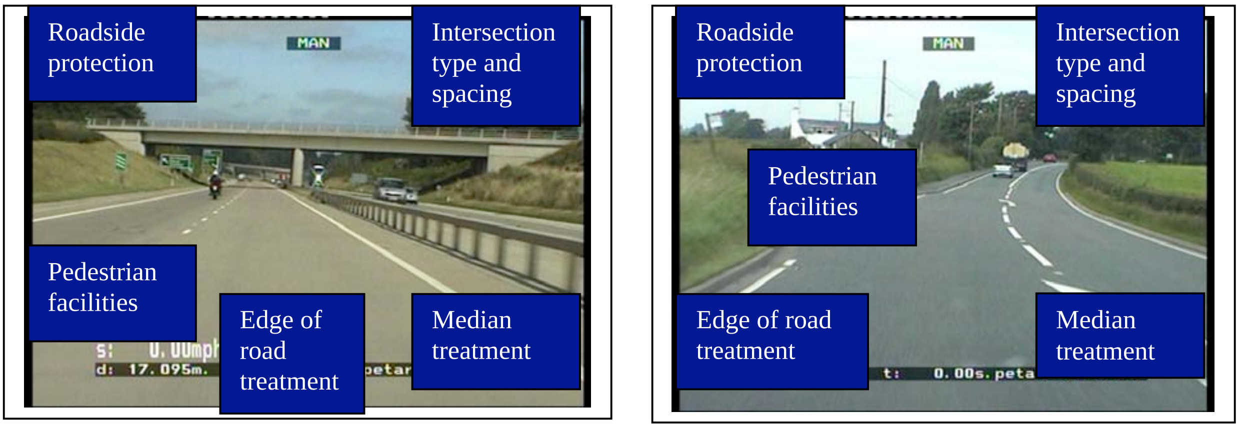


Figure 14 Areas of road which are inspected for developing the Road Protection Score

An important factor in both dimensions is vehicle speed. This has been treated as a separate variable and the risk tables have been developed for a range of different speeds. The relationship assumed between speed and accidents is that observed in accident outcomes, which includes any driver action to reduce injury severity. The speed limit for the road is assumed to represent the speed of the traffic unless there is evidence that most drivers adopt a different speed.

5.3.1 Use of biomechanical forces reflecting vehicle secondary safety

EuroRAP aims at assessing the road infrastructure contribution to overall safety – this overall safety reflects the interaction of the road, the vehicle and the road user's behaviour. The initial focus on scoring the passive safety of the road allows a direct link to be made with vehicle safety assessment by considering injury severity in both cases as a function of the biomechanical forces involved in the impact. To make this link, minimum relative risks for the RPS rating are based on the speeds at which car occupants can be expected to survive an impact in a car rated highly in EuroNCAP.

For example, vehicle safety tests for occupant protection in head on impacts are typically done at about 70km/h. A five star EuroNCAP car will protect occupants from the severest injuries at this speed. Thus for the head on accident ratings considered in the RPS, minimum relative risk has been assumed for roads with speed limits of 70km/h or below. For intersection accidents, which can be equated to occupant protection in vehicle side impact tests, a minimum relative risk has been assumed for impacts likely to occur at 50km/h or below. The link for run off accidents is less clear as occupant protection will depend on the nature of the obstacle hit. For these accidents, minimum relative risk in the RPS ratings is currently assumed at 50km/h or below.

For impacts with pedestrians, it is well established that fatalities are likely to occur at impact speeds above 30km/h. The implication of this is that pedestrian and vehicle movements would need to be segregated on any roads with higher speed limits, in order to gain maximum RPS ratings for this accident type.

5.3.2 Scope for accident likelihood factors

In many situations the speed of the impact may be moderated by driver behaviour even in situations where the speed limit of the road is well above that corresponding to minimum relative risk. Where the road design allows the driver to achieve this (by braking or by steering away from the obstacle) once a potential accident situation has arisen, this has been allowed for to some extent in the current RPS scoring.

But the driver can also moderate the likelihood of the accident occurring by adopting a lower speed through being aware of local hazards, and thus avoid a situation where he may lose control of the vehicle. The road designer can provide the driver with many clues, either directly through signs or road markings, or indirectly through road alignment and environment, of the appropriate speed to be adopted at specific locations along the route. The RPS could therefore be further refined to include the influence of these elements of road design within the rating.

