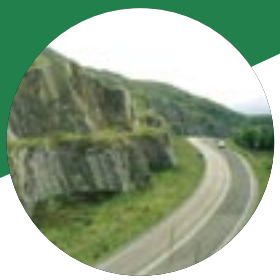
STAR RATING EUROPE'S ROADS FOR SAFETY



Star rating roads for safety

UK trials 2006-07

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IAM motoring trust

HIGHWAYS AGENCY

EuroRAP
EUROPEAN ROAD ASSESSMENT PROGRAMME

www.eurorap.org

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FOREWORD

Star rating roads to show how well or badly they would protect car occupants from severe injuries is the most innovative and exciting road safety development in recent years. There is the potential for highway authorities to have safer roads and for road users to drive and ride more safely:

- road authorities that systematically assess their roads will know how well or badly they will perform when a crash happens, and so can identify and plan where improvements would reduce injury severity
- road users who understand that their risk of being killed or seriously injured changes with star rating from one road section to the next will be better informed and enabled to make safer choices

Rural main roads were the focus of this study. Recent IAM Motoring Trust research* showed that: two-thirds of all road deaths in Britain happen on rural roads; single carriageways claim 80% of rural deaths and serious injuries; and 40% of rural car occupant casualties are in cars that hit roadside objects, such as trees.

Our rural roads urgently need systematic assessment and investment to make them safer. But safer roads also demand that drivers and riders have rural road skills, that they take individual responsibility to drive safely, and that they understand where, when and why they are most at risk. The fact that a third of all rural fatal and serious injury casualties are in cars with drivers under 25 brings into question whether our urban-focused driving test is equipping new drivers with the skills and knowledge to negotiate the rural road environment safely.

Thought is now being given to post-2010 national casualty reduction targets. The IAM Motoring Trust believes that tackling rural road safety should be a priority, with particular focus on:

- a programme of assessments and investment to target unsafe roads and raise standards of crash protection
- establishing criteria for setting and enforcing speed limits that have risk of death and disabling injuries at their head, and reviewing all rural speed limits to those criteria
- the need to ensure that the revised training and testing regimes being developed adequately equip drivers and riders for rural road conditions where they and their passengers are most at risk
- educating already qualified drivers and riders to understand the level and nature of the risks of using rural roads
- developing the growing science of ‘crash protection’ to give authorities the tools to act

We would like to hear your views on what should be done. Please contact us at info@iamtrust.org.uk

**Rural roads – the biggest killer (www.iamtrust.org.uk)*

CONTENTS

TRL was commissioned to develop a protocol for undertaking Road Protection Score (RPS) surveys in the UK that is both compatible with the protocols currently being developed by EuroRAP and iRAP (International Road Assessment Programme) and applicable to conditions on UK roads.

EuroRAP AISBL is an international not-for-profit association formed by European motoring organisations and leading road authorities to work together for improvements to the safety of Europe's roads. It is a sister programme to EuroNCAP which crash tests new cars and awards them stars for safety. EuroRAP has members from more than 20 countries and is affiliated to iRAP where global assessment techniques are being devised in partnership with programmes in Australia (AusRAP) and the US (usRAP). EuroRAP is enabled in the UK by the Road Safety Foundation.

EuroRAP has three protocols. Risk Rate Mapping rates the safety performance of the road based on its existing collision history. Performance Tracking rates the performance of road sections over time, based on collision history. The Road Protection Score rates the safety of a road based on how well its design would protect a car occupant from severe injury in the event of a collision. On the basis of this score, each road is given a star rating varying from 1 to 4, with 4-star representing a road which is engineered to minimise the likelihood of a crash resulting in a fatal injury to car occupants.

Any collision is the result of a combination of multiple factors and it is not possible to reflect accurately all of these factors in the development of a protection score protocol. The current RPS scoring system is based on the following three factors:

- the design of the side of the road
- the design of the median
- the design of junctions

In total, a route of over 7000km was surveyed, including 2350km of Highways Agency network. The route was chosen to provide a sample across as large a proportion of road types as possible. The chosen route contained a mixture of Highways Agency and non-Highways Agency roads, motorways, dual carriageways and single carriageways. The route covered roads in England, Scotland, Wales and Northern Ireland; these were selected in consultation with the national highway agencies in these countries. The route was also chosen to provide a selection of roads with different star ratings based on the EuroRAP 2003 risk map, and was planned to cover as much of the TERN network as possible.

The results were recorded in a database for all the routes surveyed, and a set of maps showing the comparative star ratings for each route.

Overall scores for motorways are significantly higher than for Class A roads, however 2% of motorways scored less than 3-star. 42% of A roads scored as less than 3-star.

Nearly 1% of Highways Agency motorways scored less than 3-star. Almost 51% scored 3-star and 48% scored 4-star. Over three-quarters of Highways Agency A roads scored 3 or 4-star compared to just over half of A roads generally. English non-Highways Agency A roads score fairly poorly with nearly two-thirds scoring less than 3-star, compared to 42% generally. However these figures include the network of roads that are below the EuroRAP network.

The sample of motorways in Scotland scored well, with over 85% scoring 4-star and less than 1% scoring less than 3-star. The ratings for Class A roads were very similar to the overall rating, but with a higher percentage, 17%, achieving 4-star.

The majority of roads surveyed in Wales were included in the pilot survey and were selected to investigate specific issues. As a result, the figures achieved for Wales are unlikely to be representative of the overall network. Despite this fact, Welsh motorways scored fairly well with over 60% achieving 4-star and no sections scoring less than 3-star. 54% of Welsh Class A roads scored 2-star, probably reflecting the selection criteria for the Welsh sample.

In Northern Ireland, 76% of motorway scored 3-star and 13% were 4-star. 81% of A roads scored less than 3-star. The scores for Class A roads reflected in part the proportion of dual carriageways in each sample.

Examples of roads with high and low scores, in total, and for the three individual accident types are given in the report.

An important aim of the RPS is to provide information that is not readily available through accident histories. Accidents are always random and accident rates subject to statistical fluctuation. Over time as accident numbers decrease, identification of higher risk sites through variations in observed accident numbers will become more difficult. The RPS aims to provide a consistent assessment of the potential long-term risk of a given road design.

While the ability to isolate the infrastructure component of risk from variations in driver behaviour is a considerable strength, it means that there is no simple way to validate the inspection scores completely through accident data. Nevertheless, comparison of RPS ratings with observed accident rates show a good degree of consistency, and suggest the extent of accident savings that could be achieved by upgrading roads in different ways. A large proportion of the fatal and serious accidents still occurring on roads rated as 4-star can be seen to be associated with HGVs or vulnerable road users.

The RPS is primarily a tool for assessing how well roads are meeting standards that maximise injury protection, and assessing the potential savings in accidents that could be achieved if roads are improved where they fall below the defined standards. The RPS results could be used at several different levels to complement existing network analysis tools:

- to assess overall standard of network
- to identify overall routes for treatment
- to identify sections within routes

The report shows how data from the scores might be used to extend the current Highways Agency methodology for identification and prioritisation of roads where improvement is justified. The approach is data-led and uses intervention levels to trigger action. The RPS thus potentially adds to current methodology by providing additional criteria for setting intervention levels and by helping to prioritise actions on broader criteria than accident density alone.

Proposals are included for further work to improve the rating system, extend the survey to all Highways Agency roads, and provide guidance on its use by local engineers.

1. INTRODUCTION

1.1 Methodology of RPS inspection process

TRL was commissioned to develop a protocol for undertaking Road Protection Score (RPS) surveys in the UK that is both compatible with the protocols currently being developed by EuroRAP and iRAP (International Road Assessment Programme) and applicable to conditions on UK roads.

EuroRAP AISBL is an international not-for-profit association formed by European motoring organisations and leading road authorities to work together for improvements to the safety of Europe's roads. It is a sister programme to EuroNCAP which crash tests new cars and awards them stars for safety. EuroRAP has members from more than 20 countries and is affiliated to iRAP where global assessment techniques are being devised in partnership with programmes in Australia (AusRAP) and the US (usRAP). EuroRAP is enabled in the UK by the Road Safety Foundation.

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Any collision is the result of a combination of multiple factors and it is not possible to reflect accurately all of these factors in the development of a protection score protocol. The current RPS scoring system is based on the following three factors:

- the design of the side of the road
- the design of the median
- the design of junctions

The RPS does not directly take into account the likelihood of a collision occurring, and assumes that drivers are driving within the law (for example, restrained, sober and not exceeding the speed limit) and are in a 4-star EuroNCAP-rated car.

More details on the development and history of EuroRAP can be found at www.eurorap.org

1.1.1 Background

It is important that the protocols developed for the UK are consistent with those currently in use within Europe and also those being developed for wider use by iRAP. For this reason it was decided to undertake UK survey work in two parts. The first (pilot) survey was carried out using existing techniques used elsewhere in Europe. The results of this survey were then analysed and the results are detailed in section 1.2 of this report. The second survey drew on the results of the first survey to ensure that the information gathered and the results obtained were appropriate for use on UK roads.

To ensure consistency with current European practice, the German motoring club (ADAC), which had carried out surveys in Germany, was appointed to carry out both the initial survey and the main survey, and the consultants (SWECO), which initially developed the RPS software for use on the Swedish surveys, undertook the initial analysis of the results using the FIKS data system. The initial survey was conducted between 12 and 25 November 2005. The second survey was undertaken between 12 October 2006 and 15 December 2006. Maps from the survey results by ADAC are included in Appendix A. A fuller report is available at www.iamtrust.org.uk and www.eurorap.org.

The information collected during the surveys is gathered via a digital tablet. The tablet was initially developed in Sweden and further developed for use in Germany. For the initial UK survey the tablet was altered to investigate issues that were specific to UK road conditions. For the second survey, the tablet was further altered to allow collection of additional features detailed in section 1.1.3 below. The overlay for the tablet is shown in Figure 1.

Figure 1 - Tablet overlay

1.1.2 RPS protocol used

The development of how and why various elements are scored and weighted in the overall RPS score has been undertaken by the EuroRAP technical committee. A summary of the principles involved is given in Lynam *et al.*, 2003.

In brief, the RPS has been developed to assess how much or how little protection a road environment will provide the occupants of a car should they become involved in a collision. Collisions result from a multi-factor event and it is not possible to take all of these events into account when developing a model such as the RPS. Therefore, in the development of RPS, it has been assumed that drivers are driving within the limits of the law i.e. not speeding or drink driving, and that they are driving a 4-star Euro NCAP car.

There are three basic categories of collisions that can be affected by elements of the road design; **head-on** – influenced by the design of the road median, **run-off** – influenced by the design of the side of the road, and **intersection** – influenced by the design of the junctions. The relative weighting to be applied to each of these collision types represents an average European collision type distribution agreed by the EuroRAP technical committee, and is shown in Figure 2 below.

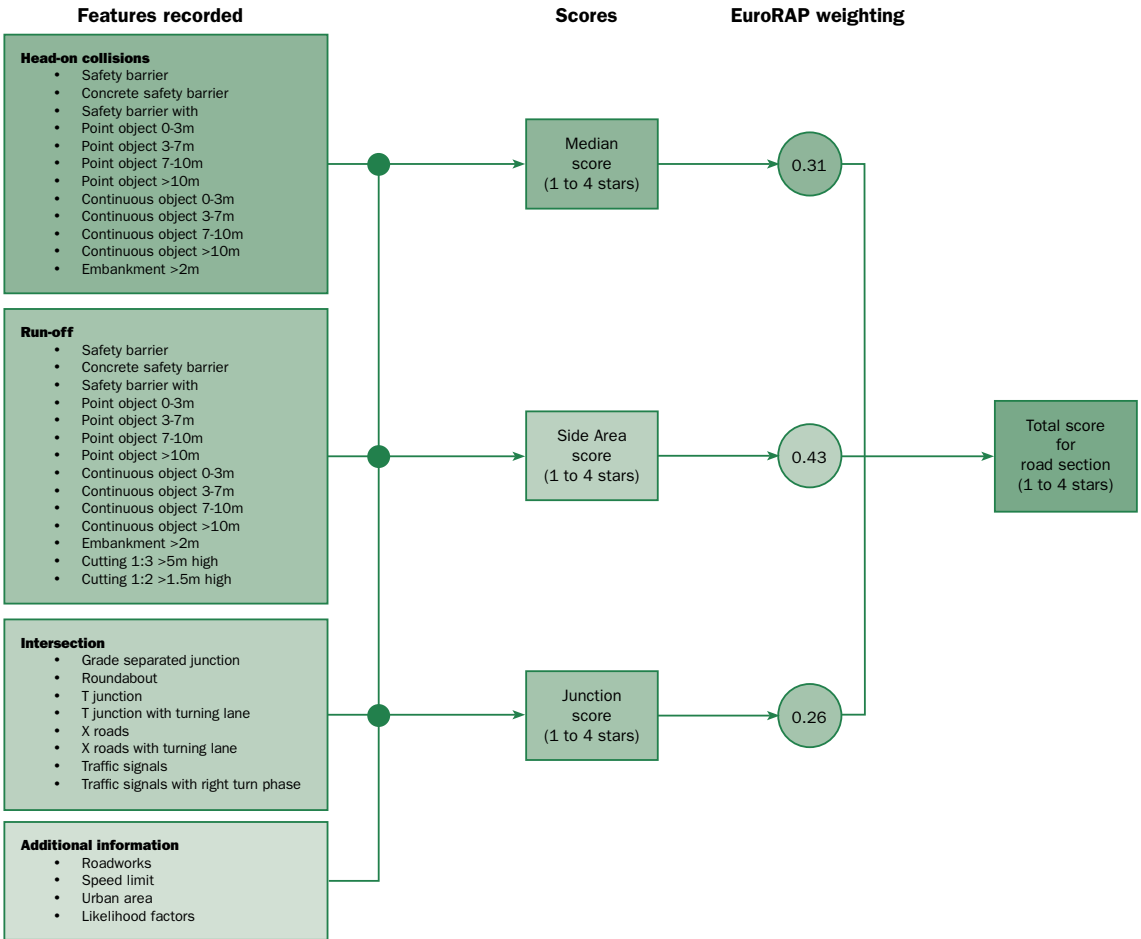

Figure 2 - EuroRAP weightings

For head-on and run-off crashes, the influence of aggressive objects (point and continuous) is calculated from the likely severity of an injury that would occur should the object be struck. It also incorporates the distance from the edge of the running lane, to allow for driver reaction and speed at impact. Junctions are rated on the likely angle of impact and the differential in speeds between two vehicles involved in a crash. The presence of turning lanes to protect turning vehicles from through traffic is also taken into account. The junction score for a link takes into account the number and quality of the intersections.

The opportunity was taken during the first UK survey to record information on some additional factors that might be relevant to estimating risk on UK roads that could be analysed at a later date. The additional information collected included:

- central hatching
- presence of 1 metre hard edge strip

In the period between the first and second surveys, significant development work was undertaken including the development of the iRAP project. Unfortunately, at the time the surveys were undertaken, the development work had not been completed. Therefore the decision was made to undertake an initial analysis of the survey results based on the original FIKS analysis system, as was the case for the first survey, and this report is based on this analysis. However, sufficient information was gathered to allow an extended analysis to be undertaken at a future date.

