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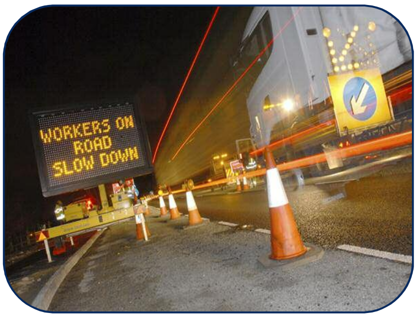

PUBLISHED PROJECT REPORT PPR770

Road Safety Models

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Prepared for: Department for Transport,

Project Ref: RM5212 SO8525

Quality approved:

Su Buttress (Project Manager)

John Barrell (Technical Referee)

Disclaimer

Contents amendment record

This report has been amended and issued as follows:

Version	**Date**	**Description**	**Editor**	**Technical Referee**

ISBN: 978-1-910377-52-9

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Executive summary

Improving safety on non-strategic rural roads is regarded as being a challenging task. This is because crashes and casualties, particularly the less numerous fatal and serious incidents, tend to be dispersed widely across these networks. Rural networks may also have poor infrastructure with high vehicle speeds and low traffic flows leading to sections which have very high safety risks but low crash and casualty occurrence.

These aspects can make identifying the rural road sections which most need to be treated to improve safety difficult. Identifying affordable, appropriate engineering-based solutions is also a challenge since these design fixes generally need to be applied along considerable lengths of road rather than at short, individual "hotspots".

This project aimed to identify ways that the Department for Transport (DfT) could research, and potentially develop tools that could help local authority staff in the UK to better manage road safety on rural roads.

The project conducted a questionnaire of English local authorities which were responsible for rural networks to identify the practices they apply for the management of infrastructure safety. This provided some context which assisted with the development of recommendations. The English local authorities still primarily use crash data analysis to identify safety problems rather than any proactive risk-based approaches[1]. Improving road infrastructure (engineering) was not generally the main way safety was reported to be improved. More respondents reported a focus on hotspot identification rather than managing safety on longer sections or networks. When economic appraisal and evaluation was done, simpler less rigorous approaches tended to be applied.

Twenty one different models or approaches to road safety management which have been developed and used in a range of countries were reviewed and assessed. This was undertaken to identify approaches which might be applied widely by local authorities in the UK to better manage safety on rural roads. Whilst reasonable information was available on the technicalities of the approaches, robust evaluations of their overall effectiveness at achieving clear safety improvements with good economic returns were almost completely absent. This made identifying models which could be recommended or further developed for UK local authority use very difficult. This reflects the general lack of robust evaluation of safety interventions.

The review process did however lead to a comprehensive understanding of the main reactive and proactive approaches which have been developed to manage safety on road networks. This knowledge fed directly into the development of a number of strategies that could be developed by DfT to assist local authorities to better manage safety on their rural road networks.

Five main recommendations have been developed which could be funded by DfT to make safety management easier and more consistent.

These recommendations were:

1. Provision of Safety Performance Functions which indicate expected crashes on different road types for different traffic levels to provide a safety level benchmark.

[1] See 1.2.2

2. Development of a web-based evaluation and economic appraisal tool linked to a dynamic knowledge base detailing cost-effective and best practice engineering solutions to make roads safer through infrastructure but also other non-engineering approaches.
3. Development of an efficient proactive network screening and safety management tool designed for the commonest rural road safety and design problems.
4. Development of technical guidance to assist local authorities to understand new proactive approaches and to improve application of reactive methods to manage rural road network safety.
5. Field testing a range of 6 of the models that were reviewed and were identified as being promising in order to objectively identify those which are easy to apply and which typically could be developed and applied effectively by UK local authorities.

A broad indication of the resource and effort required for development of the main recommendations and a discussion of the potential benefits and difficulties with each have been set out. It is suggested that the first 2 recommendations are funded as the most immediate priority followed by recommendation 3. The returns in terms of better safety outcomes resulting from recommendations 4 and 5 are less clear.

1 Introduction

This document forms the final report for the project 'Road Safety Model' research and provides detailed information on activities carried out to date, findings for the project and suggestions of future actions for the Department of Transport (DfT) to consider.

- Section 1 outlines the technical background and introduces the aims of the project.
- Section 2 provides details of the method developed to assess the road safety models which were selected following an extensive search process.
- Section 3 contains a discussion of the findings of this project.
- Section 4 sets out identified gaps and provides recommendations for how the client can develop knowledge and tools in this area to assist local authorities.
- The Appendices contain the detail of the assessments of the 21 most relevant international road safety models agreed in the Interim Report against the criteria outlined in Section 2.

1.1 Scope

The scope of this report was to identify approaches and methods that have been developed and used to effectively and affordably manage infrastructure safety on rural roads. The definition of relevant local authority "rural roads" is set out in section 1.2. The aim was to identify effective solutions that covered all the main processes required for safety management. The safety management steps range from identifying high risk road sections (network screening), identification of the specific defects, selection of countermeasures and economic appraisal; evaluation and monitoring were also included as they are important but often neglected processes. The approaches reviewed could be fully comprehensive covering all or most of the steps, or tools which focussed on only some of the steps which were intended to be applied in conjunction with others to cover all the required safety management functions.

The specific aim of the report was to identify methods which could be adapted and easily applied by local authorities in the UK to better manage road safety infrastructure investments on the UK rural road network. The review process generated a thorough understanding of a broad range of approaches. Based on this assessment the report aimed to identify strategies and initiatives which might be funded and promoted by DfT to give local authorities technical help to manage rural road safety more effectively.

The project identified a set of the characteristics which would most likely affect overall effectiveness and also ease of adoption of the different models by local authorities. These standardised features were assessed for each method that was reviewed as far as was possible. These features were rated on a simple scale to make comparison of the methods simpler and as objective as possible.

The success of the approach was dependant on the quality, range and objectivity of the information that was available for the different approaches. The subject area is diverse and complex; terminologies and local conditions vary greatly between countries. These issues mean that making clear comparisons and judgements of the approaches was challenging.

1.2 Background

The variety of types of rural road managed by local authorities is diverse. These can include sections of motorways; however here we are focussed on non-motorway dual carriageways, and undivided single carriageway roads.

For general reporting purposes DfT (2014a) defines rural roads as those which do not pass through significant areas of settlement and are less than motorway standard. The technical definition of rural roads applied by DfT for reporting casualty figures in the Road Casualty GB publications is:

> "Major roads and minor roads outside urban areas and having a population of less than 10 thousand."

To identify these roads the DfT definition requires specific GIS (Geographical Information System) datasets and analysis.