Until this is done, the RPS largely measures the passive safety of the road, ie the protection provided by the road assuming only minimum contribution of the driver to his protection. This reflects the situation where the driver has already lost control of the vehicle, for example, through illness, sleep, or vehicle failure. Thus a median lining system which either requires or encourages drivers not to cross it is given no higher score in the passive protection rating than a road with no central delineation. This reflects the fact that a driver who crosses the central line by mistake has no greater protection in the former situation than in the latter. Also in the current version of the RPS, a hardened strip at the road edge, outside the running lane, is only scored as giving additional protection equivalent to the extra distance a driver has to travel before hitting an obstacle.

But clearly it is to be expected that the total number of accident situations arising will decrease where these measures are taken, even if the proportion of them ending in fatal or serious injury is not reduced. Additional ratings could be added to a later version of the RPS to reflect greater levels of driver involvement in responding to road design by avoiding potential accidents. If these effects could be fully taken into account, then the RPS should potentially match the total accident risk along the route, and directly relate to the total numbers of fatal and serious accidents on a route. An accurate estimate of fatal and serious accident numbers from this RPS would also require an estimate of the proportion of drivers who took avoiding action of various types. Factors such as these would make up the vertical axis of the risk matrix, and collectively would equate to the probability that a driver lost control sufficiently to make a collision unavoidable.

This approach could be used to provide a measure of collective risk through the RPS rating, by also including traffic flow within the factors contributing to the likelihood of accidents occurring.

5.3.3 Behaviour within a passively safe road system

Although the RPS describing the passive safety of the road does not take account of direct driver intervention in avoiding loss of control or impact with obstacles, it does assume limits to acceptable behaviour. Thus the starting point which links road performance with vehicle safety systems assumes that the vehicle occupants are correctly using the vehicle restraint systems. Similarly by taking the speed limit as the speed against which the road is rated, the score is only appropriate for drivers who keep within these limits.

5.4 Factors recorded - methods of data collection

The factors recorded for the road protection score are described in the pilot protocol on defining factors to be scored (EuroRAP 2003).
Data are collected by visual inspection, either in real time as the road is driven or subsequently from the video record of the drive. Data can be recorded directly into computerised databases from which the RPS can be calculated.

5.5 Approach to scoring

The scoring process is described in the pilot protocol on scoring methods (EuroRAP, 2003) The main RPS is based on scoring separately the protection provided in relation to the three accident types (run off road, head on impacts, and severe impacts at intersections), and then combining their scores into an overall score. The combination of the component scores is weighted in proportion to their average occurrence across a range of European countries. A second RPS for each road is envisaged for protection provided to vulnerable road users, but that requires further development.

The score for each accident component is based on a family of risk curves reflecting the speed limit for traffic on the road and the potential variations in road design relevant to that accident types. These are illustrated in Figs 15 to 17. The variation in risk assumed between different treatments is based on engineering judgement and reported accident outcomes from various international reviews. Data available in these reports typically refer to a specific measure applied under a specific combination of conditions, so a substantial degree of subjective judgement has had to be used in compiling sets of curves. Trials of these proposed scores regimes may enable improved assumptions to be made.