1.1.3 Extended RPS protocol

A much more comprehensive scoring system is being developed for iRAP that includes likelihood factors in addition to protection factors, and assesses both urban and rural roads, with different scores for car occupants, motorcyclists, bicyclists and pedestrians. Whilst it is not planned that the next stage of development of EuroRAP RPS will include all these aspects, it is likely to include several of these additional factors. The surveys on UK roads have included a small number of these additional factors, and the roads could be re-scored using these when an extended format is agreed. The aim would be not to substantially change the protection score (except improve the junction score), but to add in a likelihood score which explains more of the observed difference in accident rate.

1.1.4 Survey technique

As previously mentioned, both of the surveys were undertaken by ADAC inspectors with experience of undertaking surveys in Europe. The surveys involved driving around a pre-determined network as detailed in section 1.3. The inspectors recorded the features specified in the handbook, using the tablet. A video was also taken of the whole survey route to allow further analysis in the future if necessary and to allow an element of quality control.

1.1.5 Handbook

SWECO developed a handbook to give guidance to inspectors on what and how to score during the surveys in Sweden. The handbook was then developed by ADAC for the inspections in Germany and further developments were incorporated for the surveys in the UK. As the survey was to be carried out by German inspectors with limited experience of UK road conditions, a number of the Swedish and German examples were retained in the handbook to assist in familiarity for the first survey. For the second survey, a UK-specific handbook was developed.

1.2 Review of pilot survey

1.2.1 Results

The results of the pilot survey showed that the RPS survey technique used in Germany by ADAC can be successfully deployed on UK roads.

The overall RPS scores obtained showed consistent variation between different road types, and between different roads of the same type. Roads within the survey route were picked to reflect a range of collision risk, and these in turn produced a range of RPS scores.

A quarter of motorway roadsides scored only 2-star. This reflects the presence of trees fairly close to the carriageways on some unprotected motorway roadsides.

Apart from this, the pattern of variation in overall scores and in median and side scores appeared broadly consistent with known collision risk component, but the variation in junction scores did not match the pattern of intersection collision risk, for example, between road types. RPS scores only measure a part of collision risk, but the difference was large enough to suggest that the RPS recording or scoring of intersections needed to be reconsidered.

Comparison of the RPS with total collision risk for whole routes (as shown on EuroRAP collision per vehicle km maps) suggests that the largest difference (i.e. the biggest relative contribution from likelihood factors rather than protection factors) occurred on the roads with the highest collision risk. Over the whole survey route, the distribution of numbers of roads by RPS scores followed a similar pattern to the distribution by collision risk, except again for the higher risk roads.

More detailed analysis of shorter sections of routes showed wide scatter in results, which is to be expected because of the very small numbers involved, but when averaged over RPS bands, showed a consistent decline in risk with higher RPS. One exception to this pattern is at very low RPS, and this needed to be investigated further.

Comparison of the worst and best scoring links by each road type suggested that the differences resulted from different collision types on each road type. For motorways, the major difference was in roadside scores. For dual carriageways, a large difference in intersection scores was recorded, while the worst single carriageways were worst in every aspect compared with the best.

Within the limitations of the small numbers available, comparison of total collision risk to RPS for each of the three individual collision types again showed an expected general trend for run-off and median collisions, but very little correlation for junction collisions.

Preliminary plots showing the density of bends on each road suggested that the addition of this variable to the RPS might improve its ability to explain total collisions risk.

1.2.2 Issues raised

Discussion in the preparation for the trial survey, and observations by the inspectors during the survey, highlighted a number of problems in defining and recording roadside features on UK roads. Particular issues were identifying roadside slopes, judging the protection provided by hedgerows, scoring cut and slope faces in the median, recording hatching and overtaking restrictions on a consistent basis, recording priority junctions of different types, recording short slip lanes and different types of sheltered turning lanes.

Hedgerows

During the pilot study hedgerows were scored as having a value equivalent to a clear area of 3-7m. Whilst this gave a good approximation, it did not provide a full representation of the effect different types of hedgerows can have. For example, a hedgerow comprising of gorse could have a positive speed reducing effect while at the same time not presenting any immediate danger to a driver or passenger. In contrast, a hedgerow containing mature trees with sizable trunks would prove extremely hazardous to an errant vehicle.

For the main survey the following was incorporated into the handbook.

- For hedgerows containing small elements only, i.e. tree trunks below the specification for point objects in the handbook, the clear zone should be recorded as if the hedge were not present. If the inspector cannot see through or beyond the hedge, the clear zone should be taken as the distance to the point that the inspector can reasonably see.
- For hedgerows containing occasional large trees, i.e. tree trunks that meet the specification for point objects in the handbook, the hedgerow should be recorded in accordance with the preceding bullet point and the larger trees recorded as point objects.
- For hedgerows containing numerous large trees, the hedgerow should be recorded as a continuous hard object. Five or more trees in a row at a spacing of less than 100m should be considered as continuous.

End treatments for safety barriers

The handbook for the first survey stated that any hard object with a height greater than 200mm should be considered as a point object. This definition therefore includes starting, or termination, blocks for safety fencing. As a result, a situation could arise where safety fencing has been installed to provide protection against a point object close to the carriageway (for example, a sign), and, due to the presence of the starting block, the safety fencing will generate exactly the same RPS side score as the original point object. Indeed as the safety fencing is closer to the carriageway it may actually produce a lower side score than the point object.

The standard design for the starting point of safety barriers has changed on the Highways Agency network and the new design (P4) will not be classed as a point object. Therefore it was decided that the current scoring description scoring should be retained and starting blocks classed as point objects.

1.3 Details of survey route

The first task was to develop a route for the survey. The route was chosen to provide a sample across as large a proportion of road types as possible. The chosen route contained a mixture of Highways Agency and non-Highways Agency roads, motorways, dual carriageways and single carriageways. The route covered roads in England, Scotland, Wales and Northern Ireland. The route was also chosen to provide a selection of roads with different star ratings based on the 2003 risk map. Finally, the route was also planned to cover as much of the TERN network as possible. Plans of the chosen route are shown in Figures 3 and 4 and a list of the road links covered is included in the version of the ADAC report available at www.iamtrust.org.uk and www.eurorap.org

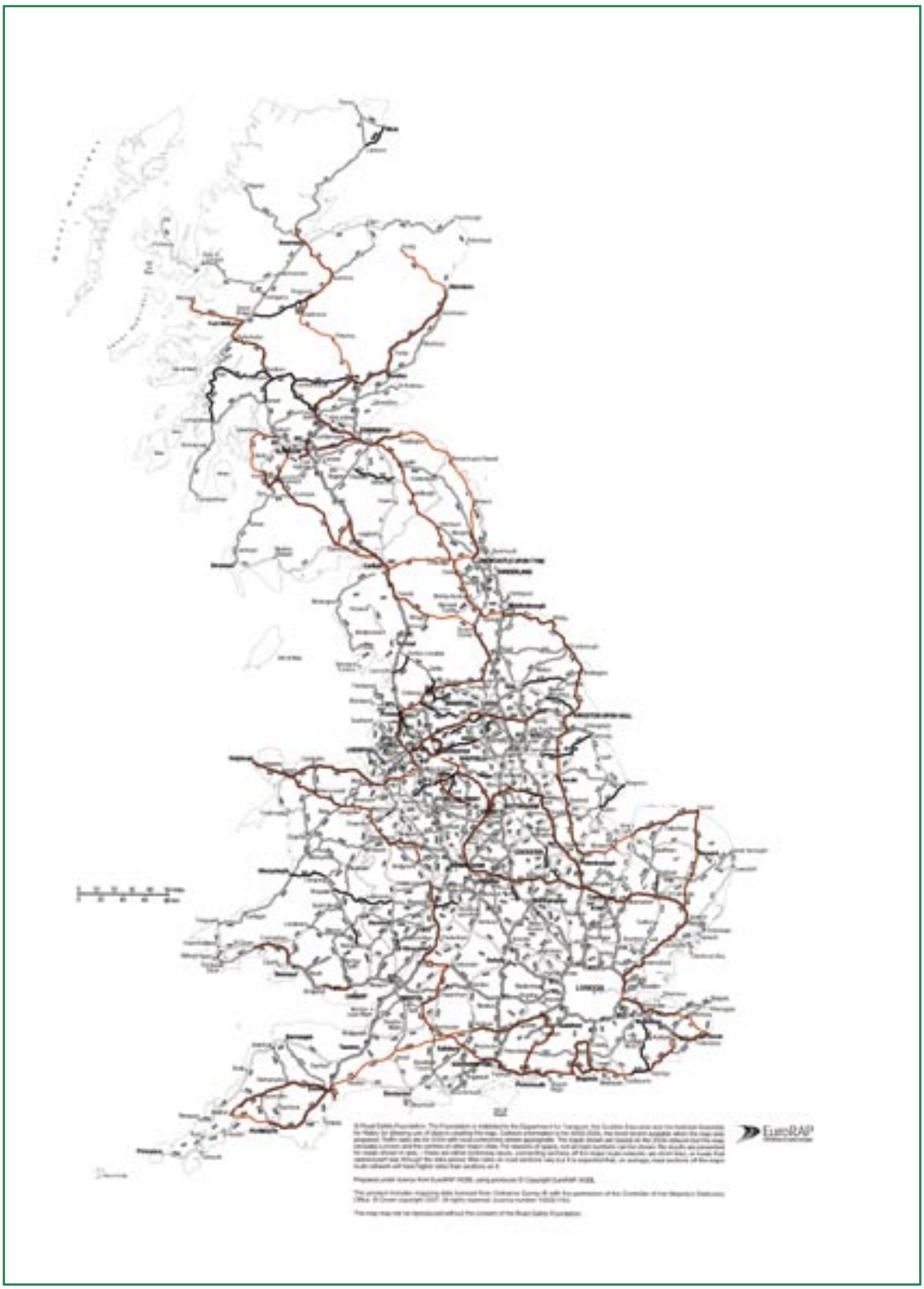

Figure 3 - Main survey route (red) - England, Scotland and Wales

Figure 4 - Main survey route - Northern Ireland (5 Corridors)

1.3.1 Overall route

When planning this project, the decision was taken to survey a total road length of approximately 7000km to form a sample size similar to the sample sizes in Germany and Sweden. Table 1 gives an indication of the lengths surveyed.

	Pilot	Main survey	Total
England - HA	342	2354	2696
England - Non HA	433	1639	2072
Scotland	0	1578	1578
Wales	282	293	575
Northern Ireland	0	620	620

Table 1 - Proposed survey lengths

The total length of the Highways Agency network covered by the main survey was 2354km. The route was planned to cover a cross section of all classifications of road for which the Highways Agency are responsible. Varying types of motorway were also covered: e.g. the M60 around Manchester and the M5. The main survey also covered 1225km of non-Highways Agency primary network. In addition to the primary network the main survey also included a network of some 414km of local roads one step down from the primary network. The purpose of including these roads was to allow a comparison between the different classifications of road. The roads surveyed in Scotland were included at the suggestion of Transport Scotland. In total, 1344km were covered in Scotland including some remote sections of the TERN. The majority of roads surveyed in Wales were inspected during the initial trial. The length of road covered by the main survey was 293km and was agreed with Roads Network Management, Transport Wales. The network covered in Northern Ireland was agreed with Roads Service, Northern Ireland. It covered a length of 620km and was mainly formed by the main road corridors.

2. SUMMARY OF STAR RATINGS

Maps showing the overall results from the main survey for each country are shown in Appendix A. The analyses in Sections 2, 3 and 4 are based on a combination of the results from both the trial and the main survey. Section 2 provides an overview and sections 3 and 4 provide a more detailed analysis.

2.1 Overall results

Figure 5 shows the proportion of star ratings achieved on the various networks surveyed by length. Overall scores for motorways are significantly higher than for Class A roads (e.g. about half of motorways and 10% of A roads scored 4-star), however 2% of motorways scored less than 3-star. 42% of A roads scored as less than 3-star.

Nearly 1% of Highways Agency motorways scored less than 3-star. Almost 51% scored 3-star and 48% scored 4-star. Over three-quarters of Highways Agency A roads scored 3 or 4-star compared to just 58% of A roads generally. English non-Highways Agency A roads score fairly poorly with nearly two-thirds scoring less than 3-star, compared to 42% generally. However these figures include the network of roads that are below the EuroRAP network.

Motorways in Scotland scored well with over 85% scoring 4-star and less than 1% scoring less than 3-star. The ratings for A roads were very similar to the overall rating, but with a higher percentage, 17%, achieving 4-star.

The majority of roads surveyed in Wales were surveyed during the trial and were selected to investigate specific issues. As a result the figures achieved for Wales are unlikely to be representative of the overall network. Despite this fact, Welsh motorways scored fairly well with over 60% achieving 4-star and no sections scoring less than 3-star. 54% of Welsh A roads scored 2-star and this result was expected due to the selection reasons detailed above.

In Northern Ireland, 76% of motorway scored 3-star and 13% were 4-star. 81% of A roads scored less than 3-star.

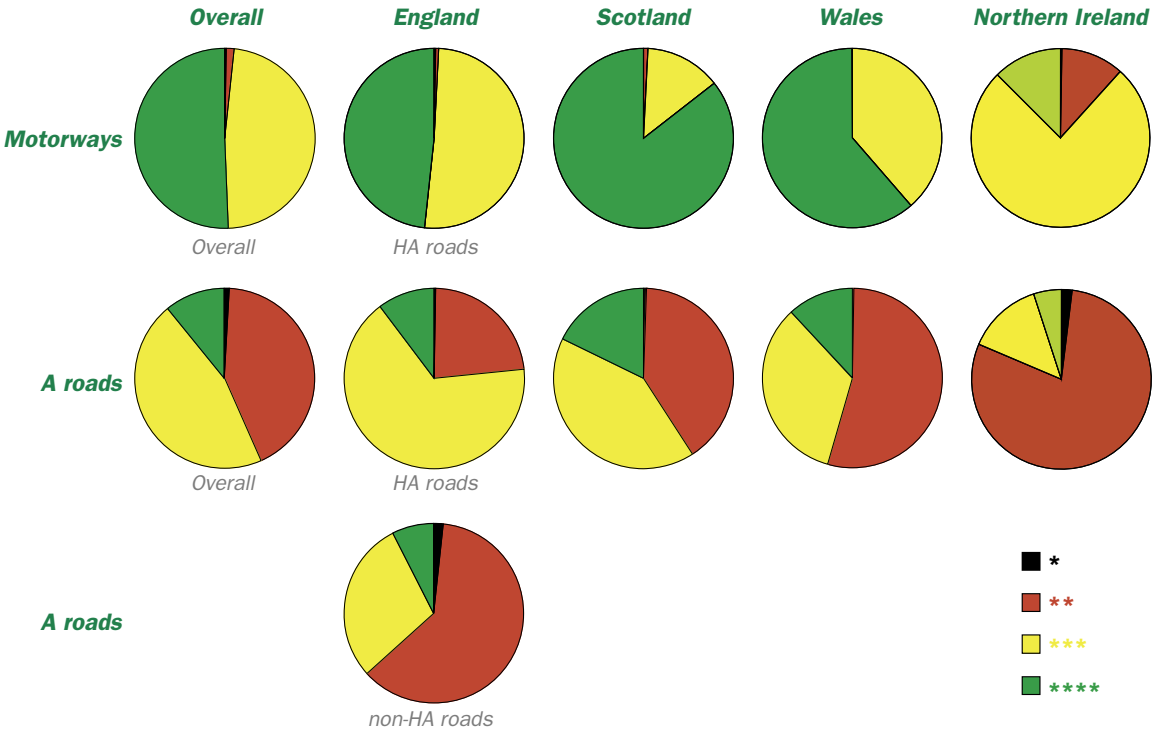

Figure 5 - Overall scores by length of each star rating

2.2 Accident types scores averaged by length of road section

As can be seen in Figure 6 below, the main factor influencing the overall scores for motorways is the run-off score. As would be expected due to the design philosophy, head-on and junction scores consistently rate in the 4-star range.