These rural roads will generally have posted speed limits of 50 miles per hour and higher; and roads with these higher speeds can be classified as being "non-built-up". The "non-built-up" definition is similar but not identical to the "rural" definition. However some roads in rural areas which pass through areas of very dispersed settlement may be posted with speed limits of 40 or even 30 miles per hour. It has been reported that DfT acknowledges that a clear and useful definition of rural roads is difficult ((Hamilton, K. & Kennedy, J., 2005).

A DfT report (2007) stated:

"Speed limits can be used as a proxy to provide a breakdown between built-up roads [40 miles/hour or less] and non-built-up roads. (However, the classification of roads as urban or rural, based on the Urban Area polygons, has been adopted for traffic estimates since 1993. This is because there has been an increase in the adoption of speed limits of 40mph or less in rural areas in recent years.). Such a breakdown could be used in computing accident rates for different speed limits and for other purposes."

The project is broadly concerned with safety on local authority roads located outside of 30 mile per hour zones associated with urban settlement areas. These roads will generally but not exclusively have posted speed limits of 40 miles per hour and above and can range from motorways to "Unclassified" roads.

The project is not concerned with the Strategic Road Network (SRN) which is managed by Highways England; the SRN includes all the main motorways but also significant lengths of rural dual carriageway and some undivided "A" roads.

1.2.1 Crash and casualties on rural roads

In comparison with the urban network, the occurrence of road fatalities is high on the rural road network given the volumes of traffic carried. In 2013 rural roads (excluding motorways) carried 53% of the total traffic but had two thirds of the fatalities (DfT 2014b). However, a higher relative proportion of the reported serious and slight casualties and incidents are reported on the urban network.

KSI casualties are increasingly becoming the main target of safety efforts rather than the far more numerous slight casualties which have much lower individual social and economic impacts. This is because the Safe System approach, which is being adopted more widely in the UK, has a main emphasis on reducing KSIs.

DfT provides TRL with a copy of the STATS19 crash database for GB, including a marker which identifies those crashes which occurred on the Highways England SRN. These data were used to identify the number of casualties which occurred on rural roads on the SRN, English local authority A roads and other English local authority roads (Table 1), disaggregated by severity.

Table 1 shows that more road deaths occurred on local authority English rural roads designated as "A" class than on other rural English local authority roads. A greater number of KSI casualties in 2013 were generated on rural roads with less than "A" road status. This indicates that if road safety efforts are to target KSI casualties then attention needs to be applied across all the classes of local authority rural roads. However this simple analysis does not take into account differences in total road lengths or traffic flows carried by the different road classes reported in Table 1.

Table 1: Fatal, serious and slight casualties on rural roads (England) in 2013

Severity	SRN A roads	Local authority A roads	Other local authority roads
Fatal	142	395	325
Serious	785	3190	3562
Slight	6114	19313	19987
All severities	**7041**	**22898**	**23874**

(Source: DfT STATS19 database)

The higher rate of fatalities on rural roads compared to urban roads is attributed to a greater tendency of drivers to adopt unsafe speeds (RoSPA 2015) combined with poorer general safety engineering standards on much of the non-trunk network (Hamilton, K. & Kennedy, J., 2005). Reducing the more severe crashes is an important focus of efforts to improve road safety, in line with the Safe Systems approach. The Safe Systems approach is less concerned about the more numerous slight injuries but focuses on reducing KSIs and especially fatalities as a priority. There is also a perception that treating individual hotspots is becoming less viable as their numbers decrease (DfT 2010a).

1.2.2 Approaches to Manage Safety

Currently the main approaches to manage safety across road networks are generally categorised as being either reactive (in response to known safety problems) or proactive (in anticipation of problems occurring due to known 'deficiencies' in the road environment). These approaches are described in greater detail in this section since these terms are used very frequently in relation to the different models throughout the report.

The well-established reactive approach that is based on the spatial analysis of crash data clustering has been used extensively by local authorities in the UK to date. It is best suited to identifying short "hotspots" which may potentially have road safety defects and identifiable numbers of treatable collisions. Typically these hotspots are 30m or less in length or may consist of single junctions or highway features (i.e. bends). Treating clear hotspots cost-effectively is regarded by local authorities as being relatively easy to do since low-cost engineering solutions can usually be readily identified (DfT 2011).

Although no recent research on the issue in the UK could be identified, it is accepted that most distinct hotspots have been treated (e.g. SWOV 2002), DfT 2011); this means that more attention needs to be focused on treating longer road stretches to manage safety effectively to reduce collisions and casualties still further (DfT 2011). Discrete hotspots are particularly difficult to identify on lower flow rural roads, because crash occurrences tend to be more highly dispersed.

The reactive spatial crash history analysis can still identify longer road stretches with possible elevated crash occurrence but the details of the methodology will differ from hotspot methods.

Globally, however, there is growing acknowledgement that these reactive methods are no longer as relevant as newer, more proactive methods to manage road safety. This is partly due to the variability in crash data quality or the lack of spatial crash data, but also due to difficulties which result from the large random component in crash occurrences. This random effect can result in the identification and treatment of hotspot sites which have higher crashes simply as a result of natural variation. This becomes much more of a problem when dealing with small numbers of crashes at identified sites. It can also appear that the treatment of these 'false' sites has been successful since the subsequent crash numbers will generally decrease even if nothing is done to improve the location.

The "Safe Systems" road safety management approach originated in Sweden, and was developed further in countries such as the Netherlands, Australia and New Zealand. It focuses on reducing the most severe crashes. These severe crashes have major social and societal cost impacts compared with the far more numerous slight injuries which have far lower consequences.

Safe System also recommends using proactive approaches to identify and manage the potential risk of crashes occurring as a result of poor infrastructure design before this causes problems and crashes result. The Safe System approach also has a particular focus on reducing the potential severity of injuries when a crash does occur by improving engineering and the road features.

This risk based proactive approach identifies deficiencies in the road environment which are known to be associated with the generation of crashes and higher severity injuries. The main physical risk factors to be found on rural roads are: poor alignment such as unsafe bends; poor sight distances; poor road side delineation; and the presence of aggressive objects close to the roadside (Hamilton, K. & Kennedy, J., 2005).

This proactive approach has the merit that it can identify locations which represent a high risk to road users even where elevated numbers of crashes have not yet occurred. Due to the large random element in crash occurrence it is not always the case that the high risk sites always have higher crashes occurring. Conversely, sites with no real underlying safety problem can have higher crash occurrence. The proactive approach can also be applied when crash data is sparse or absent.

1.3 Project Approach

The aim of this project is to identify the best strategies to provide UK local authorities with standardised methods to assist them in managing engineering safety issues on rural roads. The approaches will ideally be easy to apply, proactive and effective for achieving significant and economically viable improvements in safety.