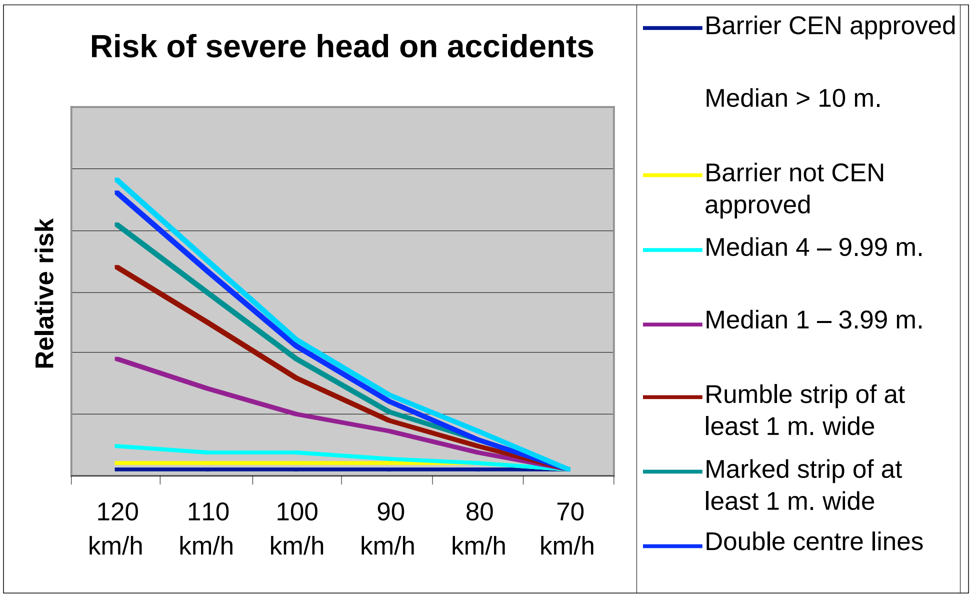


Figure 15 Assumed relative risk of fatal and serious head on accidents by speed and by median treatment

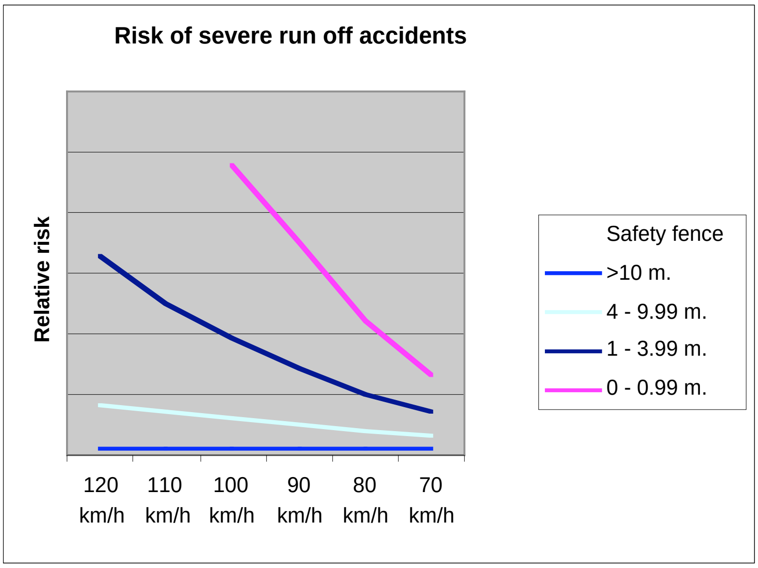


Figure 16 Assumed relative risk of fatal and serious run off accidents by speed and edge of road treatment