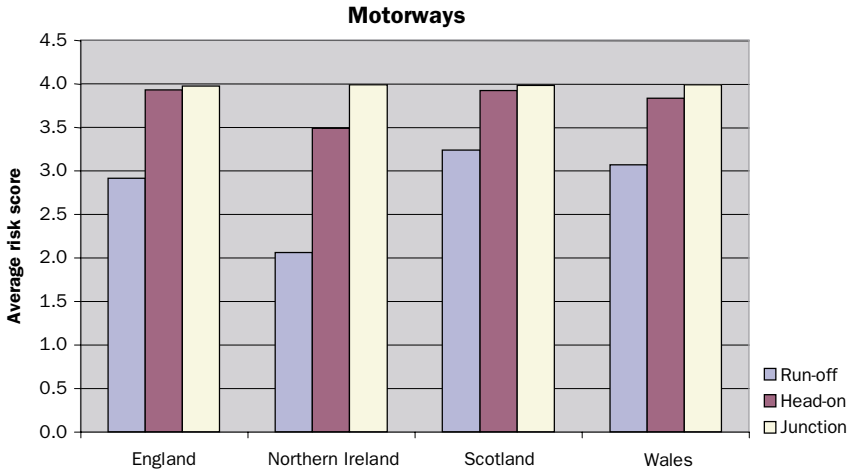

Figure 6 - Overall scores for motorways

The star ratings for A roads (Figure 7) are far more variable, indicating the wide range in design standards. It must be borne in mind that the category of A roads includes both dual and single carriageways, therefore the variation between countries may be due to the mix of roads in the survey.

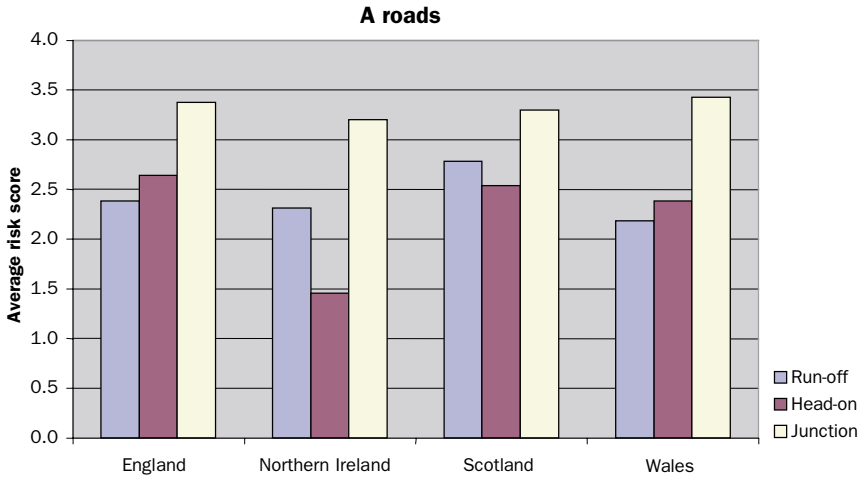

Figure 7 - Overall scores for A roads

Figure 8 shows there is a large variation on the average star ratings achieved between Highways Agency roads, other primary but non-Highways Agency roads, and non-primary roads. Junction scores are relatively similar on all three networks, as are run-off scores to a lesser degree. The greatest variability is in relation to median scores. The differences could be due to the high proportion of dual carriageways in the Highways Agency network.

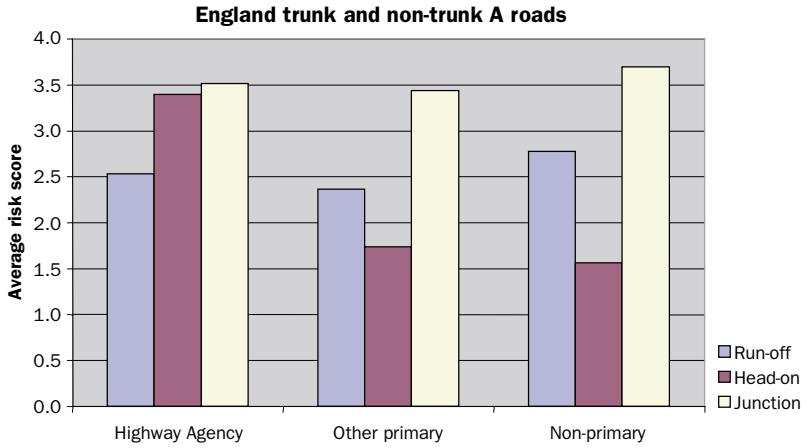

Figure 8 - England Highways Agency and non-Highways Agency roads

3. DETAILED ANALYSIS OF RESULTS

3.1 Data available for analysis

Section 1 describes the total routes driven in the trial and main surveys, and how this is broken down between the four countries, between trunk and non-trunk in England, and between motorways and A roads.

For the pie charts in section 2, all scored sections on these roads have been included. For the more detailed analysis in this section, only surveyed sections on the British EuroRAP network have been included (Trunk and Primary roads in England, Scotland and Wales). For most of the analyses, these data have been combined to provide scores for full EuroRAP routes, consistent with those used in accident risk mapping published at www.eurorap.org. The aim of this is to provide a manageable picture of the whole network surveyed, and also to enable comparisons between RPS and accident data. Section 4 gives examples of how both the aggregated score data and the detailed variation in scores within a route could be used to identify potential improvements.

When the data are compiled into full EuroRAP routes, some routes are only partially covered, and on others some data items are missing; where there are substantial shortfalls, these routes are omitted from the analysis. The lengths over which the subsequent analyses have been made are given in Table 2; this includes data from the trial survey, where this comprised whole EuroRAP routes. The Northern Ireland accident data have not yet been combined with inspection scores and thus Northern Ireland roads are not included in this detailed analysis.

Road type	*England trunk*	*England non-trunk*	*Scotland*	*Wales*
Motorway	541	-	234	14
Dual	831	160	198	161
Mixed DC/SC	591	182	324	-
Single	317	1009	739	89
Total	**2280**	**1351**	**1495**	**264**

Table 2 - Length (km) of inspected road included in RPS and accident rate analysis

3.2 Variation in total scores between routes

Table 3 shows the length in km (and percentage in brackets) of each road type with scores at each star rating. Note that in Table 3 the value for the star ratings has been averaged over the length of each of the EuroRAP risk map network sections, giving one star rating value per section, and that therefore the maps provided in Appendix A show greater detail, showing for example, that some shorter parts of the network score only as 1-star. Similarly, Figure 5 shows this disaggregated data.

Road type	*4-star*	*3-star*	*2-star*	*1-star*
Motorway	476 (60%)	314 (40%)	-	-
Dual	30 (2%)	1221 (98%)	-	-
Mixed DC/SC	93 (9%)	757 (71%)	221 (21%)	-
Single	-	726 (34%)	1427 (66%)	-
Total	**609 (12%)**	**3018 (57%)**	**1648 (31%)**	**-**

Table 3 - Length and proportion of each road type (EuroRAP network sections) scoring different star ratings

The RPS risk scores can vary from 1.0 to 4.0. All risk scores above 3.5 are assigned a 4-star rating, from 2.5 to 3.5 a 3-star rating, from 1.5 to 2.5 a 2-star rating. Of the roads included in this analysis, only 60% of motorways scored 4-star, and virtually all other dual carriageways scored 3-star. About one third of single carriageways scored 3-star and the remainder 2-star.

3.2.1 Examples of roads with relatively high or low scores

The network surveyed comprises around 30% of the EuroRAP network in Great Britain. It should therefore provide a good general indication of the standard of the overall network but it does not necessarily comprise a fully representative sample.

The survey routes were compiled to provide a wide variety of road types and accident risks. The non-English authorities were asked to suggest routes of interest to survey and thus they may in part have selected roads with high risk or known poorer standard. Within this sample network, roads scoring relatively well or relatively poorly can be identified, but there will be other roads of equal and possibly more extreme scores within the whole EuroRAP network. Examples of motorway routes scoring less than 4-star are shown in Table 4.

Road	*Description*	*Length*	*Score*
M6	M6 J0 to J4a	42.5	3.49
M27	M27 J1 to J8	25.2	3.49
M25	M25 J28 to J31	14.2	3.48
M62	M62 J25 to J28	16.6	3.44
M62	M62 J22 to J25	20.1	3.41
M4	M4 J14 to J15	19.7	3.41
M20	M20 J10 to J13	19.0	3.41
M6	M6 J21a to J28	34.3	3.40
M6	M6 J40 to J44	35.3	3.38
M3	M3 J5 to J6	7.7	3.35
M2	M2 J1 to J7	39.9	3.31
A1 (M)	Alconbury - Peterborough	17.8	3.28
M3	M3 J3 to J5	22.1	3.27
	Total	**314.4**	

Table 4 - Motorways scoring 3-star

Only two sections of dual carriageway, totalling 30km, rated four stars. These were the A66 Middlesbrough ring road north, and the A720 Edinburgh ring road. Both had junctions which were either well designed roundabouts or merging junctions with long slip roads and so scored 4-star rating for junctions as well has high ratings for median and run-off areas. All remaining dual carriageway routes had an overall rating of 3-star, but Table 5 shows those with risk scores below 3.0.

All single carriageways rated either 2 or 3-star. Those with a risk score of less than 2.0 (i.e. the lower half of the 2-star rating) are shown in Table 6.

Road	*Description*	*Length*	*Score*
A38	Birmingham - Burton-upon-Trent	41.9	2.97
A38	Exeter - Saltash	71.5	2.96
A303	M3 - Beacon Hill (A338)	34.7	2.94
A12	Colchester - Ipswich	18.0	2.91
A1	Dishforth - Scotch Corner	39.6	2.86
A449	Kidderminster - Worcester	21.1	2.85
A1	Stamford - Grantham	33.1	2.84
A24	Horsham - A272	12.0	2.82
A14	Kettering - Huntingdon	35.4	2.79
A1	Peterborough - Stamford	19.6	2.76
A40	Carmarthen - St Clears	14.1	2.66
A48	M4 J49 - Carmarthen	24.7	2.62
A38	M1 J28 - Mansfield	10.2	2.61
A24	A272 - Worthing	20.2	2.61
A264	M23 - A24	10.3	2.58
A27	A29 - M27	34.8	2.54
A31	Guildford - Farnham	10.9	2.53
A1	Grantham - Newark	23.2	2.50
A419	Swindon - Cirencester	27.2	2.58
	Total	**502.5**	

Table 5 - Dual carriageways scoring low 3-star ratings (i.e. risk score less than 3.0)

Road	*Description*	*Length*	*Score*
A682	M65 J13 - A65 Long Preston	24.0	1.97
A54	Congleton - Buxton	23.6	1.95
A5	A494 Rug - Bangor	62.2	1.93
A59	Skipton - Harrogate	30.0	1.91
A5	Chirk - A494 Rug	27.0	1.75
	Total	**166.8**	

Table 6 - Single carriageway scoring low 2-star (i.e. risk score less than 2.0)

3.3 Variation in accident type scores between routes with different total scores

Table 7 shows the average accident type RPS for roads with different total RPS.

Road type	Star rating	No of sections scored	Average RPS risk score		
			Head-on*	Run-off	Junction
Motorway	4-star	195	3.97	3.26	3.98
Motorway	3-star	217	3.94	2.69	3.98
Dual	4-star **	43	3.98	3.40	3.69
Dual	3-star	1588	3.67	2.44	3.43
Single	3-star	804	2.35	2.65	3.41
Single	2-star	611	1.18	2.18	3.48

* "Motorway" sections can include short non-motorway link lengths at the end of the sections which can result in head-on scores being slightly less than 4.0

** Note: this represents one 20km route of urban ring road

Table 7 - Average RPS for individual accident types by overall star rating

Examples of routes with higher than average scores for specific accident types are shown in Table 8.

Road type	Road number	Route	Head-on	Run-off	Junction
Motorway	M62	M62 J28-J38		3.16	
	M62	M62 J20-J22		3.06	
Dual	A331	M3 - A31		3.17	
	A90	Perth - Dundee		3.06	
	A90	Dundee - Aberdeen		3.04	
Single	A4	Chippenham - Bath	2.28		
	A419	M5 J13 - Cirencester	2.10		
	A82	Ballachulish - Fort William	2.06		
	A27	Eastbourne - Lewes		2.70	
	A617	A614 - Newark		2.64	3.94
	A59	Whalley - Skipton		2.44	
	A682	M65 J13 - A65 Long Preston			4.00
	A701	Dumfries - M74 J15			3.92

Table 8 - Examples of routes with higher than average scores for particular accident types

Examples of routes with lower than average scores are shown in Table 9.

Road type	Road number	Route	Head-on	Run-off	Junction
Motorway	A1(M)	Alconbury - Peterborough		2.32	
	M3	M3 J5-J6		2.49	
	M2	M2 J1-J7		2.49	
Dual	A264	M23 - A24	2.16		
	A331	M3 - A31	2.74		
	A38	Exeter - Saltash			2.48
	A90	Dundee - Aberdeen			2.54
	A40	Carmarthen - St Clears		1.66	2.82
	A1	Grantham - Newark		1.28	
	A1	Dishforth - Scotch Corner		1.52	
	A1	Peterborough - Stamford		1.55	
	A24	Horsham - A272		1.66	
	A12	Colchester - Ipswich		1.70	
Single	A27	Eastbourne - Lewes			2.24
	A59	Skipton - Harrogate			2.95
	A5	A5 - A494 Rug		1.25	
	A682	M65 J13 - A65 Long Preston		1.45	
	A5	A494 Rug - Bangor		1.46	

Table 9 - Examples of routes with lower than average scores for particular accident types

3.4 Validity of RPS results

The RPS measures only part of the risk on the road. There are therefore no simple data against which to validate the scores. In this section, four ways of considering the internal validity of the data are discussed. First, a comparison is made between the distribution of inspection scores and the distribution of the known fatal and serious accident rates for the routes inspected. Second, the variation in fatal and serious accident rate for roads of different ratings is examined. Third, the variation of RPS and fatal and serious accident rate for each of the three individual accident types is plotted. Fourth, the occurrence of fatal accidents on roads rated as 4-star is investigated.

The interpretation and application of the RPS results are discussed in more detail in section 4, drawing on these comparisons.

3.4.1 Comparison between risk rates and RPS

The RPS measures only part of the risk on the road. While we would expect some general correlation between RPS and accident rate, the value of the RPS will be to identify those roads where there is a particularly high component of risk associated with the infrastructure. Table 10 shows the number of routes with various combinations of RPS rating and accident rate ranking. The dark green cells indicate where ratings might lie if there is direct correspondence. The relatively large number of routes with 2-star rating but low to medium overall accident rates suggests that infrastructure deficiencies play an important part in risk on these roads. In general, the 42 routes in cells above the dark green diagonal appear to have a relatively low accident risk for their RPS rating, possibly indicating low accident likelihood factors. The 16 routes in cells below the diagonal

appear to have relatively high accident risk for their RPS rating; on these roads behavioural issues may be relatively more important than infrastructure deficiencies.