To gain an understanding of the main approaches being used to manage safety on rural road networks around the world, this project has identified and then reviewed a range of models which are used. Some of the approaches are reported to be suitable for application on a variety of road types with varying flow levels and different cross sections. Some of the models were reported to have been developed specifically for managing lower flow roads. The project aimed to identify models which could be effective on the typical rural road networks which UK local authorities manage or approaches which could be adapted to work on these roads.

An initial literature search identified a range of models, methods, guidance, tools, software packages and programmes which have been developed for, or could be used for managing safety on rural roads. For this project, the term 'model' has been adopted to represent all of these approaches.

In addition, TRL consulted local authorities in England, together with several international research communities of which TRL is a member, to gain a more detailed understanding of the various road safety approaches used domestically and abroad. This process assisted in identifying any less well known, and potentially innovative, road safety models which may be in isolated use, that were not discovered during the literature search process. A summary of the local authority consultation process is given in Section 1.4.

Each model has different data requirements and different levels of difficulty in terms of operation; they also have different levels of effectiveness. From an initial assessment of these aspects, based on available information, the most promising models were selected for detailed review.

The understanding of the approaches used to manage rural road safety enabled the project team to identify gaps in current practices, data and resource availability in the UK which may affect which new approaches may be successful for local authorities.

1.4 Review of Questionnaire Responses

A web-based questionnaire was created using the Smart Survey online tool. The questions were varied slightly for international contacts to ensure they were relevant.

The questionnaire was sent to:

- 90+ English local authority contacts responsible for rural networks;
- the International Road Traffic Accident Database Group (IRTAD) which has over 70 member organisations from nearly 40 countries; and
- Conference of European Roads Directors (CEDR) representatives.

The response rate for the English questionnaire was:

- 16 completed responses
- 5 partial responses
- 18 blank responses

The response rate for the international questionnaire was:

- 28 completed responses
- 11 partial responses
- 31 blank responses

The following summarises the findings of both questionnaires:

- The majority of respondents worked for authorities in areas which had mainly rural roads or an even mix of rural and urban roads.
- The majority of respondents stated that there was 'some activity' related to casualty reduction through investment in safer infrastructure but that it was not the biggest focus for road safety.
- Hotspot based approaches were more common than longer road section analysis for site identification in the UK. To some extent this was the opposite pattern to that reported by the international respondents.
- Several international respondents (who were predominantly from Canada) reported that they compare their roads against safety performance functions. This allows for the number of actual crashes to be compared with the number of expected crashes for a location or road section.
- SCRIM (Sideway force Coefficient Routine Investigation Machine) data which measures the skid resistance of the road surface is used extensively in the UK in addition to crash history data as a factor in road safety decision making. A greater range of alternative road condition data types were used by international respondents.
- First year rate of return (FYRR) was the economic appraisal method used by almost all UK respondents. International respondents showed a more varied group of appraisal methods which tended to be more complex and comprehensive (i.e. net present value and/or cost-benefit ratio based)
- UK respondents used locally developed lists of estimates for road safety treatment costs and effectiveness whereas international respondents had a more varied range of answers and were more likely to use standard national or international sources.
- UK respondents were more likely to state that they evaluated road safety treatments after implementation and none of the respondents reported that they never undertook evaluation.

The questionnaire identified the current approaches around the world but did not uncover any new models that were not already known to the research team from other sources. It did indicate the differences in practices between English authorities and the international contacts that were approached, and identified some challenges that local authorities may face if applying some of the international models that are described in the next section.

2 Assessment Method

This section outlines the approach which was developed to assess the selected road safety models in a consistent and comprehensive manner.

Twenty one models were reviewed in detail to identify and understand their main approaches and to evaluate their characteristics and merits. The review also aimed to identify key aspects that would make the systems potentially suitable for UK use or which would be potential barriers.

The approach comprised three stages:

1. Development of a summary of the model;
2. Assessment of its technical comprehensiveness; and
3. Assessment of its relevance for UK local authorities.

A clear set of procedures and guidance for the assessments of the models was developed and was followed by all reviewers. This ensured that the review process was as consistent as possible and that the results were as comparable as possible.

2.1 List of 21 Road Safety Models

The project aimed to include as wide a range of relevant models in the review as possible. In addition to the broad knowledge of the research team, a number of extensive library and internet searches were conducted to ensure a comprehensive range of models was identified. This final listing was agreed in the Interim Report. Table 2 lists the models assessed and their countries of origin.

Table 2: List of the 21 assessed models

Model	Country / Region of Origin
High-Risk Rural Roads Guide (HRRRG)	New Zealand
Manual for Selecting Safety Improvements on High Risk Rural Roads (HRRR)	United States of America
Systemic Safety Project Selection Tool (SSPST)	United States of America
iRAP Risk Mapping	International
Users' Safety on Existing Roads (SURE)	France (Germany)
Regional Road Safety Explorer (RRSE)	Netherlands
Route Analysis Tool	United Kingdom
PTV Visum Safety	International
Safety Analyst	United States of America
17-38 Spreadsheets for Applying the Highway Safety Manual Predictive Methodology for Rural Two-Lane, Two-Way Roads (17-38 spreadsheets)	United States of America

Model	Country / Region of Origin
HiSafe: Companion Software to the Highway Safety Manual (HiSafe)	United States of America
Interactive Highway Safety Design Model (IHSDM)	United States of America
International Road Assessment Programme Star Rating (iRAP)	International
NetRisk Rating Tool (NetRisk)	Australia
RANKing for European Road Safety (RANKERS)	Europe
Identification of Hazard Location and Ranking of Measures to Improve Safety on Local Rural Roads (IASP)	Italy
Road Infrastructure Safety Assessment (RISA)	New Zealand
Road safety inspection and assessment (RSI / RSA)	International
Australian National Risk Assessment Model (ANRAM)	Australia
Safety Network Evaluation Tool (SafetyNet)	New Zealand
Road Safety Risk Manager (RSRM)	Australia

2.2 Assessment: Summary Development

The first stage of the assessment process was to summarise each model. Each summary includes a fact box outlining key details about the model as well as 2-4 pages of text.

2.2.1 Fact Box

The fact box, as shown in Figure 1, contains a range of information including the cost of the model relating to data, human resources and software / licencing as well as the summary star ratings for the overall technical comprehensiveness and suitability for UK local authority use. These criteria are discussed in more detail later in this section.