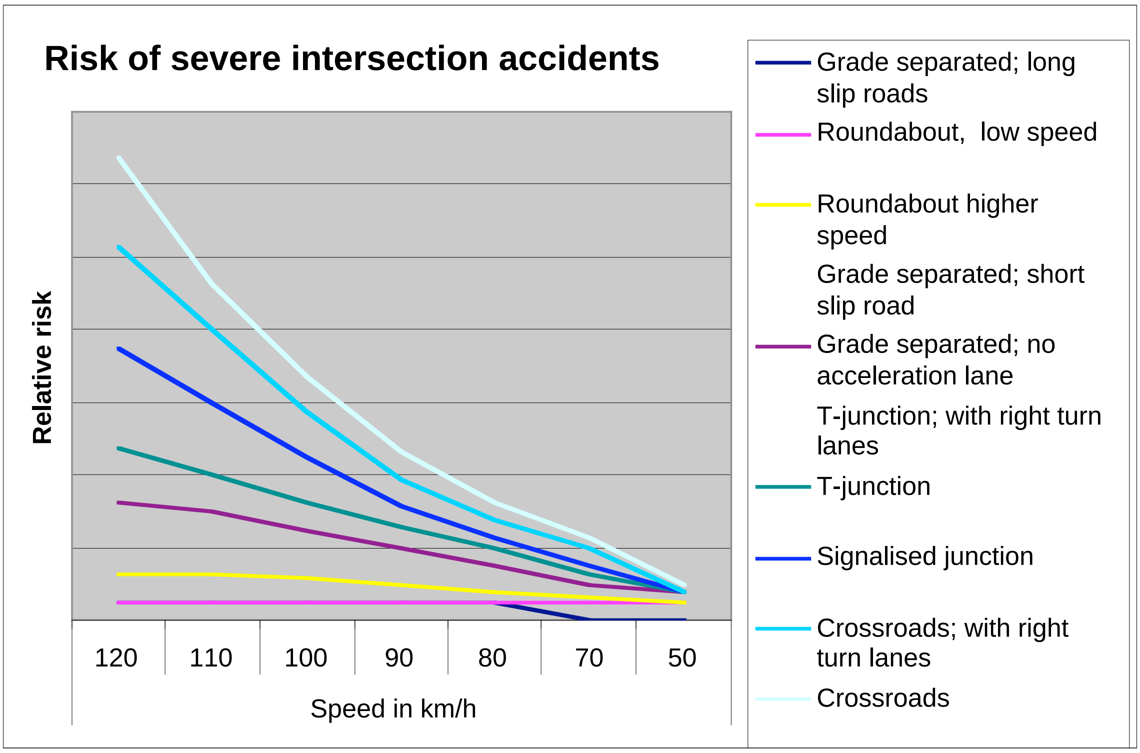


Figure 17 Assumed relative risk of fatal and serious intersection accidents by speed and intersection type

5.6 Examples of scoring

Fig 18 gives examples of road environments and the scores given for median, roadside or intersection treatments for these sites.

Median 2; Runoff 1; speed 90km/h

Median 2; Runoff 2; speed 80km/h

Median 3; Run off 4; speed 80km/h

Median 4; Run off 4; speed 90km/h

Intersection 4; speed 80km/h

Intersection 1; Speed 80km/h

Figure 18 Examples of scores for a sample of road environments

5.7 Results

A total of 60 routes have been selected from the video inspections of seven countries. The routes were selected to provide a variety of road types in each country. The purpose of the analysis is to demonstrate typical scores for different road types, and to give an indication of how these scores varied within a country and between countries. A very much larger sample of roads would be needed to begin to reflect performance differences between designs in different countries, but even these indicative scores can be used, with the accident rate frequency distributions, to help further understand the role of road infrastructure in contributing to the total accident risk in each country.

In principle, once sufficient routes have been inspected and scored, these data could be used as a further safety indicator. A distribution of the Road Protection Scores, similar to those used to describe the distribution of accident rates, might provide the basis for comparing both average scores and variation in score. It is likely that some countries with relatively high accident rates may have relatively good Road Protection Scores. This would suggest that factors other than infrastructure design were responsible for the inflated accident rates. This should be mirrored by seeing relatively low variance in the distributions of accident rates in these countries, as discussed in section 4.5.4.

5.7.1 Typical scores for road types in different countries

Fig 19 shows the range of scores across all countries for divided and undivided roads. The distributions overlap; relatively high scores can be obtained for the undivided roads where the traffic speeds are lower and some physical separation of the opposing traffic streams is attempted. Note these are scores based on potential protection; this only one of the factors contributing to the expected total number of fatal and serious accidents.

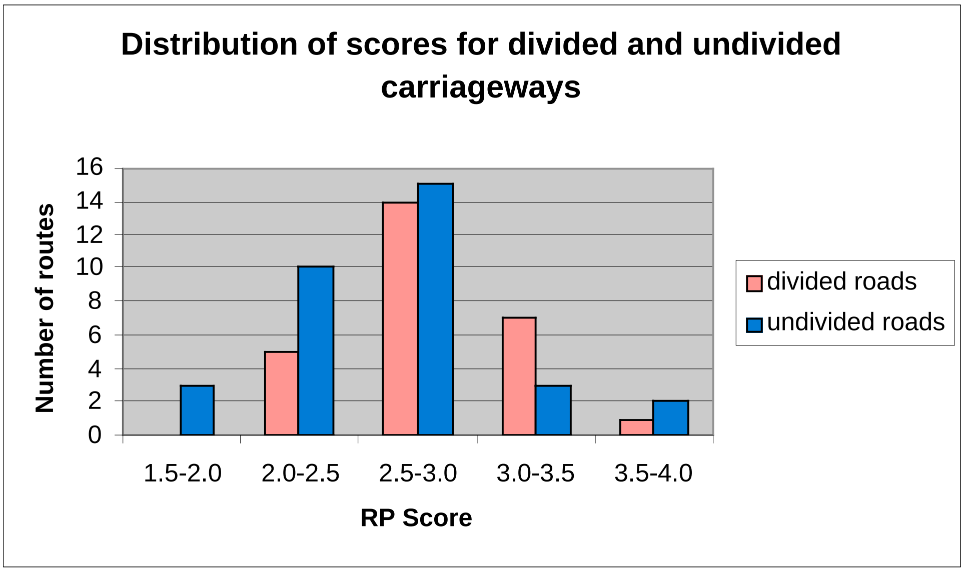


Figure 19 Distribution of Road Protection Scores for a sample of divided and undivided roads