Accident rate		RPS star rating			
Ranking	F&S acc per billion veh km	4	3	2	1
Low	0-15	16	22		
Low to medium	16-61	3	64	20	
Medium	62-120		7	13	
Medium to high	121-180		3	5	
High	>180			1	

Table 10 - Distribution of accident rates and RPS star rating on EuroRAP routes

3.4.2 Variation in accident rate with RPS rating for different road types

Figure 9 shows the average fatal and serious accident rate per vehicle km for roads with different RPS star ratings. Taking all roads together there is a clear increase in accident rate with decrease in RPS star rating, but this is to be expected as higher quality road types such as motorways which have a low accident rate will have a high star rating, while single carriageway routes will generally have a relatively low star rating and high accident rate. But the same general pattern is also mirrored within each road type and this provides much firmer evidence that the RPS is generally distinguishing between roads of poorer and better quality. It should be noted that the 4-star bars for both dual carriageway and mixed carriageway A roads are based on only a small number of accidents.

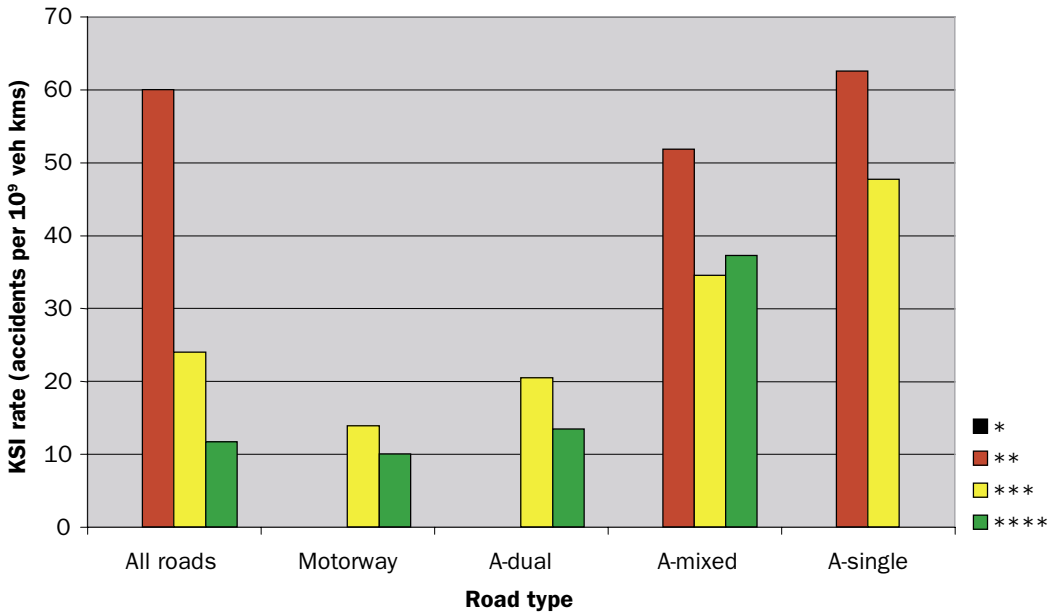

Figure 9 - Variation of accident rate per vehicle km with RPS ratings

This overall pattern linking RPS ratings and accident rates is similar to comparisons made with Swedish data reported in Lynam *et al.*, (2007).

3.4.3 Variation in RPS and accident rate for individual accident types

Figures 10-12 show the variation of individual accident type rate per vehicle km with RPS ratings for that accident type. Although the numbers of accidents are smaller when accident types are considered separately, the plots still suggest a strong relation between accident rate and RPS for run-off and

head-on accidents. The link between accident rate and RPS for junction accidents is much less clear; this is discussed further in section 4.2.1, but caution is needed in interpreting junction scores.

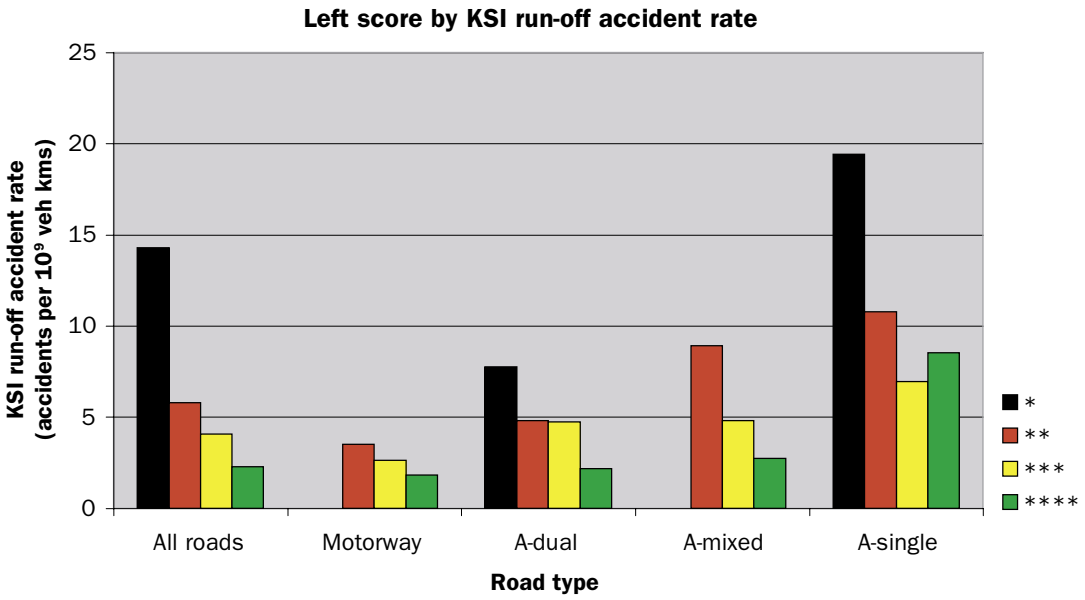

Figure 10 - Variation of run-off accident rate by run-off RPS score to left

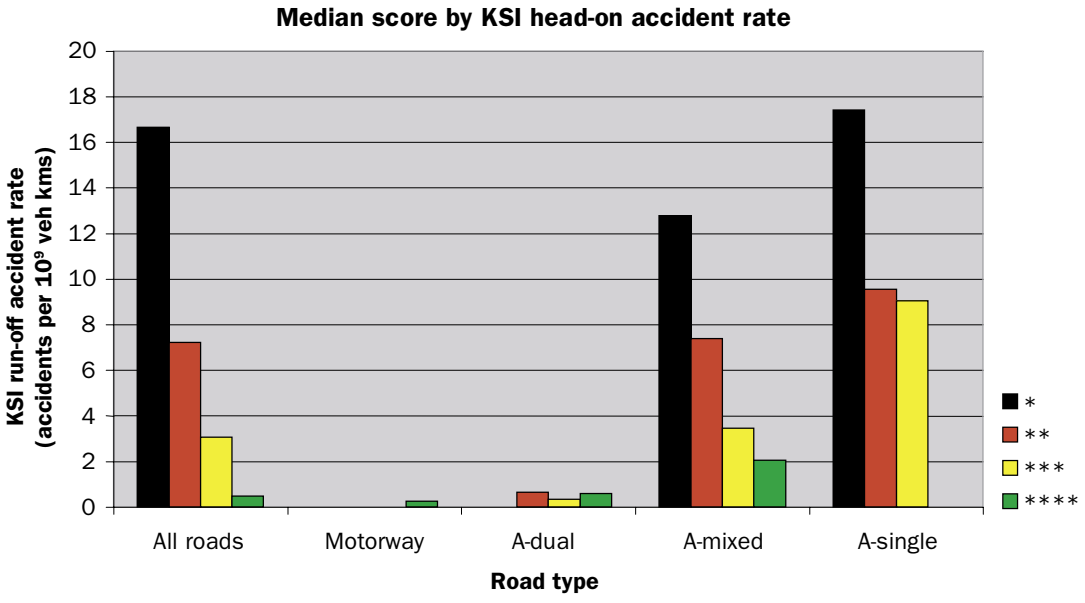

Figure 11 - Variation of head-on accident rate by median RPS score

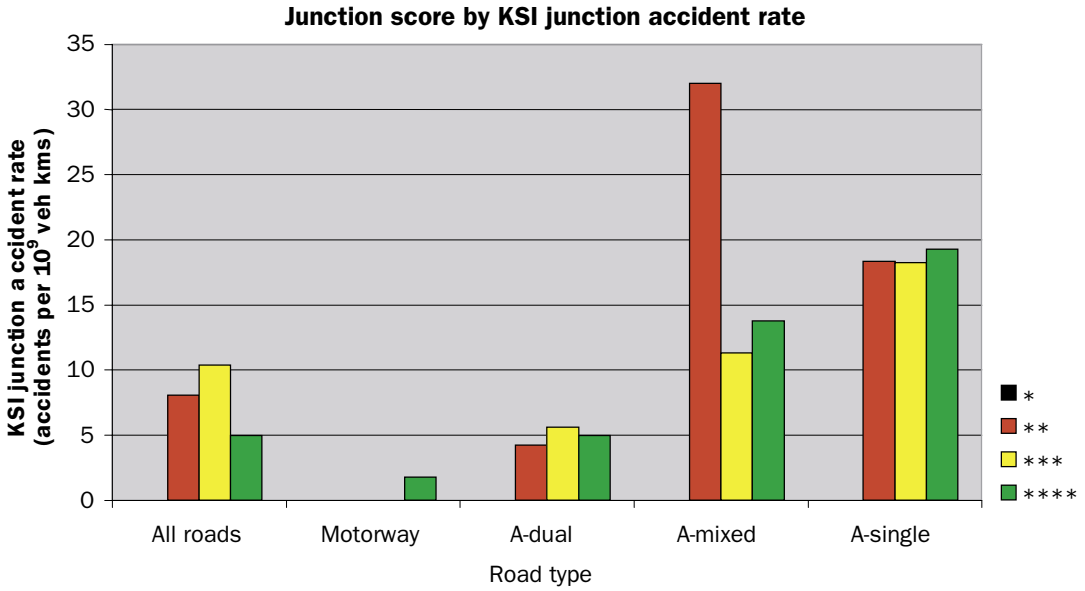

Figure 12 - Variation of junction accident rate by junction RPS score

Figure 13 shows plots of RPS and accident rate for the individual accident types. Points are plotted for each of the six road type/star ratings shown in Table 7 except for 4-star dual carriageways for which the numbers of accidents of each type was very small. These plots suggest that RPS changes with accident rate in a consistent way for run-off and head-on accidents and the range of values is wide enough to discriminate between roads of different standard. This plot of junction accidents and the comparison in Figure 12 both confirm the current inspection scoring for junctions is less consistent with known accident rates and does not provide useful discrimination between junction types. A different junction scoring routine is already being considered for iRAP and for an extended RPS.

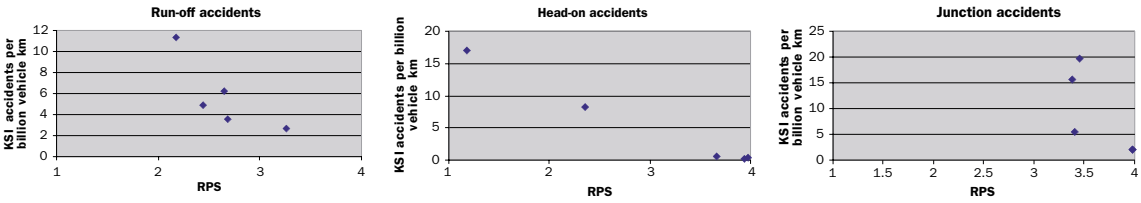

Figure 13 - Variation of accident rate with RPS for individual accident types

3.4.4 Accident history on 4-star roads

The RPS 4-star rating is intended to identify roads where fatal injuries to car occupants would be unlikely, as a result of the protection designed into the road layout. Fatal accidents will still occur on 4-star roads for a number of reasons, for example:

- cars provide less protection to their occupants (i.e. have low NCAP ratings)
- car drivers are behaving inappropriately (i.e. are unbelted or driving at speeds above the limit for the road)
- injuries are to very frail car occupants or to road users more vulnerable than car occupants

Data are not available to investigate accidents on the survey sections in depth, but Table 11 shows the numbers and proportions of fatal and serious accidents on 4-star and 3-star motorways and on 4-star dual carriageways.

	Road type	Length	Fatal accidents	Serious accidents	Total F&S	% fatal	Fatal accident/km
4-star	Motorway	295	46	226	272	17	0.16
3-star	Motorway	312	74	317	391	19	0.24
4-star	Dual	20	2	-	-	-	0.10

Table 11 - Fatal accidents on 4-star roads

Table 11 does not show the proportion of fatal accidents on 4-star motorways to be substantially less than that on 3-star motorways as might be expected, although it does show less fatal accidents per km on the 4-star roads. More detailed investigation of the 46 fatal accidents occurring on the 4-star motorways shows them to involve 11 pedestrians, 18 HGVs and 4 motorcyclists (although four accidents involved both pedestrians and HGVs). Other reasons why fatalities may occur despite the relative high infrastructure quality include vehicles travelling above the speed limit or car occupants unbelted or travelling in older cars with poor occupant protection. Old and frail occupants may also die in lower energy impacts than those survivable by most other occupants.

4. INTERPRETATION AND APPLICATION OF RESULTS

This section discusses what the RPS is measuring and how it adds to assessment of the road quality. It uses the data from section 3 to explore further the changes in accident rate that might be achieved if roads were improved to score a higher RPS, and considers how many roads might benefit from this. This is consistent with current Highways Agency methodology using a data-led approach and intervention levels to trigger action. The RPS potentially adds to current methodology by providing additional criteria for setting intervention levels and by helping to prioritise actions on broader criteria than accident density alone (section 4.6.2).

4.1 What risk does the RPS represent?

An important aim of the RPS is to provide information that is not readily available through accident histories. Accidents are always random and accident rates subject to statistical fluctuation. Over time as accident numbers decrease, identification of higher risk sites through variations in observed accident numbers will become more difficult. The RPS aims to provide a consistent assessment of the potential long-term risk of a given road design. While the ability to isolate the infrastructure component of risk from variations in driver behaviour is a considerable strength, it means that there is no simple way to validate the inspection scores completely through accident data. Section 3 has used four different analyses to show that RPS appears to give a good indication of overall injury risk, and of risk arising through run-off and head-on accidents, although less effective in presenting junction risk.

The Road Protection Score seeks to assess the quality of the road infrastructure only, and does not reflect those accidents in which driver behaviour is inappropriate to the road design principles occurs, e.g. excessive speed or non-wearing of seatbelts – occurs. The RPS also seeks to assess the ability of the infrastructure to mitigate serious injury of car occupants in vehicles which meet 4-star EuroNCAP standards. Thus serious injuries involving other road users or involving less crashworthy passenger cars will not be truly reflected in the scores.

The RPS is thus primarily a tool for assessing how well roads are meeting standards that maximise injury protection, and assessing the potential savings in accidents that could be achieved if roads are improved where they fall below the defined standards.