Model:	**High-Risk Rural Roads Guide**
Country:	New Zealand
Developer:	NZTA
First released:	2011
Model type:	Risk-based and crash history
Format:	Text-based guidelines which references several established road safety models

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
££	£££	£	★★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	x	✓	-	✓

Figure 1: Example of assessment fact box

In addition, the fact box summarises which of the main processes or steps required to manage safety are covered by the model (ticks and green for yes, crosses and red for no, dashes and yellow for partially).

These key processes or steps considered are:

- Prioritisation of high-risk sections;
- Identification of road safety deficits;
- Generation of potential treatments;
- Economic appraisal; and
- Monitoring and evaluation.

2.2.2 Text

The summary text introduces the main features of the model, such as:

- the background to its development;
- how the model works;
- the data required to run the model;
- where the model has been applied; and
- software/hardware requirements and licencing considerations.

This summary text is designed to allow readers with a non-technical background to understand the subject matter. The summary sheets for each model are provided in Appendix A.

2.2.3 Cost of implementation

The cost of implementation for a road safety model was split into 3 categories. These were:

- Data requirements cost;
- Human resources requirements cost; and
- Software / licencing requirements cost.

These three categories were assigned a symbol to signify the cost level. The values range from **£** (lowest cost) to **£££££** (highest cost). Costs are approximate, relative and based on the judgement of the authors. A review session was held to ensure the costs assigned by different reviewers were comparable between all the models.

These costs are reported twice, once in the summary fact box and once in the relevance of the model to UK local authorities table following the summary text.

2.2.4 Star rating for relevance for UK Local Authorities

The next stage was to assess each model to identify in more detail how easily it could be adapted for use by UK local authorities, based on aspects such as ease of use, issues related to Intellectual Property (IP) rights, data requirements and likely costs of operation.

Thirteen different features were considered in the assessment process; each of these features was scored on a star rating basis to give a standardised and comparable indication of how transferable and suitable a model might be for rural road safety management in the UK. One star indicates that the feature is either not present or represents a major barrier to UK adaption; whereas five stars indicates that the feature makes the model ideal for UK use or represents no barrier (Notes setting out the rational for each star rating assessment are listed in Appendix D).

A better indication of the overall potential of each model for UK adoption has been developed, based on these scored features, and is given in the summary information. Each model was given an overall score, based on the totalled star ratings over all the individual assessment criteria. Full results have been provided in Appendix B.

A value assigned to indicate the relevance of the model to UK local authorities is displayed in the fact box above each summary. The value ranges from ★ (least appropriate or relevant) to ★★★★★ (most appropriate and relevant).

The method of calculating this value was to:

- Average the star ratings for all criteria in the relevance for UK local authorities table found in Appendix A.
- Round up or down to the nearest star at the discretion of the assessment team based on the general impression of whether the model deserved a higher or lower star rating compared to the other models being assessed.

2.2.5 *Star rating for technical comprehensiveness*

The final stage was to assess the model against a list of the most relevant or important methodological and technical aspects of road safety and infrastructure related factors that a fully comprehensive model should address. The list is provided in Appendix C.

An assessment of comprehensiveness and fit was made based on how many aspects each model covers and thus how relevant it might be for use in UK rural road safety management.

A single table has been constructed for all reviewed models indicating whether they take account of each aspect using a tick (✓) for yes or a cross (**X**) for no.

A single value was also assigned to signify the overall technical comprehensiveness of the model. The value ranges from ★ (least technical) to ★★★★★ (most technical).

This summary rating is also displayed in the fact box above each summary.

The method of calculating this was to:

- Review the table of technical comprehensiveness (Appendix C)
- Assign a star rating based on the proportion of ✓ to **X**, ignoring **n/a** within the completed tables

2.3 Limitations of the assessment approach

The quantity and quality of information available on individual models varied. This made it challenging to create consistent summaries and assessments in some cases.

The research team had particular knowledge of some models, since they had either used a particular approach themselves or had been involved in developing the methodology. In these cases, care was taken to ensure that any bias was minimised by subjecting all the summary reports and assessments to scrutiny by other team members. The multiple stage review processes also helped to ensure consistency between the scorings given by different team members.

The aim was to obtain enough information on each model, as economically as possible, to enable a high level but accurate and fair assessment to be undertaken. In a number of cases the team requested further details or clarifications from the model's developers in order to produce a full summary and assessment.

2.4 Available information on Models

Generally, it was possible to obtain good information on the more technical aspects of the models' methodological approaches and data requirements. This information was used to assess the level of experience staff would require to operate the model and how much resource would be needed. Where the available information was very limited, the project team made efforts to contact personnel who had either developed or used the approach in order to fill gaps in knowledge as far as possible.

Information on the overall costs of applying or accessing each model tended to be difficult to identify; a general interpretation has been given based on the research team's assumptions of software costs, staff resource requirements, and equipment or questionnaire requirements etc.

It has been particularly difficult to identify objective and reliable assessments of the models' performances in the field in almost all cases. Related to this, information on how widespread a model has been, or is being, applied has also been difficult to identify. In such cases, colleagues from the particular country who may know details about the specific model were contacted.

3 Discussion

Managing road safety on the non-built-up or rural road network, which is the responsibility of local authorities, is generally regarded as being challenging. The non-strategic rural road network can have low flows and therefore few casualties despite being high risk for road users. It is easier to justify engineering improvements on roads which have higher flows and therefore generally higher crash densities because the potential for reducing casualties mean the potential for economic gains is much higher. However, a significant proportion of KSI crashes and especially road deaths occur on non- strategic rural roads. A significant number of KSI crashes occur on rural roads of less than A road status.

KSIs are the main target for the Safe System approach rather than the more numerous slight injuries and crashes. The dispersed occurrence of the scarcer severe crashes means that identifying stretches of road that have clear safety issues can be difficult. Improving rural road safety therefore tends to require that longer stretches of road are treated for systematic design problems. As a result, developing appropriate, affordable and cost-effective countermeasure schemes is also problematic.

This review process has provided an in-depth understanding of key aspects of a wide range of approaches which are applied to manage road safety on rural road networks. This has led to clear recommendations on options that could be developed or adopted to assist UK local authorities in managing this difficult problem better.

The quality of the information available on the different models was variable and material for some important aspects has been consistently limited or absent. This has meant that identifying specific models which are clearly proven to be highly beneficial to the process of identifying and treating longer rural road sections has not been possible.

However, an understanding of the strengths and weaknesses of the individual models has been developed, allowing useful comparisons between them to be made.

Some promising models have been identified by this study. However, further investigation would be needed in order to fully assess how these models would perform on the UK target roads and to identify how much effort and money their operation would require.

3.1 Overview

There were some clear, broad categories to which the different models could be relatively easily assigned. The categorisations are based on whether the models are predominantly reactive or proactive in their approach.