The overall distributions are made up of a sample of roads drawn from different countries. Fig 20 shows which divided route scores related to each country surveyed. These do NOT reflect the overall quality of this type of road in that country, but they do suggest that even with this small sample, significant variation in scores can be identified within each country. Although the sample is very small at present, it is likely that the Dutch roads in this sample are scoring more highly due to their lower (80km/h) speed limits and their work on experimenting with low level median obstructions.

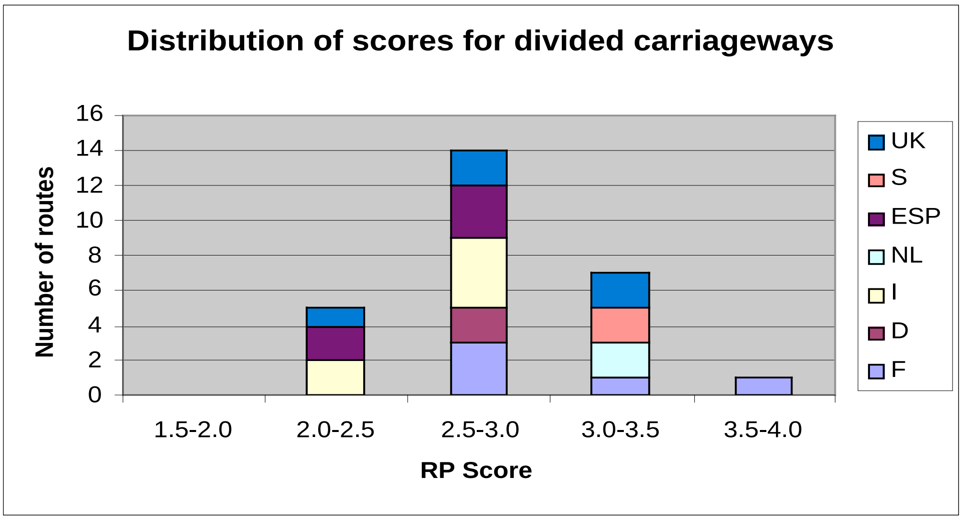


Figure 20 Countries in which individual routes were scored (sample not representative of all roads in that country)

5.7.2 Variability between roads (examples of higher and lower scores)

Figs 21 and 22 show how the overall scores have been affected by the component scores for divided and undivided roads. The scores are for substantial parts of each route. The run off and head on scores are averaged from individual score band ratings for each km along the length scored. The intersection scores are compiled from numbers of intersections of each type multiplied by a rating for each intersection; an integer band rating is given for this overall score.

Most of the divided roads (Fig 21) were given maximum scores for protection against head on accidents, reflecting the well designed medians. Many also scored well for intersection risk, reflecting the general use of intersections involving only merging manoeuvres, although in some cases, the score was lower either due to the merging manoeuvres not being allowed sufficient length of acceleration lanes, or because the intersections allowed many more conflicting manoeuvres. Most of the roads however scored poorly for run off protection, reflecting the fact that serious accidents are likely to occur unless very wide safety zones or barriers can be provided.