4.2 Interpretation of comparisons with accident rates

The differences in rates shown in Figure 9 could be interpreted as illustrating both the change in injury protection as a result of the inspection score (by comparing accident rates for different RPS ratings on the same road type) and the change in accident likelihood (by comparing the accident rates for different road types with the same protection rating). Table 12 illustrates the percentage accident rate changes implied (the data for 4-star bands for dual and mixed carriageways are based on relatively small fatal and serious accident numbers; the estimates involving these numbers are shown in brackets).

	Changing from...	*...gives this percentage reduction in fatal and serious accidents for these road types*			
		Motorway	***Dual***	***Mixed***	***Single***
Injury protection	3-star to 4-star	28	34	(-8)	
	2-star to 3-star			33	24
Likelihood		***4-star***	***3-star***	***2-star***	
	Single to mixed		28	17	
	Mixed to dual	(64)	41		
	Single to dual		58		
	Dual to motorway	(25)	32		

Table 12 - Percentage reduction in accident rate per vehicle km implied by RPS ratings

Thus, for example, the top half of the table suggests that improving injury protection on a 3-star dual carriageway to 4-star rating would reduce fatal and serious accidents by 34%. The bottom half of the table shows that upgrading a 3-star dual carriageway to a motorway at the same traffic level but still only with 3-star rating for injury protection would result in a similar accident reduction (32%).

4.2.1 Junction scores

It is clear from the comparisons in 3.4.2 that the current scoring of junctions does not discriminate well between roads with different junction accident rates. Whereas injury protection is the most critical issue when dealing with run-off and with head-on accidents, for junction accidents the factors affecting the likelihood of the accident occurring will probably have a much stronger effect than for the other two accident types. Thus we would expect a less good fit when only injury effects are considered (as in the current RPS). At the same time, the range of junction types that are scored does not really cover the variation in potential turning movements. This is reflected, for example, in side roads accessing a dual carriageway. These are scored in the same way as side road T junctions on single carriageways. On single carriageways, there is usually scope for turning right in and out. On some dual carriageways the movement across the median will be allowed, on others only left in and left out is possible.

The methodology for scoring junctions and the range of designs to be scored will be reviewed as part of the extension of the scoring system to include accident likelihood. The lack of a good fit in terms of this accident component does not prevent a fairly good fit between total score and total accident rate, as shown in Fig 9, but this fit should be improved if the junction scoring system is improved. The current total scores can therefore be used to identify potential road sections for improvement, but care should be taken not to rely on low scores that only arise due to low junction scores.

4.2.2 Effect of flow differences

Lynam and Lawson (2005) showed that fatal and serious accident rate per vehicle km on EuroRAP routes in Britain was lower on higher flow roads than on lower flow roads for both single and dual carriageways. But

it is not clear to what extent the lower rates on the higher flow roads are an effect of flow on accident likelihood or a result of more improvements having been made to the higher flow roads. It is reasonable to suppose that part of the effect is from improved quality of the higher flow roads, as any given improvement would yield greater accident savings on these roads than on lower flow roads, and thus be more likely to be targeted through standard accident appraisal processes.

	RPS star rating		
	4-star	3-star	2-star
Motorway	64,879	76,073	
Dual		35,594	
Single		12,697	7,864

Table 13 - Average traffic flow (AADT) for roads of different type and star rating

The uncertainty in ascribing the observed reduction in accident rate to flow effects or road quality improvement potentially confuses interpretation of the comparisons between RPS and accident rate if flows are higher on the higher rated RPS roads. Table 13 shows that this is the case for the two single carriageway groups but not for the motorway groups.

4.3 Interpretation of difference in accident type risk

Figure 9 has shown that accident rates vary with RPS rating, and Table 12 suggests that an improvement of one in star rating could result in a reduction of a quarter to a third in accident rate. The data available on the types of accident making up each accident rate enable this to be investigated in more detail, using the breakdown in accident risk per accident type discussed by Lynam and Lawson (2005). Table 14 shows how each accident type risk contributes to total risk for the five different road type/star rating groups used in Figure 9 and Table 7. The "run-off" risk only relates to single vehicles leaving the carriageway; the total number of F&S accidents in which vehicles leave the carriageway (including hitting the barrier and rebounding) is about double this number, but it is not clear in multi-vehicle incidents what part the roadside played in the injury.

Road type and rating	Number of F&S accidents	F&S accidents per billion vehicle km					
		Total	Head-on	Run-off	Junction	VRU *	Other *
4-star mway	127	9.8	0.4	2.7	1.9	0.2	4.5
3-star mway	313	13.8	0.2	3.6	1.8	0.6	7.6
3-star dual	1053	20.6	0.6	4.9	5.5	1.8	7.7
3-star single	556	48.9	8.3	6.2	15.8	8.4	10.3
2-star single	554	64.6	17.1	11.3	19.5	7.1	9.6

* these accident types are not part of the risk scored during inspections

Table 14 - Components of total accident risk on roads with different star ratings

Changing from 3-star to 4-star motorway produces virtually no change in junction, head-on or VRU risk as would be expected. Single vehicle run-off risk is reduced by about a quarter but the largest change is in "other" accident types. This may include some run-off injuries where two vehicles are involved, but may also reflect poorer behaviour on the 3-star motorways, which Table 13 shows are carrying a higher flow. Changing from 2-star to 3-star single carriageway approximately halves head-on and run-off risk and reduces junction risk by about a fifth.

4.4 Illustration of roads with different star ratings

Appendix B gives examples from the survey video of situations that have resulted in higher or lower than average scores for particular road types. Motorways generally scored lower when roadsides were poorly protected. Other dual carriageways scored lower when either roadsides or median were poorly protected. Single carriageways scored higher when speed limits were reduced to compensate for poorer protection, when central hatching or short sections of dual carriageway were provided, and when turning lanes were provided at junctions.

4.5 Examples of case studies of individual routes

The database allows the variation in scores to be assessed in detail along the length of the route.

Figure 14 shows the variation in Road Protection Score along a sample route, for both total score and run-off score. Sections with particularly low scores occur near the middle of the route, where both total and run-off scores are low. At the ends of the route, run-off scores are very high, but other deficiencies have pulled down the total score.

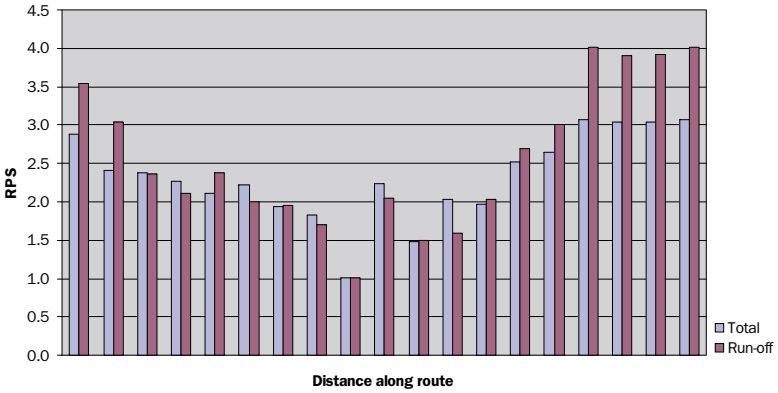

Figure 14 - Example of variation of scores along a route

This information can be presented in aggregate form to show what proportion of the length of the route scores at different ratings. Figures 15 and 16 show an example of the distribution of ratings, for both total accidents and run-off accidents, for two motorway sections, one which averages 4-star overall and one which averages 3-star overall. The difference in run-off score distributions between the two sections can clearly be seen.

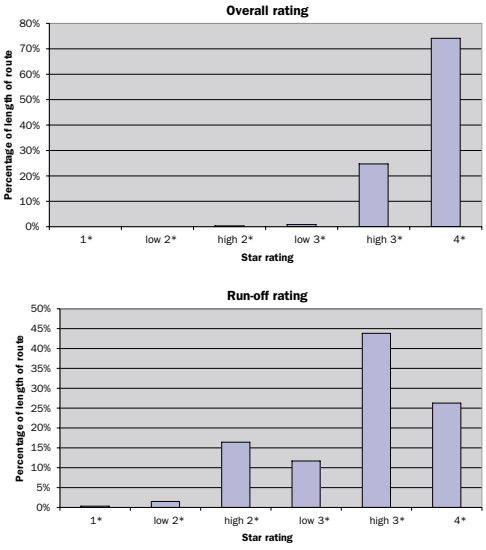

Figure 15 - Lengths of 4-star motorway section with different scores

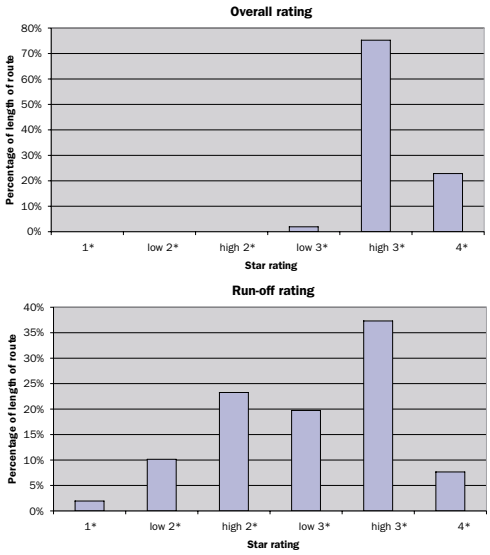

Figure 16 - Lengths of 3-star motorway section with different scores

4.6 Application of RPS ratings to network assessment

The RPS results could be used at several different levels to complement existing network analysis tools:

- to assess overall standard of network
- to identify overall routes for treatment
- to identify sections within routes

4.6.1 Assessing overall network standard

At a simple level this might be, for example, the proportion of motorways scoring only 3-star. For the sample surveyed, Table 3 shows 40% scoring 3-star. If this were representative of the whole motorway network, then 1300km of motorway could be considered for improvement to 4-star. The 3-star motorways in the sample inspected had an average accident rate of 13.8 fatal and serious accidents per billion vehicle km and an average AADT of 76,073 giving an accident density of 0.38 fatal and serious accidents per km. Table 12 suggests that improving a 3-star motorway to 4-star might reduce accidents by 28%. An approximate estimate of the potential saving from improving the whole 1300km scoring only 3-star might thus be 1300 x 0.38 x 0.28 = 138 fatal and serious accidents per year. Note that table 14 suggests that only part of this improvement can be achieved through better roadside protection. This type of calculation is explored in more detail in 4.6.3 below.

4.6.2 Identifying routes for treatment

Although one target might be general improvement of the network to minimum standards, in the short term priority might be given to identifying those substandard routes giving the highest potential return. These will be the routes with high accident density and low RPS.

If it is assumed from Table 12 that a change of one star in rating could produce a 30% potential reduction in accidents, then each 0.1 change in star rating would produce, on average, 3% saving, although the results are very unlikely to be accurate for such a small change. Routes with scores below 4-star could be ordered according to score and accident density as in the examples in Table 15, to rank them for potential accident savings.

Many of the routes with highest potential saving would also be identified as having high fatal and serious accident rates per km. But there are also examples where either additional routes are identified through the potential saving ranking or routes with high accident rates per km appear not to have high potential accident savings through infrastructure improvement.

It can be seen, for example, that two single carriageway sections (the first A59 section and the A259) both have accident densities of 0.31 fatal and serious accidents per km, but the potential saving on the A59 is double that on the A259, if they could be brought up to the same standard at similar cost.

This approach might be extended to consider poor ratings for individual accident types, and used to develop programmes for different types of treatment. Potential accident savings could be estimated in a similar way to the calculations in 4.6.1 and 4.6.3.

Road Number	Length	Acc/km per year	KSI acc rate 03-05	Total score	Target score	Diff in score	Acc saving per km
Motorways		*(higher values shaded in yellow for ease of reference)*					
M25	14.2	0.94	26.7	3.48	3.75	0.27	0.08
M62	20.1	0.61	17.9	3.41	3.75	0.34	0.06
M3	7.7	0.43	12.5	3.35	3.75	0.40	0.05
M2	39.9	0.34	16.9	3.31	3.75	0.44	0.04
A1(M)	17.8	0.28	13.4	3.28	3.75	0.47	0.04
M6	34.3	0.36	10.1	3.40	3.75	0.35	0.04
M6	42.5	0.43	14.8	3.49	3.75	0.26	0.03
M62	16.6	0.32	7.7	3.44	3.75	0.31	0.03
M6	35.3	0.25	16.0	3.38	3.75	0.37	0.03
M20	19.0	0.26	14.6	3.41	3.75	0.34	0.03
Dual carriageways							
A27	34.8	0.43	21.1	2.54	3.50	0.96	0.12
A264	10.3	0.42	29.7	2.58	3.50	0.92	0.12
A12	35.9	0.81	35.6	3.07	3.50	0.43	0.11
A24	20.2	0.33	29.2	2.61	3.50	0.89	0.09
A23	25.5	0.58	25.0	3.01	3.50	0.49	0.08
A1	39.6	0.42	25.9	2.86	3.50	0.64	0.08
A31	10.9	0.28	17.0	2.53	3.50	0.97	0.08
A12	18.0	0.43	25.2	2.91	3.50	0.59	0.08
A14	28.9	0.61	27.6	3.11	3.50	0.39	0.07
A1	19.6	0.29	19.6	2.76	3.50	0.74	0.06
A12	28.9	0.59	25.5	3.16	3.50	0.34	0.06
A1	23.2	0.20	18.1	2.50	3.50	1.00	0.06
A14	35.4	0.26	18.0	2.79	3.50	0.71	0.06
A14	11.9	0.50	23.3	3.15	3.50	0.35	0.05
A38	41.9	0.32	24.5	2.97	3.50	0.53	0.05
A303	34.7	0.30	23.3	2.94	3.50	0.56	0.05
A40	14.1	0.19	15.7	2.66	3.50	0.84	0.05
A449	21.1	0.24	29.5	2.85	3.50	0.65	0.05
A24	12.0	0.22	16.3	2.82	3.50	0.68	0.05
Single carriageways							
A59	30.0	0.31	95.6	1.91	3.00	1.09	0.10
A682	24.0	0.32	202.6	1.97	3.00	1.03	0.10
A556	8.1	0.33	29.9	2.08	3.00	0.92	0.09
A27	25.2	0.41	53.2	2.34	3.00	0.66	0.08
A54	23.6	0.25	169.0	1.95	3.00	1.05	0.08
A628	23.8	0.34	114.8	2.28	3.00	0.72	0.07
A59	31.1	0.29	76.4	2.30	3.00	0.70	0.06
A36	49.2	0.27	57.7	2.36	3.00	0.64	0.05
A140	27.0	0.23	31.2	2.30	3.00	0.70	0.05
A259	30.9	0.31	88.8	2.48	3.00	0.52	0.05
A148	62.9	0.20	62.2	2.19	3.00	0.81	0.05
A15	69.2	0.24	75.6	2.34	3.00	0.66	0.05
A84	43.9	0.25	171.9	2.36	3.00	0.64	0.05
A5	27.0	0.11	42.4	1.75	3.00	1.25	0.04
A15	33.4	0.19	51.8	2.34	3.00	0.66	0.04
A701	26.4	0.14	52.8	2.13	3.00	0.87	0.04
A5	62.2	0.11	75.0	1.93	3.00	1.07	0.04

Table 15 - Ranking of potential accident saving compared with accident density

4.6.3 Identifying sections for treatment within routes

The analyses above relate to averaged scores for whole routes. More detailed analysis could reflect the variation in score along the route so that treatments could be targeted to specific parts of the route. If the example of the run-off rating for the 3-star motorway in Figure 16 was considered in more detail, it can be seen that 55% of the length of the motorway is rated below 3.0 (i.e. below the higher half of the 3-star rating). Consider upgrading this length so that it scored 4.0. Figure 10 suggests that an increase in risk score of 1 for run-off might reduce risk by about one fatal and serious accident per billion vehicle km. Table 16 shows estimates of the potential accident saving for each length along this route scoring 1-star, low 2-star etc. The current valuation (Department for Transport, 2006) of saving one fatal and serious accident is about £400,000. The last column of the Table shows an estimate of the Net Present Value of the investment that would be justified for a benefit/cost ratio of one if a life of 20 years was assumed for the countermeasure. If the countermeasure was provision of a safety barrier, this cost would need to cover the cost of barriers on both sides of the road. The results suggest that positive returns should be achievable for most of this length, particularly if economies of scale were obtained from mass-action treatments. These estimates are also likely to undervalue the potential benefits as (a) the run-off accident rates used only include single vehicles and (b) the value per fatal and serious accident saved would be increased if slight injury accidents were also reduced by the measure. In practice a much more detailed study would be needed to justify investment at any particular site, but these broad estimates could be used to define the scale of action potentially justified.