The categorisations for the models are given in Table 3.

Table 3: The 21 models categorised by their broad approaches

Guidance (Section 3.2.1)	Mixed (Proactive & Reactive) (Section 3.2.6)
• HRRRG – New Zealand • HRRR – US • SSPST – US	• ANRAM – Australia • SafetyNet – New Zealand
Proactive (Section 3.2.3 - 3.2.5, 3.2.7)	**Reactive (Section 3.2.2)**
• iRAP Star Rating – International (3.2.3) • NetRisk – Australia (3.2.3) • RANKERS – Europe (3.2.3) • IASP – Italy (3.2.4) • RISA – New Zealand (3.2.4) • RSI & RSA – International • (3.2.5) • RSRM – Australia (3.2.7)	• iRAP Risk Mapping – International • SURE – France • RRSE – Netherlands • Route Analysis Tool – UK • PTV Visum – Germany • Safety Analyst – US • 17 – 38 Spreadsheet – US • Hi-Safe – US • IHSDM – US

3.2 Models by category

The following sections give a general outline of the approaches and some key points about the individual models. They are reported in sections according to their main approach categorisation.

Some of the main issues identified which may have relevance for developing and improving UK local authorities' practices are also given.

3.2.1 Rural road management guidelines:

- High Risk Rural Road Guide – New Zealand (A.1)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
££	£££	£	★★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	X	✓	-	✓

- Manual for Selecting Safety Improvements on High Risk Rural Roads – US (A.2)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£	£	£	★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	✓	-	-

- Systemic Safety Project Selection Tool - US (A.3)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£	££	£	★★★★	★★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	✓	-	-

These guidance documents (the High Risk Rural Management Guide and Manual for Selecting Safety Improvements on High Risk Rural Roads) are comprehensive and cover a range of methods that can be used to manage road safety on rural roads. They recognise that there are many options of doing this and that data and resource availability can vary significantly. This data and resource availability determines which options are practical.

Rather than identifying road sections which may have a safety problem based on patterns of all crashes, the Systemic Safety Selection Tool takes the approach that screening networks separately for crashes of particular sub-types will identify sections which have clearer and more treatable problems. For example, identifying stretches where there are high rates of single vehicle run-off road crashes may indicate that the alignment and delineation are poor, or that sections identified with high head-on collision occurrence may require widening or better centre-line treatment may need to be provided.

Some key conclusions identified which could benefit safety management for UK local authorities from reviewing these guidance documents are:

- Development of clear guidance and recommendations on the best approaches for local authorities could help to encourage better and more consistent approaches to manage rural network safety;
- Screening networks on the basis of crash types with common causes may have merit in the UK;
- Guidance can also help to explain the benefits and requirements of the proactive approaches.

The provision of guidance material to increase awareness and understanding of proactive approaches would be particularly useful for local authorities if it was developed in support of a risk based software system which was readily available to staff. This software could provide a practical methodology for identifying the safety risks associated with infrastructure on typical rural roads and would ideally have low operation resource requirements and minimal needs for flow data.

3.2.2 *Reactive approach (using crash data)*

- iRAP Risk Mapping – International (A.4)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
££	££	££	★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	X	X	-	-

- SURE – France (A.5)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	£££	£££	★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	X	✓	-

- Regional Road Safety Explorer – Netherlands (A.6)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	££££	££	★★	★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
X	X	-	✓	✓

- Route Analysis Tool – UK (A.7)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	££	£££	★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	X	X	X	X

- PTV Visum – Germany (A.8)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	£££	£££	★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	X	✓	X

- Safety Analyst – US (A.9)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	££££	£££££	★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	✓	✓	✓

- 17 – 38 Spreadsheets– US (A.10)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
££	££	£	★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	X	X	X	X

- Hi-Safe – US (A.11)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	££	££££	★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	X	✓	✓	X

- IHSDM – US (A.12)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	££	£	★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	X	X	X	X

The reactive crash data analysis approach is currently the most commonly used method. These reactive models are used most successfully on higher flow roads where there are more crashes, though the crash risk may be lower. The use of reactive screening on roads where crash numbers are higher is less subject to statistical problems resulting from the variability in crash occurrences.

Many of the methodologies of these models go well beyond simply identifying higher densities of crashes along longer road sections. They use more sophisticated methods to identify abnormally high risk sections by comparing crash numbers at locations to expected normal rates. This enables better identification of those sections that warrant treatment as a priority and those sections where the potential for reducing crashes may be highest.

The approaches generally have a strong emphasis on analysis of the crash characteristics from problem stretches to help identify the underlying safety problem and so to identify appropriate treatments. This is an approach that UK local authorities might be able to readily adopt since it a well-established element of hotspot treatment.

Research for the Highways Safety Manual (HSM) developed a range of Safety Performance Functions (SPFs) for main road types including the target lower flow undivided rural roads. These SPFs are simple but useful general relationships that are developed between flow and crashes for average road types.

The expected crash number estimated by the SPF equation can be compared with the actual crash rate from a road section to identify whether it has excessive crashes.

The SPFs are also used in conjunction with some well-researched US Crash Modification Factors (CMFs) for the critical road engineering features to identify optimal designs. This should result in good crash reductions as their effectiveness is well-established. These fundamental SPF models and CMFs are built into a variety of different software packages of varying complexity and user friendliness to assist with design decisions.

The US methods 17-38 Spreadsheets, Hi-Safe and IHSDM all use the HSM SPFs and crash data to assist personnel in identifying appropriate road safety infrastructure design improvements.

The PTV Visum Safety design planning tool adopts a very similar approach.

- The availability of robust Safety Performance Functions for lower flow UK rural roads could greatly help local authorities to screen for longer sections where excessive crashes are occurring;
    - However reasonable flow data is required for this to work well.
- Research to produce a list of effective countermeasures for the typical infrastructure problems of lower volume rural roads would greatly help local authorities to treat problems effectively;
    - This could promote consistent approaches from area to area, making it easier for drivers to identify the behaviours expected of them on unfamiliar roads, thus promoting safety;
    - An agreed list of Crash Modification Factors for countermeasures relevant to UK situations could be identified;
    - General costs for implementation and maintenance measures could also be identified to feed into local authorities' economic appraisal practices.

iRAP Risk Mapping plots Killed and Serious (KSI) crash density (crash rate per KM) and KSI crash risk (crashes per vehicle-KM driven) to identify extended road sections with higher risk. This approach may not be appropriate where flows, and hence crash occurrence, are low, since the variability in crashes will be problematic (as described in relation to the iRAP approach later in this report) unless very long sections are mapped. Currently this mapping is only done for UK motorways and 'A' roads where flow data availability is more consistent.