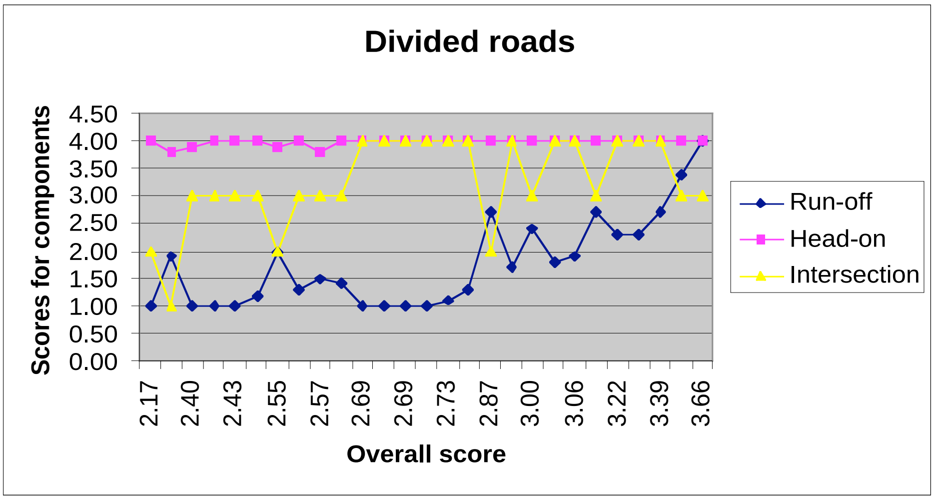


Figure 21 Variation in component scores for divided roads

Fig 22 shows that for single carriageways there is more variability in the designs and the resulting protection from injury. The lowest scoring roads generally scored poorly for all three accident types. Across the middle range of scores, protection against all three accident types had improved. The highest scores reflected particularly the Dutch median treatments, but scores close to the maximum for each accident type were scored in some roads.

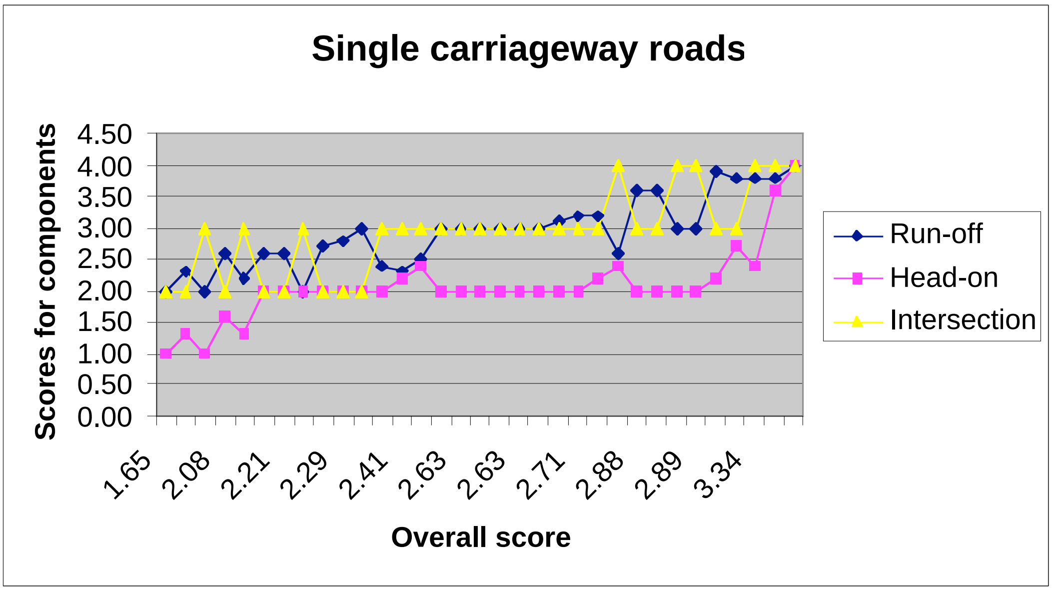
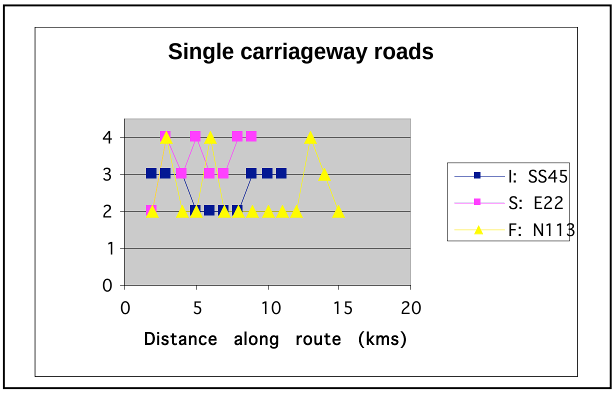


Fig 22 Variation in component scores for undivided roads

5.7.3 Variability along routes

The scores for routes have been built from scores for individual parts of the route, typically some 2kms in length, so it is possible to examine how variable the score is along the route. While many routes score fairly consistently along their length, Fig 23 shows that some routes can be identified where scores vary considerably along their length, particularly in run off score. Although the aim is still to focus on the overall quality of the route, it is possible with this level of data recording to identify those sections of the route which are performing less well than the average.