Risk score group (Fig 16)	Average star rating for group	% of length of road	Change in risk if scored 4-star	F&S accidents saved per km	NPV of accidents saved (£k/km)
1-star	1.25	2	2.75	0.075	420
Low 2-star	1.75	10	2.25	0.062	350
High 2-star	2.25	23	1.75	0.049	275
Low 3-star	2.75	20	1.25	0.035	200

Table 16 - Example of estimate of potential investment justified for run-off countermeasures

A more detailed discussion of this example is given in Appendix C.

5. FUTURE DEVELOPMENTS

The next stages of work on RPS might involve four streams of work, possibly some of them in parallel.

- Consultation with local engineers on the results obtained so far and the potential uses proposed. This would a useful step prior to the full launch of the results.
- Development of the approach as a tool for Highways Agency agents. If the analysis to date is considered sufficiently promising, this is likely to involve:
  - producing a guidance note on the data available and its potential use
  - completing a full survey of Highways Agency roads
  - checking the repeatability of inspection results – this could be done by repeating in the next survey some of the routes already inspected, or it might be done from the existing videos, using different inspectors
  - considering the scope for regular sample surveys to monitor the state of the network

- Further analysis of the data already collected, including:
  - development of case studies for a range of routes with different characteristics
  - matching Northern Ireland accident and RPS data
  - assessing the potential role of the additional "likelihood" data collected as part of the main survey, in addition to the protective ratings
  - reviewing the scoring regime, particularly for junctions, in parallel with the development of an extended RPS including likelihood factors
  - analysis of data collected for sample of lower tier roads
  - comparison of GB ratings and estimated changes in accident rate with RPS with those obtained in other countries
- Wider roll-out of RPS as a tool for use on all major roads in Britain:
  - more extensive surveys of all British major roads
  - development of protocols and survey techniques, particularly junction scoring
  - development of guidance

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Lynam D, Castle J, Scoons J, Lawson S D, Hill J and S Charman (2007) EuroRAP II Technical Report (2005-6).

Department for Transport (2006) Road Casualties Great Britain, 2005. HMSO London.