SURE plots the crash cost per kilometre on similar sections and compares this to the crash cost density for roads with the same basic characteristics but the best engineering design. Low traffic volumes and related lower crash numbers may make this method less appropriate for use on lower volume roads.

- Risk mapping using crash rates, risks and costs may help local authorities to identify longer sections with safety problems on lower volume UK roads;
    - The potential of these approaches on lower volume rural roads could be assessed relatively easily;
    - The availability of reliable flow data on road less than "A" level may limit their usefulness.

Safety Analyst is comprehensive and sophisticated; it also includes the best facility for before and after evaluation of any of the models which were reviewed. However a significant financial effort went into developing the software and it is relatively expensive to use. This model systematises all the management steps and allows access to advanced, best practice approaches for road screening and evaluation and monitoring.

Amongst the mainly reactive approaches reviewed, this model is closest to the comprehensiveness of iRAP Star Rating.

The Regional Road Safety Explorer model is primarily an area/state level tool. It was included because some of the literature indicated that it could be used to identify treatments for specific road sections. However, this is not true for lower volume roads due to data limitations. It is one of the few road safety tools to emphasise evaluation as a main function.

The North Yorkshire County Council Route Analysis Tool is interesting because it is a UK development. It is a custom developed tool for identifying longer road sections which have statistically higher numbers or rates of crashes than surrounding sections.

3.2.3 Proactive risk assessment (video based)

- iRAP Star Rating – international (A.13)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££££	££££	££££	★★★★★	★★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	✓	✓	✓

- NetRisk – Australia (A.14)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	££	£££	★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	-	x	x	x

- RANKERS – Europe (A.15)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	£££	££	★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	x	✓	-	x

Video based proactive risk assessment involves rating the severity of road features from video images collected by a survey vehicle. This approach can be far quicker for network level assessment than direct inspection of roads (driving or walking based) to identify hazards and score risks.

iRAP Star Rating is the most well-established method of this type. It uses the most comprehensive rating form with the greatest number of features rated for risk. Rating is done over 100m road sections. iRAP is extremely comprehensive in its scope and is built on the best available research.

Ideally it would be useful for local authorities to run iRAP on much of their rural network. iRAP protocols are designed to be valid for lower volume roads. However, its requirement for extensive flow data and the demanding scoring process may make its application difficult for use on networks with less than 'A' road status.

It has been trialled recently on high risk 'A' road sections in two local authority areas with flows of around 6,000 vehicles per day. The countermeasures suggested for one scheme had good Benefit to Cost Ratios (BCRs) (between 2 and 11) over 20 years but were relatively expensive (£3 million).

NetRisk assesses a smaller number of road features and is therefore simpler than iRAP.

RANKERS adopts a much quicker and simpler rating process than the other two models and scores over much longer road segments which leads to coarser results.

3.2.4 Proactive risk assessment (inspection based)

- IASP – Italy (A.16)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	££££	££	★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	X	✓	X

- RISA Assessment – New Zealand (A.17)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	££££	££	★★	★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	X	-	X	X

The field based inspection for risk assessment method involves one or two personnel being driven along the route at relatively slow speed and scoring the features in real time.

It has advantages in that personnel gain a better understanding of the hazards but it is far more time and labour intensive than desk or video based risk assessment.

The IASP model was developed specifically to identify risks on low volume rural roads and it may be suitable for use on shorter networks. Two inspectors rate a limited set of features as safe, moderately risky or very risky over 200m sections. Compared with iRAP, for example, the data collection task and data requirement is minimal. However, inspection is less efficient than video analysis and the results are relatively coarse.

RISA data collection and rating is also onerous, requiring three staff to drive kilometre sections four times in order to do the rating.

- It would be useful to see if these inspection based approaches could be applied in a more targeted way than iRAP (for example) by UK local authorities.

There is a fairly clear gradation in the complexity and data requirements for these main risk based video assessment and inspection approaches.

For example:

- iRAP requires amongst the greatest input and effort in terms of data collection and the assessment of the risk of design and road elements. A large range of elements are reviewed and scored over 100m road sections. Detailed flow and speed data for a range of road users is needed.
- The Italian IASP proactive system requires two coders to drive routes but scores a much more limited set of road attributes than iRAP Star Rating, for example, over 200m sections.
- RANKERS scores the risk of road features for limited data over 1.5km sections.

The differences in the data collection effort required means that there are big differences in the overall costs of the different models and corresponding differences in the quality and use of the output.

3.2.5 *Proactive road safety assessment and inspection*

- Road Safety Assessment and Inspection - International (A.18)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
££	£££	£	★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	x	x	x

Road inspection techniques can identify the most detailed information about a road safety issue but are generally considered less suitable on a network level. It is recommended that a network level reactive or proactive screening approach is used first to identify the highest risk sites and then a formal road assessment or inspection is used to investigate the section further.

3.2.6 Mixed Reactive and Proactive approaches

- ANRAM – Australia (A.19)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££££	££££	££££	★★★★	★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	✓	✓	x

- SafetyNet – New Zealand (A.20)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££££	£££	£	★★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	-	x	x	x

The mixed approaches from Australia and New Zealand combine analysis of crash history with risk assessment of road features to identify high risk road sections; this is a relatively new concept.

ANRAM is the most comprehensive as it seeks to use the more appropriate of the two methods (using crash history or infrastructure risk) based on traffic volumes on the road considered. ANRAM gives greater weighting to the infrastructure risk analysis (based on the iRAP vehicle occupant star rating models) when the traffic volume is lower because crash numbers are lower and less 'statistically reliable' than when traffic volumes are higher. Results for vulnerable road users are not currently included in the ANRAM model.

SafetyNet is predominantly a crash history based method but also includes an infrastructure risk method (based on the iRAP - KiwiRAP assessment). This method was specifically developed to help personnel rank segments with similar levels of priority (assigned by KiwiRAP alone) better by using a weighted average of a range of screening analyses results.

3.2.7 Additional Tools

- RSRM – Australia (A.21)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	£££	£££	★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
X	✓	✓	✓	-

Road Safety Risk Manager is a tool for cataloguing road safety hazards on specific sections after they have been identified. It helps with treatment selection and economic appraisal. It is not used for screening networks and requires input on road features from other models or from video of the road.

4 Conclusions

The remit for this project was broad. The key requirements were to capture the fundamental features and effectiveness of a range of existing methodologies used to manage network safety; to use this review process to make an assessment of their potential for use by local authorities; and to identify gaps in knowledge which require further investigation. The aim was to identify cost-effective solutions that DfT could develop and promote that would make rural road safety management by local authorities more consistent and effective.