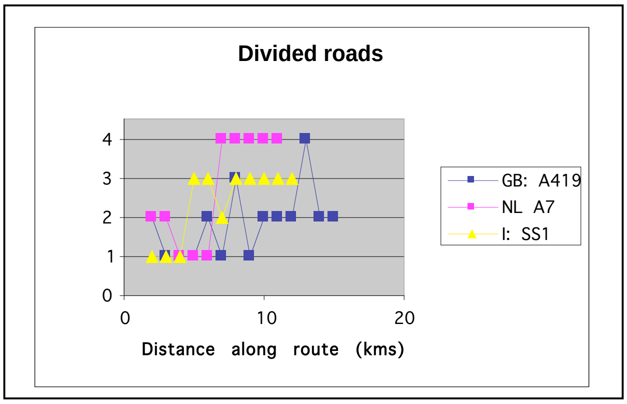


Figure 23 Variation in run off scores along a sample of routes

5.8 Use of Road Protection Score assessments

The Road Protection Score indicates the way in which accidents that happen are likely to result in severe injuries. Scores for the three main accident types indicate where an accident involved vehicle occupant is vulnerable to injury in each accident type. This shows whether, and to what extent, protection is provided from known sources of injury risk on different types of road for the speed traffic are allowed to travel along those roads. In its current form the RPS does not include the likelihood of an accident occurring. This means that it only reflects one factor contributing to the total numbers of fatal and serious accidents on a specific route.

The results highlight the fact that on many roads there is substantial scope to improve the potential for injury protection, and that fatal accidents will not be minimised unless this is done. Even many motorways, which are the safest roads in all highway networks, do not necessarily score the full four stars – usually due to the scope remaining for serious injuries resulting from vehicle run offs. British accident data show that around half the risk of fatal and serious accidents on motorways arise from shunt or lane changing accidents that primarily result from close following behaviour or poor lane keeping. These cannot be easily affected by road design and are therefore not included in the RPS. Of the other 50% of fatal and serious accidents, almost 20% arise from single vehicle run offs.

On other divided roads, scores for run off accidents can also be relatively low. On these roads too, particularly in Britain, scores are reduced by the incidence of access from side roads without sufficient acceleration lanes to allow safe merging when main road flows are high. On ordinary 2-lane roads, despite the lower speed limits adopted, protection is often limited by narrow safety zones and poor access provision as well as by the lack of separation of opposing traffic streams. Some good examples of median treatment of the roads can be seen in Sweden and the Netherlands.

There is a general need to find ways of providing better protection in all these areas at reasonable costs if large scale affordable networks are to be provided which can cater for desired traffic speeds without resulting in fatal or serious accidents. Highlighting this need through the RPS should encourage innovative experiments, which can capitalise on the potential cost savings from large scale investment in mass action treatments. At the same time, there is a need to focus on mitigating serious injuries through adopting lower speeds at sites and along routes where risk is particularly high, until higher levels of protection can be provided that will enable higher speeds to be adopted safely.

6 INTERPRETING RESULTS

6.1 Road networks to which results refer

The aim of EuroRAP is to cover national road networks within which at least 30% of the national total of fatal road accidents occur. This generally requires a substantial proportion of two lane roads, often managed by regional highway authorities, to be included as well as the national road networks. The exception is the Netherlands where 40% of the traffic occurs on the dense network of motorways, and where the current EuroRAP network is limited to the national network.

Route lengths within the EuroRAP networks typically average around 20kms, but many of the links are much shorter. The average number of fatal and serious accidents included in the assessment of a route risk rate varies between 16 in Spain to 25 in Britain, but is only 5 in Sweden, despite the use of many long route lengths, as a result of the generally low density of accidents on the Swedish network. Comparison between years has demonstrated that for most networks apart from Sweden, the estimates of risk rate remain reasonably stable over time on most routes.