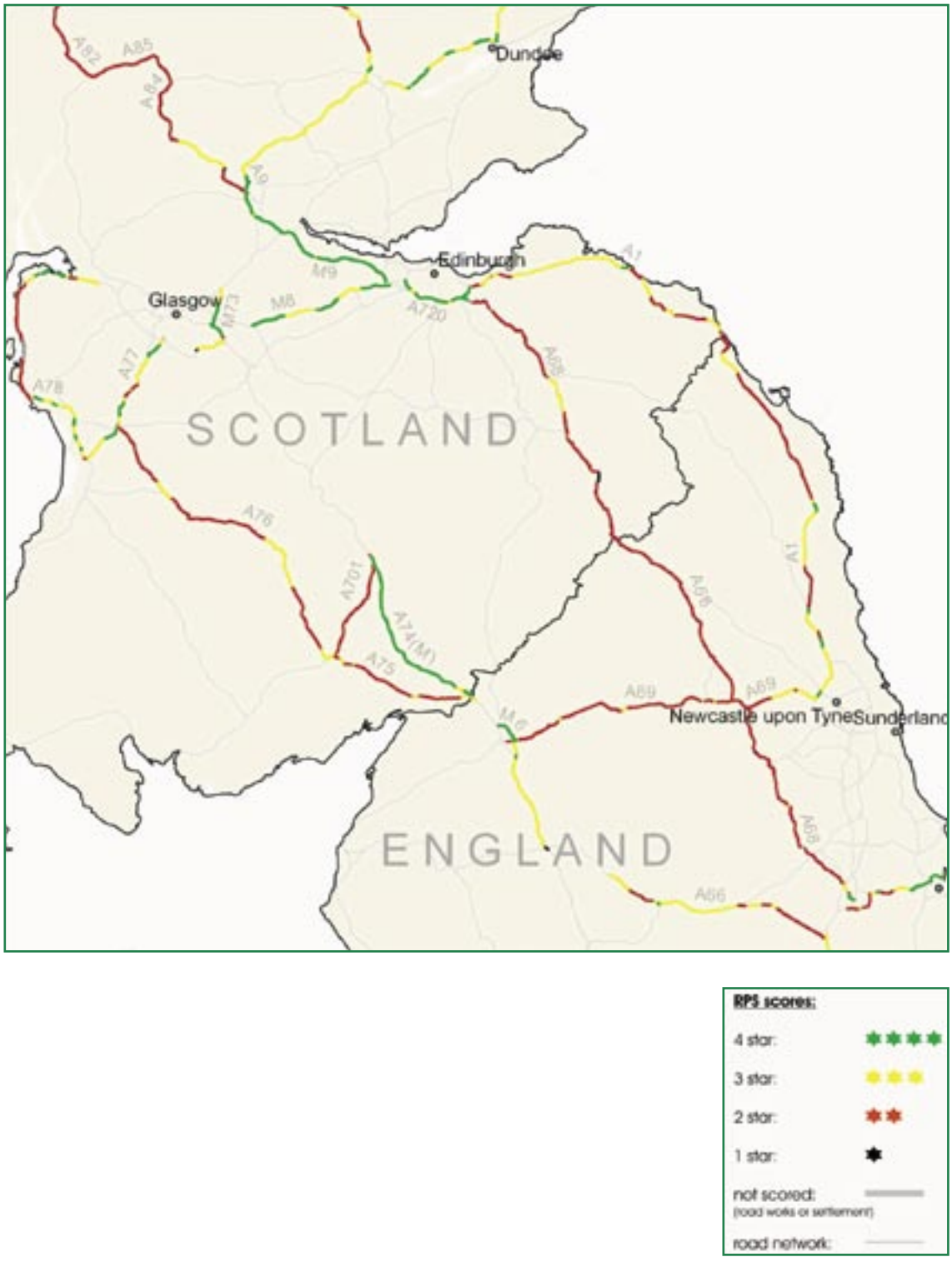
UK trials 2006-07 – total RPS score

UK trials 2006-07 – total RPS score

UK trials 2006-07 – total RPS score

UK trials 2006-07 – total RPS score

UK trials 2006-07 – total RPS score



UK trials 2006-07 – total RPS score

UK trials 2006-07 – total RPS score

UK trials 2006-07 – median score

UK trials 2006-07 – median score

UK trials 2006-07 – median score

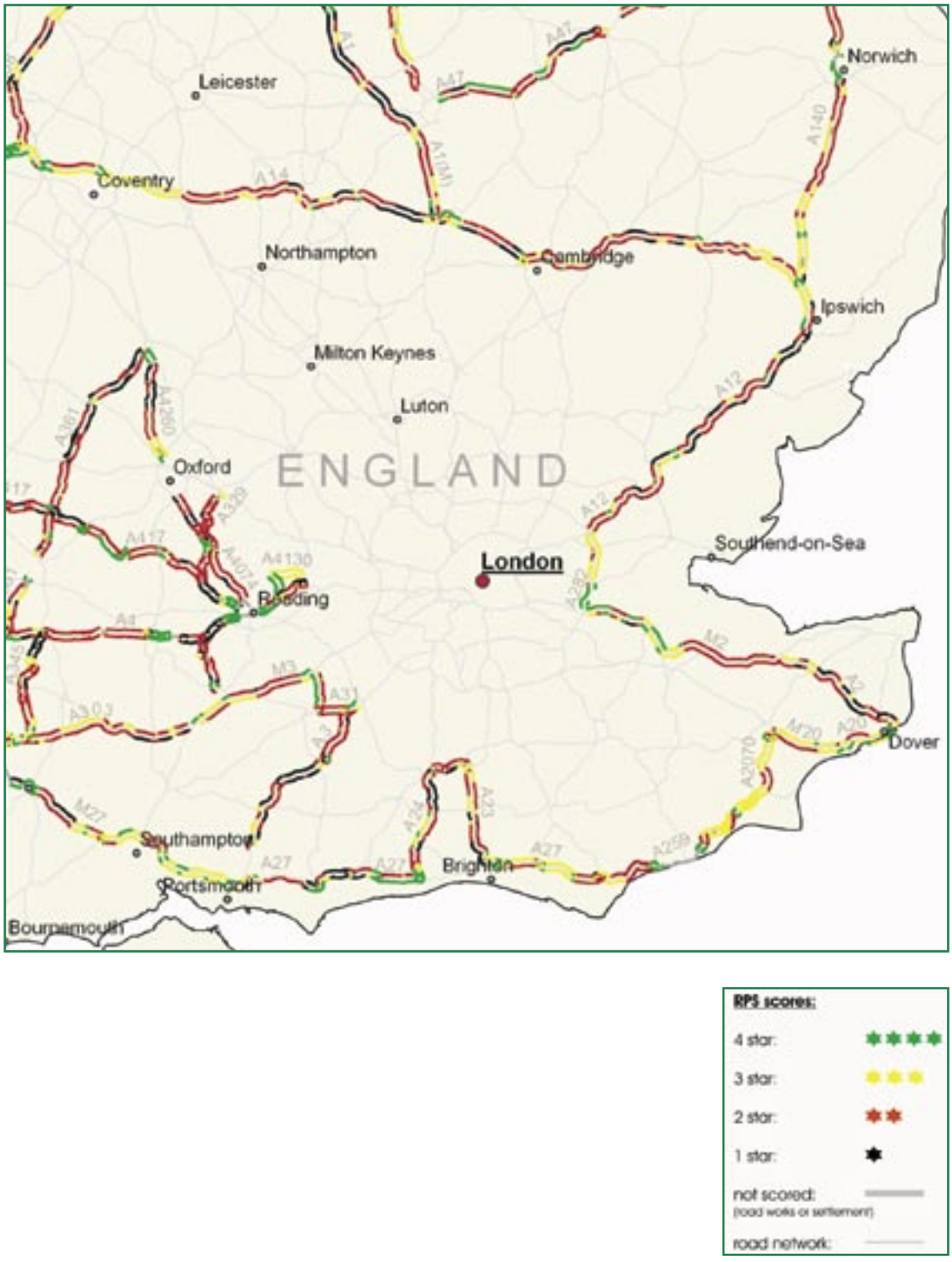
UK trials 2006-07 – median score

UK trials 2006-07 – median score

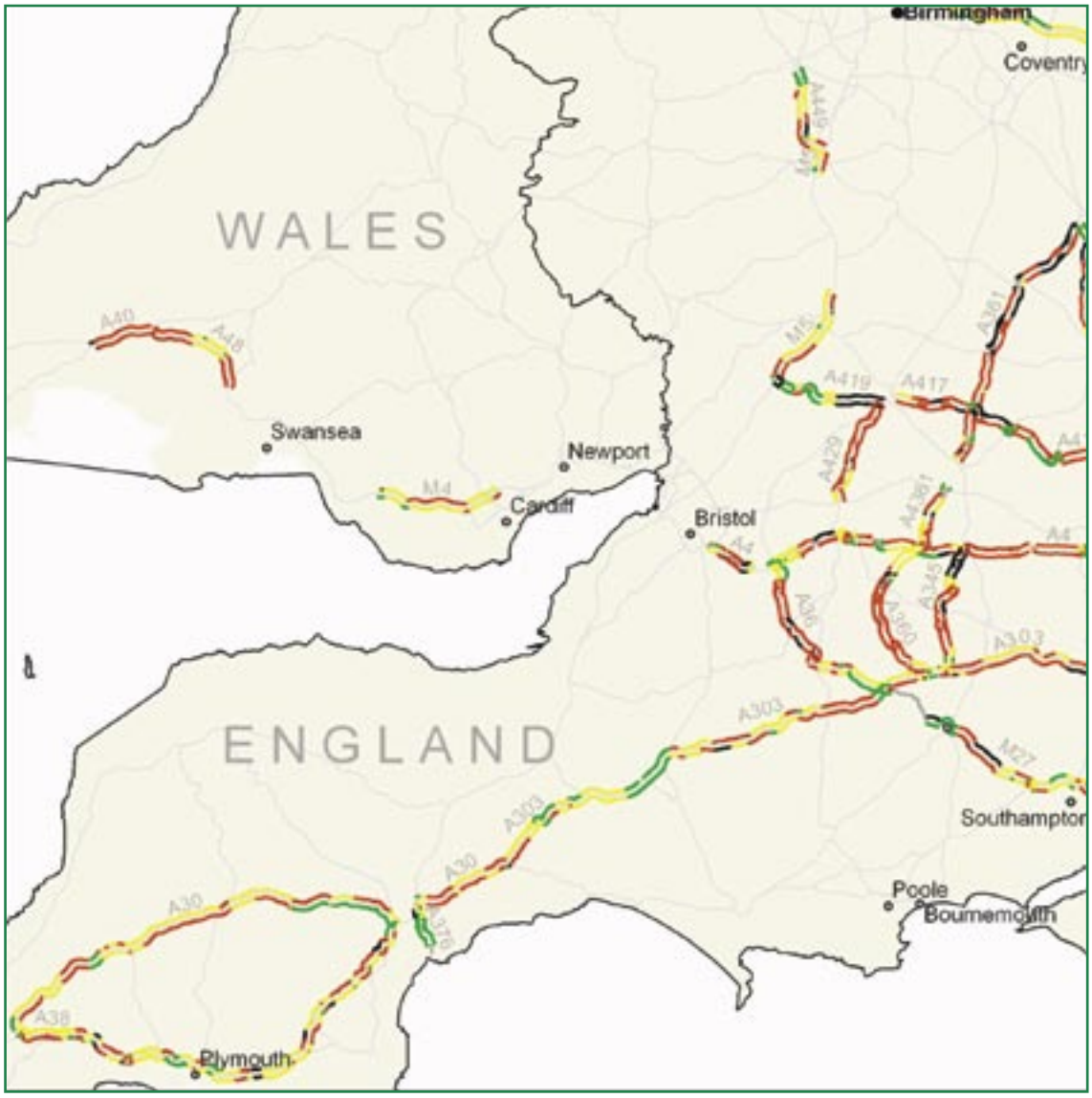
UK trials 2006-07 – median score

UK trials 2006-07 – median score

UK trials 2006-07 – left and right side run-off score



UK trials 2006-07 – left and right side run-off score



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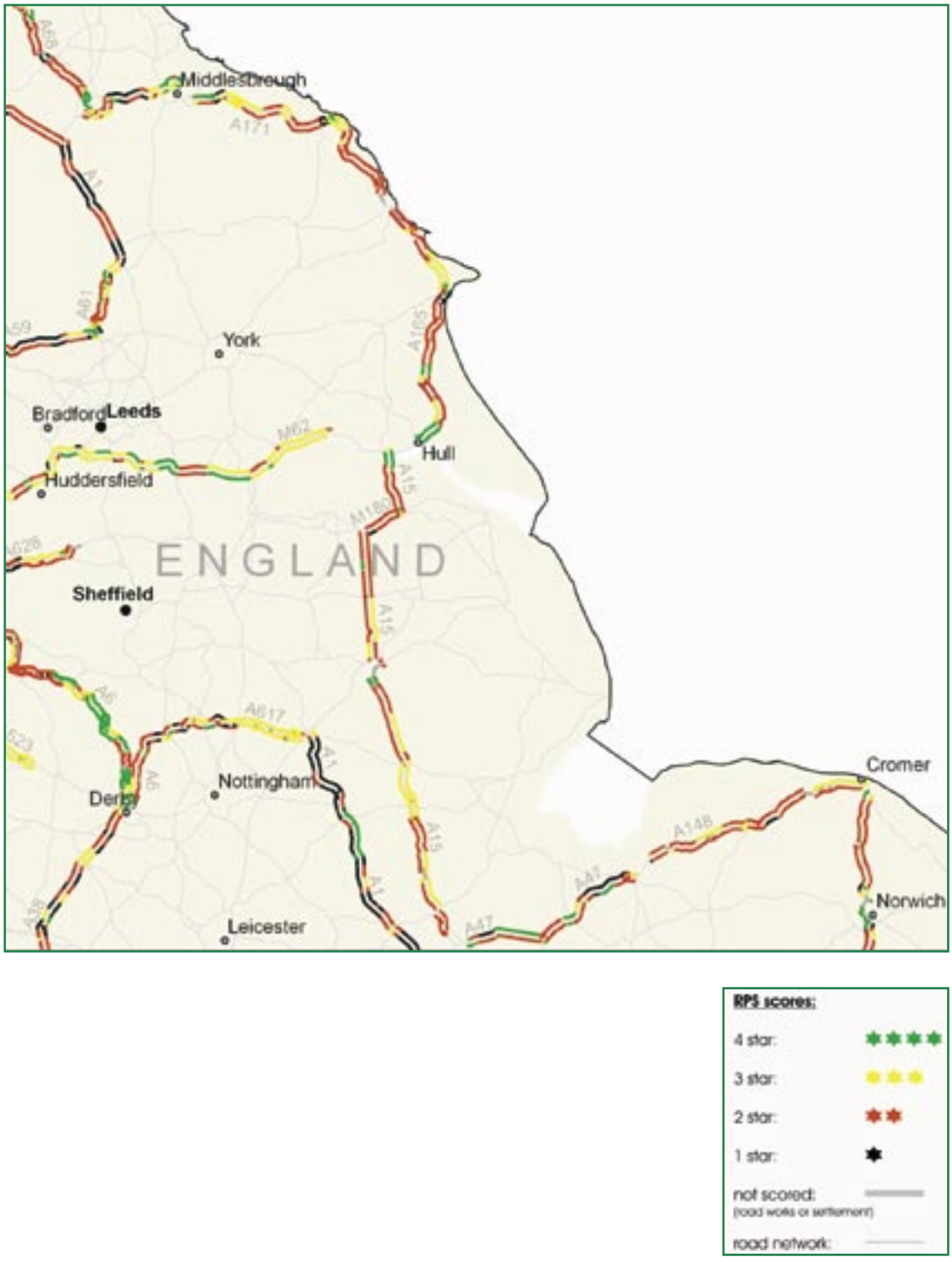
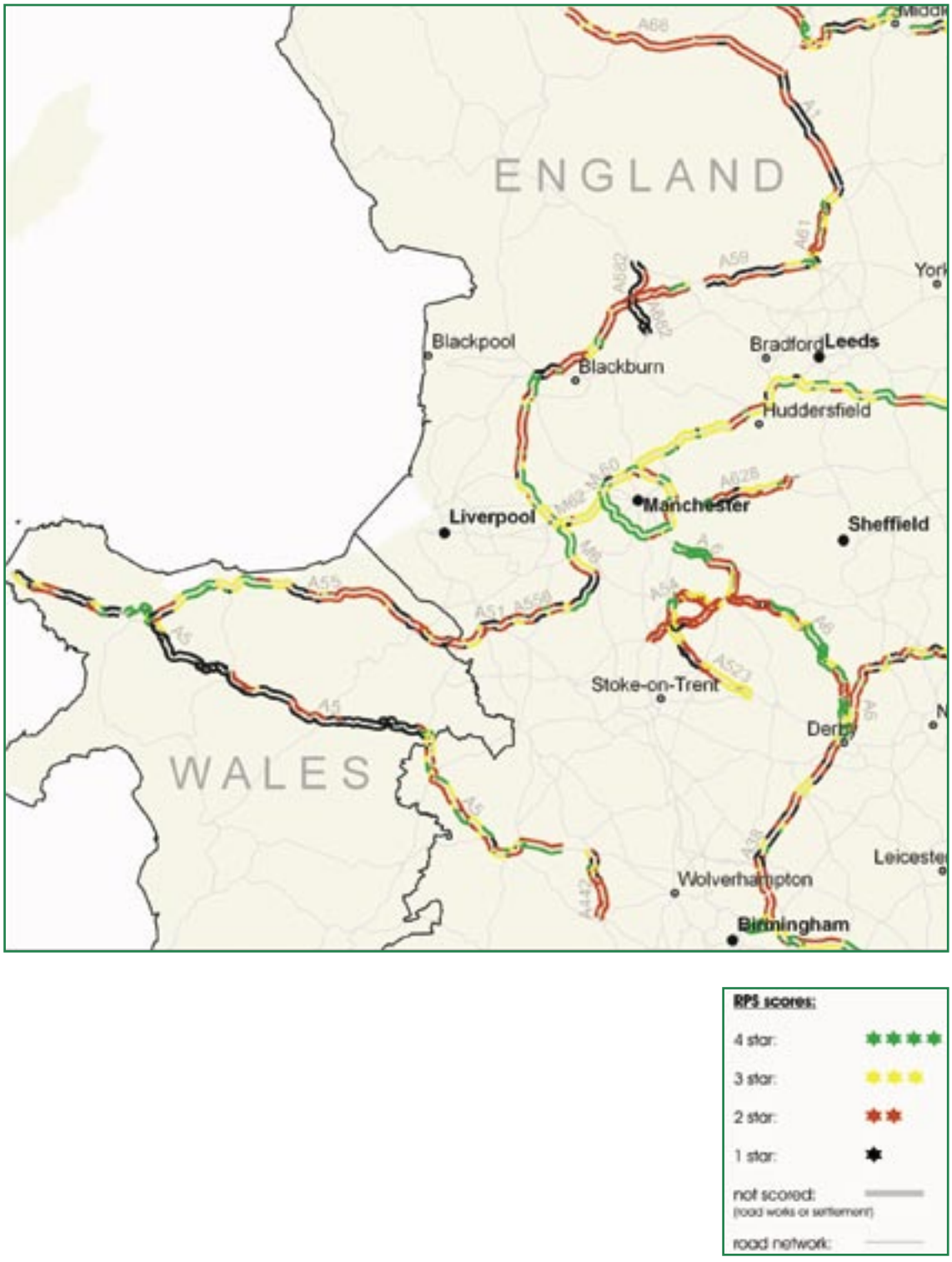


UK trials 2006-07 – left and right side run-off score



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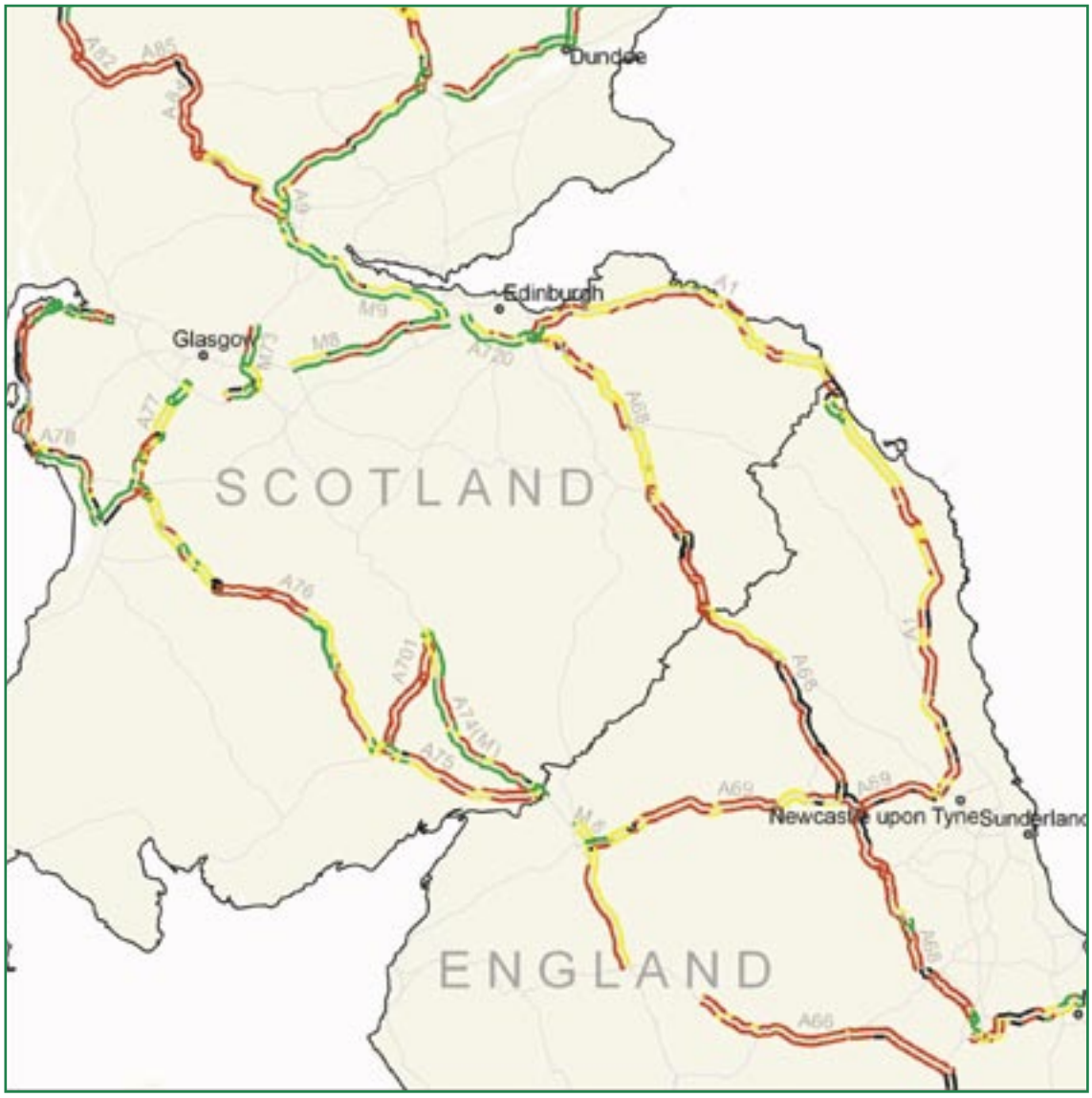
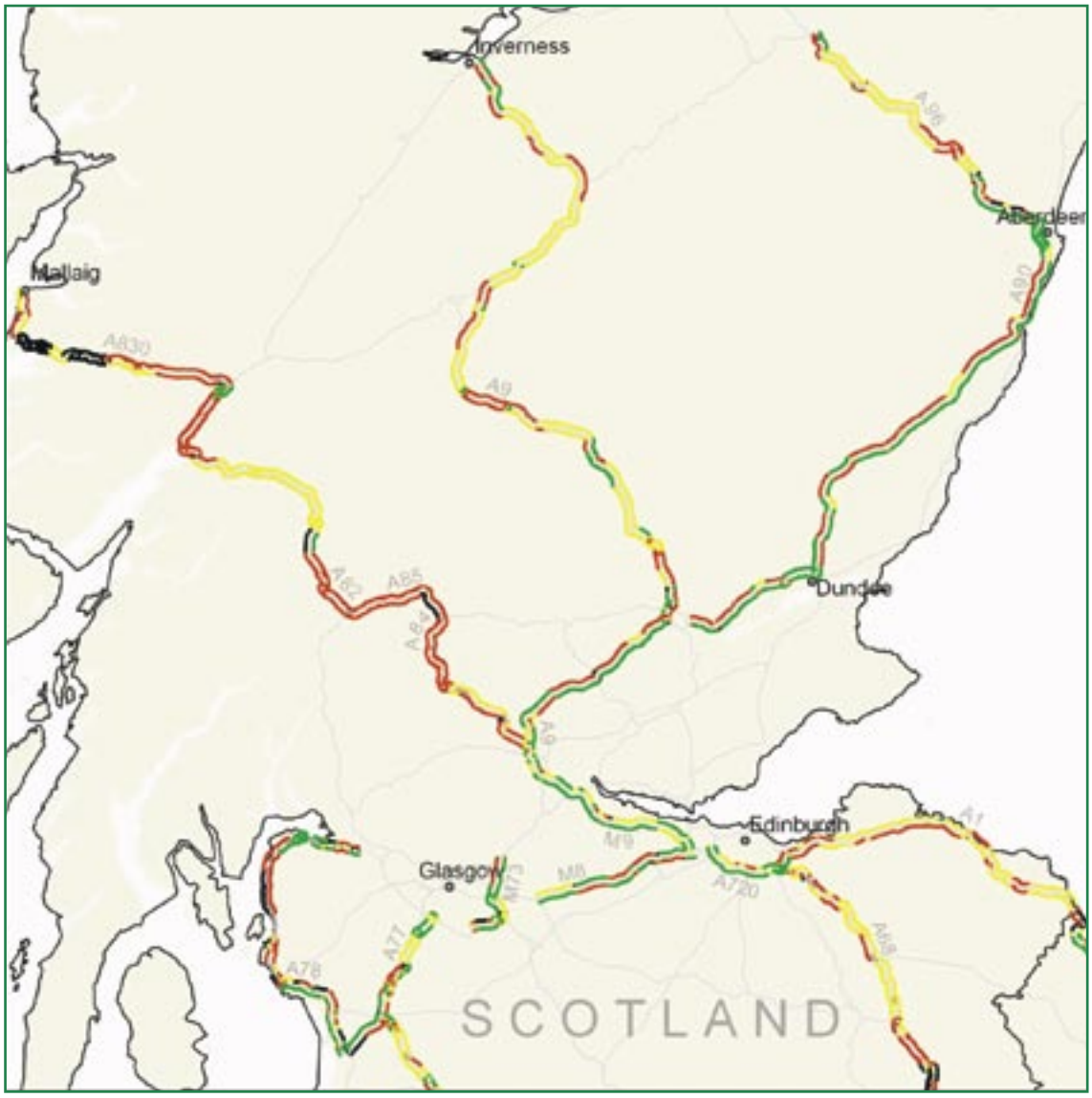