There is a range of well-developed reactive and proactive approaches available in countries where national and local road authorities are addressing the problem of crashes on rural networks in a coordinated way. Development of these approaches has generally been funded at the national (central) level (suggesting their endorsement by government) and their more open availability to practitioners may encourage their greater uptake and use.

Objective and rigorous evaluations of the effectiveness of the different approaches were found to be largely absent which made clear judgement of their relative merits very difficult. This has made recommending a single method for adoption for local authorities challenging.

UK local authorities would potentially benefit from having access to a range of well researched information and guidance on best practice for applying reactive and proactive methods to manage rural network safety. The UK lacks the availability of unified national information and guidance to assist practitioners; these types of materials are available to staff in the US, Australia and New Zealand for example.

The availability of clear centrally researched guidance on how crash data can be best used for the identification of longer stretches of road, or routes, which have excessive crashes would help local authorities greatly. In addition a thoroughly researched list of measures which are both effective and economically efficient would assist staff to treat stretches more successfully once problems have been identified. Guidance on the appropriateness of individual measures for treating specific safety problems would assist practitioners in the selection of better solutions and could improve consistency of the road environment for drivers across the UK.

4.1 Results

There are a number of approaches that were identified that could be employed by local authorities depending on the resources available (data, human and financial). Whilst a large amount of information has been analysed and many diverse models reviewed, this did not give any clear 'winner' in terms of a single clearly appropriate standard approach that can be readily recommended for UK local authorities.

The great differences between the detail of the models mean that direct comparisons of them (even for those that adopt broadly similar approaches) are difficult and it is also hard to make clear value judgements on the merits of one model over another. The original intention of the project scope was to use any existing evaluations of the typical economic returns achieved from applying the different models to identify which systems were most effective. No such clear evaluations were found during the literature search.

It was apparent that the levels of effort and amount of supporting data required to initially screen networks to identify problem sections varies greatly between different models. The impression is that more intensive and detailed the information on the network that is gained at the initial screening stage, then the better the potential identification of the problem should be, leading to better safety outcomes. However, this cannot be verified because of the lack of evaluation of the success of the outcomes achieved by using the different methods.

What was sought was a method that would be a good balance such that the effort to screen the network was not too great and the understanding of the network problem locations and characteristics was still good enough to develop appropriate solutions. This would then represent the proactive "optimal" approach.

As stated, the required clear and impartial information indicating the overall effectiveness of the different models is almost completely absent from the literature. Significant effort was made to identify any clear evaluations that indicated what kinds of Benefit to Cost Ratios were achieved by application of the different models by practitioners.

In practice the methods generally used and applied by local authorities and road authorities internationally to manage safety are seldom validated comprehensively by checking that predicted BCRs are achieved or that the solutions implemented result in the expected or predicted crash or casualty reductions.

For this reason the project approach gave particular emphasis to the issue of whether the models incorporated economic appraisal and monitoring and evaluation.

4.2 Current gaps

There are several major gaps in knowledge and the availability of systems to support UK local authority staff in identifying and treating road safety problems on longer sections of rural roads.

It is apparent that greater central funding for research in the US, Australia and New Zealand for example has led to the availability of a range of systems which can be used to assist staff specifically in screening networks, prioritising identified stretches and then identifying appropriate and cost-effective solutions.

The key reactive methods available in the US are tools based on the HSM research and knowledge.

There is a range of primarily proactive options and methods available to authorities in Australia and New Zealand.

4.2.1 UK knowledge gaps

Local authorities are generally approaching the identification and treatment of longer road stretches with safety problems using a diverse range of methods at the present time. This was a finding that the client identified from consultation with local authority staff and this was a motivation for undertaking this project. A questionnaire circulated to stakeholders for this project indicated that approaches are still primarily reactive; relying on analysis of crash data to screen for possible sites. This interpretation of the situation is supported by a thread of very relevant discussion amongst Local Authority staff on this issue which was conducted on the "Road Safety Knowledge Centre"[2] web site.

Contributors to this discussion outlined a wide range of reactive crash analysis methods which are being applied. Some use flow data to highlight sections with high crash risk rates, using a wide range of standard site lengths; these approaches are therefore extensions of standard hotspot analysis. The methods are not novel and local authorities can already apply such approaches.

Some standard recommended methods to assist Local Authority personnel to screen reactively for longer sections and to prioritise these in more consistent ways would be extremely useful.

In the United States there is a range of nationally available tools which make use of Safety Performance Functions to assist staff to screen and prioritise sites with high crash rates. This kind of approach has been applied by some UK Local Authorities in the past using standard crash rates (rather than SPFs) derived locally as a comparison base rate for road types. A better reactive approach is based on the availability of SPFs which can be used to test or identify road sections where the number of crashes may be higher than expected;

- There are no current, reliable SPFs developed nationally for UK road circumstances.
- A major gap is that there is no clear knowledge of what measures are most effective in cost effectively treating longer stretches of road.

A further but related gap which applies to the UK and also more widely is the lack of robust monitoring and evaluation (e.g. before and after tests for crash number changes) once measures have been applied (DfT 2011). This is probably because local authorities lack the time and resources to do this properly and consistently (TSC 2015). The statistical approaches to do this rigorously are also technically challenging.

This evaluation information is used to develop the required Crash Modification Factors which help practitioners choose appropriate treatments and to do economic appraisal. These CMFs are also involved in the development of many of the advanced proactive approaches.

There have been attempts to share this experience between UK local authorities (e.g. Molasses) but these have not been sustainable. There are a variety of reasons for this such as reporting bias (positive results are more likely to be reported), the additional work load required to provide this information and, in some cases, a lack of robustness of the evaluation method.

The treatment of stretches of road using engineering improvements requires a higher investment level than the treatment of hotspots (see RSF 2015, TSC 2015). Whereas effective measures may be relatively cheap to implement at discrete hotspot sites, applying these over extended stretches of roads becomes expensive.

- Indications are that effective engineering measures for treating road stretches could require much higher capital investment than traditional hotspot treatments or maintenance related measures;

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[2] http://www.roadsafetyknowledgecentre.org.uk/help-forum/559.html

- If this is really the case, the level of funds that could realistically be available to treat lower volume road stretches, needs to be identified.

The greater resources that are required for route and network treatment schemes compared to hotspot treatment also requires more rigorous economic appraisal than is generally applied by local authorities currently (See Hill, J. & Starrs, C. 2011). The questionnaire of English local authorities conducted for this project identified that local authorities primarily rely on first year rate of return appraisal but fuller Cost to Benefit methods are more appropriate for higher value investments (Hill, J. & Starrs, C. 2011).