6.2 Comparison within and between countries

The primary aim of EuroRAP is to provide a means of benchmarking the safety of routes within highway networks to highlight where remedial action may need to be taken to improve network safety. Comparisons are made between roads of similar types, both within and between countries. Non-motorway roads are also compared on the basis of the traffic function they perform. Within countries, relating the risk rate on a specific route to the overall distribution of risk rates shows where risk to individual drivers is high.

Between countries, distributions can similarly be used to compare either roads of similar type or similar flow function. But these comparisons will reflect not only differences in infrastructure standard but also differences in driving behaviour between countries. To minimise this latter effect, distributions of rates as a function of the mean rate in that country can be compared. The spread of this latter distribution indicates whether roads of a similar type are performing to a similar standard within a country, relative to the variation found in other countries.

The comparisons described so far relate to the risk for individual drivers on these roads. To indicate more clearly where road authorities might concentrate their investment, it is important also to assess the accident savings that can be achieved at reasonable cost. In parallel therefore, comparisons are also given of the lengths of road with different numbers of potential accidents that might be saved in each country. The return on investment in a particular country will depend on the cost of the measures in that country band the value they attach to their accident savings. For the estimates given in this report, an improvement to the average accident rate for each road traffic function in each country is targeted. An alternative would be to target rates associated with the best roads in each country.

The performance of different road types relative to each other in each country provides a further basis against which to assess the relative standards of roads in each country. Motorways in Britain and the Netherlands perform well in comparison with other divided roads in those countries, whereas in Sweden and Spain the differential is less marked. Rates for two lane roads, relative to those for divided roads, are higher in Britain than in the other countries.

EuroRAP data are now available for more than one time period in some countries, and changes in rates can be tracked over time both in terms of the average rate across the network and the relative changes in different parts of the national risk distributions.

6.3 Potential road improvement programmes

The Road Protection Score adds to the understanding of the accident data by highlighting the road features which fail to prevent deaths or serious injuries when accidents do occur. This provides a focus for road improvement programmes to reduce injury outcomes, and also enables road users to understand more clearly the sources of risk on different roads.

By highlighting the extent of the change in environment needed to avoid the most serious injuries, the rating of roads by road protection score encourages the development of innovative median, roadside and intersection treatments that would minimise serious injury risk. The protection scoring system is closely linked to vehicle speed, and demonstrates that an appropriate balance between speed and road design can produce high levels of protection on most road types.

6.4 Use of results

By bringing together estimates of both individual risk and the potential accident savings from road improvement, based on the same database, EuroRAP enables risk to be understood from several viewpoints and provides a basis for dialogue between road authorities and the public. This dialogue can cover what levels of risk are acceptable, what investment is appropriate to achieve these risk levels, and how drivers can minimise the risk on those roads where roads cannot be improved to eliminate all risk of fatal accidents.

EuroRAP analyses should be made in parallel to those that focus on more local road improvements to reduce risk at individual hazards. These latter programmes are very cost effective and should continue to be a priority where high returns can be obtained. EuroRAP analyses are more similar to route management programmes, but they extend the focus of these programmes to the long term improvement of network quality. In particular they can be used to set an agenda for targeting future safety standards, and therefore help define the total investment directed to this objective. EuroRAP therefore complements existing programmes rather than substituting for them, and sets an overall context within which specific improvement programmes all have a role.

The road inspection programme being developed as part of EuroRAP provides one option for road safety audit of existing roads. It would enable these audits to be underpinned by risk tables, but the risks being audited focus on mass action treatments throughout the route, and in the current form relate only to injury protection. They would need to be extended to cover all features contributing to accident risk along a route.

Overall, EuroRAP data provide a means for road authorities and the public to understand the relative risks on different roads within a country, and plan investment programmes and driving behaviour accordingly. Bringing together data from many European countries will help the transfer of good practice between these countries, and provides a good basis for monitoring infrastructure safety at European level.

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Road Protection Score Handbook beta version

Comparison of fatal and serious accidents over road lengths – descriptions of how accident rates vary by high-level design factors

Methodology in developing networks – criteria for the selection of road sections and their formation

Technical appendix – completion of the 2003 programme and fulfilment of the European Commission grant agreement requirements

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Dr Norbert Klassen (Allgemeiner Deutscher Automobil Club, Germany)
Dr Steve Lawson (AA Foundation for Road Safety Research, UK)
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