UK trials 2006-07 – left and right side run-off score



RPS scores:

4 star:

3 star:

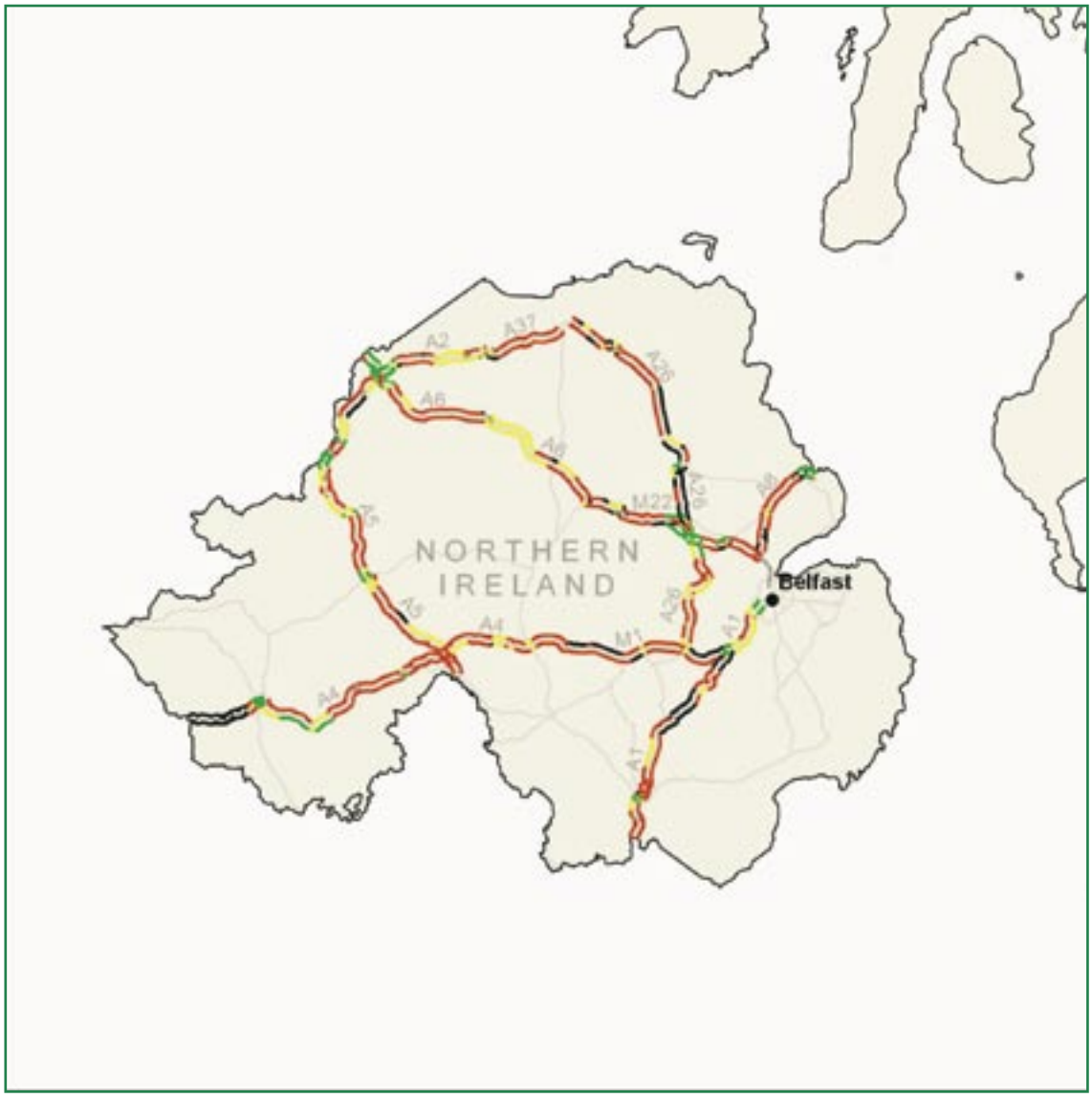
2 star:

1 star:

not scored:
(road works or settlement)

road network:

UK trials 2006-07 – left and right side run-off score



UK trials 2006-07 – junction score

UK trials 2006-07 – junction score

UK trials 2006-07 – junction score

UK trials 2006-07 – junction score

UK trials 2006-07 – junction score

UK trials 2006-07 – junction score

UK trials 2006-07 – junction score

VIDEO STILLS OF ROADS WITH DIFFERENT STAR RATINGS

Appendix B: Video stills of roads with different star ratings

The following are examples taken from the video of the survey route. They have been chosen to illustrate the contents of Table 15 (section 4.6.2).

POOR SIDE SCORES

A1 north of Peterborough (not A1M) northbound carriageway J17–A47. Poor side score due to close tree line soon after end of motorway section

A1M Southbound J15–J14. Poor side score due to tree line

A1 Grantham to Newark. Lay-bys adding to poor side score

A1 Grantham to Newark. Tree line close to edge of dual carriageway

A1 Scotch Corner to Dishforth southbound. Tree line close to edge of dual carriageway. (There was a recent fatal crash on this section of road due to a car hitting tree at side of road.)

A24 Horsham to A272 northbound. Tree line and very large sign not protected by safety fencing

A12 Colchester to Ipswich southbound. Tree line close to edge of dual carriageway

A40 Carmarthen to St. Clears. Poor run-off score due to tree line

A5 A494 to Llangollen eastbound.
Poor run-off score, stone wall as highway barrier, large trees and telegraph poles on apex of bend

A5 Bangor to A494 eastbound. Poor-run off score - vertical rock face

A5. Stone wall and large trees

A5. Residential walls and garage access

A682 southbound – unprotected bridge pier

A682. Edge of building very close to edge of road

POOR MEDIAN SCORE

A264 median dual with no barrier in median; large tree as aggressive object in median

A264 As above, but with narrow median

POOR JUNCTION SCORE

A38 Exeter to Saltash, poor junction score due to short deceleration and acceleration lanes

A38 Lay-by. Lay-bys are also classed as junctions and so do not score well

A90 Aberdeen to Perth southbound. Poor junction score, at-grade right turn on dual carriageway and no acceleration and deceleration lanes

A40 Carmarthen to St. Clears. Poor junction score, at-grade right turn on dual and no acceleration and deceleration lanes

A27 Eastbourne to Lewes westbound. Poor junction score: staggered cross roads without turning lanes

A59 Skipton to Harrogate eastbound. Poor junction score: staggered cross roads without turning lanes

A59. Poor junction score, T junction without turning lane, risk of stationary traffic in outside lane of crawler lane section

RAISING SIDE SCORES

M62 J20-J32. Good run-off score, high percentage of safety fencing

A331 high percentage of safety fencing

A90 Dundee to Aberdeen. High percentage of 10m clear zone

A27 Eastbourne to Lewes. Sections of dual carriageways and lower speed limits effect side scores. Significant percentage of 10m clearance behind hedges

A617. From the A614 to Newark eastbound. 50 mph limit, some 30 mph. High percentage of hedge, then 10m clear zone, some significant trees

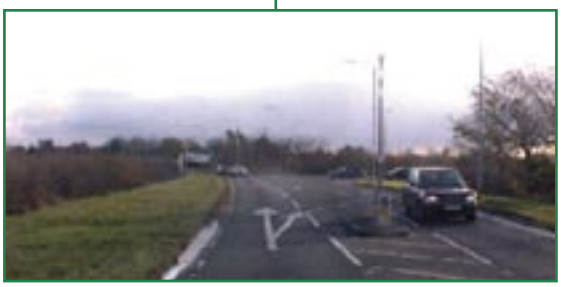
A59 Whalley to Skipton, eastbound. 10m clear zone behind hedges, but occasional large trees

RAISING MEDIAN SCORES

A419 Cirencester to M5 J13 westbound. Improved median score (to be incorporated in later RPS versions) – central hatching

A82 Fort William to Ballachulish. Short section of dual, some 40 mph, short sections of hatching

RAISING JUNCTION SCORES



A617. A614 to Newark eastbound. Some protected turning lanes and traffic signals

A701 Dumfries to M74. Junction has turning lane

APPENDIX C

Worked example: cost benefit for reducing run-off risk on motorways – extension to calculations in 4.6.3

If the example of the run-off rating for a typical 3-star motorway is considered in more detail, it can be shown that 55% of the length of the motorway is rated below 3.0 (i.e. below the higher half of the 3-star rating). Consider upgrading this length so that it scored 4.0. An increase in risk score of 1.0 for run-off is likely to reduce risk by about one fatal and serious accident per billion vehicle km. Table C1 shows estimates of the potential accident saving for each length along this route scoring 1-star, low 2-star etc. The current valuation (Department for Transport, 2006) of saving one weighted KSI accident is about £400,000. The last column of the Table shows an estimate of the Net Present Value of the investment that would be justified for a benefit/cost ratio of one if a project life of 20 years is assumed for the countermeasure (discount rate 3% assumed). The results suggest that very positive returns should be achievable. These estimates of benefits are also likely to be conservative (undervalued) as:

(a) the run-off accident rates used in RPS protocols only include single vehicles but the reality is many two-vehicle accidents also leave the road

(b) the value per fatal and serious accident saved would be increased if slight injury accidents were also reduced by the measure

(c) congestion benefits have been ignored in this assessment and

(d) the life of interventions is typically higher than 20 years

Risk score group (Fig 16)	*Average star rating for group*	*Change in risk if scored 4.0*	*F&S accidents saved per km per year*	*% of length of road with these star values*	*Resultant F&S accidents saved per 100km per year*	*NPV of accidents saved (£k/km)*
1-star	1.25	2.75	0.075	2	0.15	420
Low 2-star	1.75	2.25	0.062	10	0.62	350
High 2-star	2.25	1.75	0.049	23	1.13	275
Low 3-star	2.75	1.25	0.035	20	0.70	200
High 3-star	3.25	0.75	0.021	37	0.78	120
4-star	3.75	0.25	0.007	8	0.06	40

Table C1 - Example of estimate of potential investment justified for run-off countermeasures assuming AADT of 75,000

This table shows that varying investments could be justified depending on what level of safety was sought. For example, between £200k and £420k could be justified per km if only sections of motorways scoring 3-star or less were improved. The cost of safety barrier is typically around £200k per km (if installed on both sides of the road). In practice the costs of interventions should be significantly less than £200k and hence the BCR is increasingly healthy, because:

- economies of scale should result
- some existing safety barrier gaps can be joined up
- safety barrier is an expensive solution and in many cases crash-friendly signs etc. can be installed far less expensively than barrier
- this assessment assumes a 20-year return period. Typically a 60-year period would be used, further enhancing the reported benefits

Summing column 6 for the first 4 rows suggests that 2.7 KSIs per 100km per year can be saved in upgrading side area run-off on 3-star motorways to give a minimum side area score of 3.0. For the sample surveyed, around 40% of motorway scored 3-star. If this were representative of the whole Highways Agency motorway network, then 1300km of motorway could be considered for this improvement. An approximate estimate of the potential saving from improving the whole 1300km scoring only 3-star might thus be 1300 x 2.7 /100 = 35 fatal and serious accidents per year. Greater accident savings are achievable if higher scoring roads were also upgraded to fully 4-star, but rates of economic return would reduce. From the example in table C1, 55% of the length of the 3-star motorways would need to be upgraded. If it were assumed that the cost of upgrading 1km was around £100,000 then the cost of upgrading this 55% of 1300km would be about £72m. The minimum benefits would amount to 35 x £400,000 = £14m, giving a payback period of around 5 years (or a FYRR of about 20%).

In practice, a much more detailed study would be needed to justify investment at any particular site, but these broad, yet conservative, assumptions justify further consideration.

In principle, similar calculations for dual carriageway and single carriageway roads can be derived but are likely to include an even greater degree of uncertainty because the numbers of run-off accidents are very small when considering groups of roads with some star ratings.

This is particularly the case for 4-star dual and single carriageways, as few of the roads attain this rating; thus it is difficult to define a rate for the “target” level of improvement for these roads. The reduction in run-off accident rate is not so clear cut for these roads (particularly for dual carriageways), across the star rating bands, as it appears for motorways; the reason for this is not fully understood.

Nevertheless, estimates can be made of how the benefits from improving these roads are likely to compare with those for motorways.

The key factors affecting the NPV for road sections on different types of road with a particular current run-off score are the traffic flow and the change in accident rate per change in risk score for that road type.

Compared with the AADT of 75,000 assumed for motorways, Table 13 shows the average AADT for dual carriageways to be about 35,000, and for higher quality single carriageways about 12,000. Thus the potential benefit from improving these roads will be lower due to the lower flows. However, although the data on run-off rates do not show a completely consistent change with risk score for dual and single carriageways, they suggest the change in accident rate with improved star rating is higher for these roads than for motorways. This will increase the case for improvement of these roads.

A best estimate might be that compared with a change of 1 (in accident rate per risk score) for motorways, values of 1.5 and 2 might be assumed for dual and single carriageways respectively. Dual carriageway traffic flows are assumed to be about half those for motorways, and for single carriageways about a sixth those for motorways. Taking these two factors together implies that for improvement from any specific risk score, the benefits for dual carriageways sections with that score will be about three-quarters those for motorways, while the benefits for single carriageways will only be about a third of those for motorways.

Using these assumptions, the NPVs (rounded to nearest 5) for the lower class roads are compared in Table C2 with those for motorways for improving run-off score to 4.0.

	Motorways	*Dual*	*Single*
1-star	420	315	140
Low 2-star	350	260	115
High 2-star	275	205	90
Low 3-star	200	150	67
High 3-star	120	90	40
4-star	40	30	15

Table C2 - NPV of accidents saved (£000 per km) on different road types

Thus for example, if it was necessary to obtain an NPV of 200, only motorways with low 3-star or below rating and dual carriageways with high 2-star and below would be improved. No single carriageways would qualify on this basis, although the fact that improving roads with a 1-star score would typically produce a higher change than the average assumed above might suggest the worst single carriageway sections may also justify some improvement. Also there may be a greater length of dual carriageway with high 2-star rating than there is motorway with low 3-star rating, so the extent of investment justified in each road type depends on the proportions of each road type with different scores.

All of these estimates include extensive assumptions and thus should only be used to indicate general relativities.

APPENDIX D

Overall score pie charts (available only at www.iamtrust.org.uk and www.eurorap.org)

APPENDIX E

Links surveyed (available only at www.iamtrust.org.uk and www.eurorap.org)

Star rating roads for safety

The Road Protection Score rates the safety built in to the road, based on how well its design would protect car occupants from severe injury in a collision. This score is used to give each road a star rating varying from 1 to 4, with 4-star representing a road engineered to minimise the likelihood of a severe injury to car occupants.

In these UK trials more than 7000km of road was surveyed. Overall, scores for motorways are significantly higher than for Class A roads – about half of motorways and about 10% of Class A roads scored 4-star. However, 2% of motorways and 42% of Class A roads scored less than 3-star.

The report shows how data from the star rating might be used to extend the current methodology for identification and prioritisation of roads where improvement is justified.

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