There may in reality be little point identifying unsafe routes if the funding required to fix them effectively simply isn't available. However, approaches other than engineering enhancements (e.g. enforcement and/or education) may be more cost effective and therefore more feasible. The US has initiated a number of special funding programmes precisely to support local authorities to make safety changes on rural roads which they otherwise would not be able to afford. DfT has also funded special rural road safety pilot projects to enable local authorities to trail new approaches in the past (DfT 2010b). It may be that the DfT needs to develop a significant funding scheme specifically to assist local authorities (TSC 2015), and this would include the implementation of engineering solutions on longer road sections in particular

Apart from some recent very limited application of iRAP Star Rating on a trial basis to some problematic Local Authority road sections (and widespread ad hoc inspection by Local Authorities at identified problems), use of proactive approaches to screen networks appears to be absent in the UK.

- Most proactive screening approaches, using video and especially inspection, require significant resources. The feasibility of these approaches, especially for roads of less than A road status is unknown.
- Many proactive approaches require some reliable vehicle flow data. The lack of this information for the lower volume rural UK roads, specifically B roads and lower will affect application of these approaches.

4.3 Recommendations

It is suggested that there are a number of resources and facilities that could be developed and made readily available to UK local authorities that would improve their ability to manage rural road networks beyond the current dominant reactive approaches.

4.3.1 Better reactive screening tool for UK Local Authorities

It is currently challenging for practitioners to identify longer sections which may have a significant safety problem using crash data compared to identifying hotspots. It is also difficult for local authority staff to justify the decisions to prioritise particular longer road sections for treatment because the safety problems are less well defined.

Recommendation 1

- Better collection of flow data on busier roads is needed to support reactive identification of longer sections which may have possible safety problems, since this will enable the use of Safety Performance Functions (SPFs).

SPFs could be developed for a defined number of the main target road types and main junction types. This is not technically difficult to do, but the SPFs derived would need to be tested to check that they function well across the country. A simple accident threshold approach could be developed to be taken on lower priority, lower flow roads where vehicle count data are less likely to be available.

The task requires that a standard range of the main cross section road types which are present on local authority rural road networks are defined. These could be dual carriageway with full shoulder, dual carriageway with narrow "hard strip", single carriageway etc.

Consistent lengths of road with the standard cross sections need to be identified. Ideally the sample sections to be used for the analysis should carry a wide range of traffic flows on them. The numbers of crashes occurring on the individual sections in a three or five year period are obtained and these crash numbers are statistically modelled (typically using log-linear regression). The developed SPF equations give the relationship between flow and crashes for the specific cross sections. Each cross section type would have its own SPF equation.

The developed SPFs should be tested to see how well they predict the crash numbers occurring on roads with the same cross section in locations away from the areas where the SPFs were developed.

The approach can also be used to model junction safety, but this is more complex than developing these for main line sections.

This approach links better to the established reactive methods currently being applied which are more intuitive to practitioners; the SPFs can be used to check whether sections are performing much worse than would be expected.

The cost would be moderate for developing SPFs for main line road cross sections. SPFs could also be developed for a range of standard junction types such as T-junctions, crossroads, roundabouts, mini-roundabouts. These would likely require a greater effort to develop compared to developing SPFs for main line road cross-sections.

The SPFs can then be used as the basis for statistically rigorous before and after crash testing (e.g. Recommendation 2). This approach will require flow data to be available on roads on which they are to be used.

The approach can be developed into a simple web based system that local authority staff can access to help them identify if road sections do have excessive crashes occurring.

4.3.2 Information and standard systems

An identified gap is that staff in the UK do not have access to a range of standard, national information and guidance to help them select the best solutions for road safety problems of the kind that are available to staff in several other countries. The systems required include a standard, national source indicating the effectiveness of measures and also clear information on how cost effective different solutions may be.

This information should be based on the results of robust "before and after" statistical analysis of UK local applications of a range of the engineering (and ideally other) solutions and also UK experience of the scale of economic benefit for specific measures.

Clear national recommendations indicating the best solutions for various typical safety problems and the sharing of real experience of applying specific solutions would be very beneficial. It could significantly improve and standardise the resulting actions to improve safety arising from the diverse current approaches adopted by local authorities to manage road safety on longer rural road stretches.

The availability of this information would improve overall performance, consistency and transparency and should build a body of knowledge from direct UK experience from which more sophisticated (proactive) approaches could be developed in future.

This recommendation requires firstly improved standard systems which will enable local authorities to evaluate their schemes better and also to perform and check economic appraisal more rigorously. The information generated from the improved statistical and economic analysis would then be collated and made available to guide staff in the selection of more efficient and effective countermeasures.

Recommendation(s) 2:

- Development of an internet based system which provides a facility to test before and after performance with statistical rigour and share the outcomes;
    - This would develop local Crash Modification Factors for measures;
    - An internet based approach may be more accessible and therefore successful than previous efforts to share evaluation information;
    - SPFs would be required for the statistical approach.
- Standard best practise Cost Benefit Analysis made available in the form of guidance and as an internet accessible economic appraisal system;
    - This requires standardised Crash Modification Factor values for a full range of treatments;
    - This requires realistic costs and on-going maintenance estimates for measures.

This information can all be built into a UK specific knowledge base to help practitioners select the best countermeasures (again available as a web based tool).

- A knowledge base detailing information on the effectiveness of measures and the situations where they are appropriate would also benefit UK local authorities.

The result would be a dynamic knowledge base and systems that could be used so that local authority staff can identify appropriate and cost effective countermeasures better once they had identified rural road lengths that require treatment. It would fit in with and improve the main reactive approaches which are currently being used to identify problem road stretches.

These systems need to be actively used by local authority staff. This recommendation has been specifically suggested since it should improve levels of evaluation which are not currently robust (e.g. TSC 2015). In addition it could improve application of better economic appraisal methods by local authorities (RSF 2011).

The systems would require:

- Research to identify the details of the statistical before and after (based on Empirical Bayes analysis);
- Development of SPFs for a range of road types and possibly junctions;
- Definition of the economic appraisal methodology to be incorporated;

- Development of the detailed software specifications and interfaces;
- Software development;
- Software and database hosting;
- Administration of the web site to check that submitted evaluations were conducted correctly and to specify the CMFs developed from local studies.

The research required would be relatively expensive requiring a large research and development project followed by hosting of the system and on-going hosting, maintenance and site management.

Development of the system should only commence after consultation with a range of local authority stakeholders to assess their perceptions of how useful the system will be. This consultation process can also help to develop the user interface. The feedback and experience from use and uptake levels of the recent DfT speed tool should also be taken into account to shape the development.

Use of the system could be encouraged by linking its use to the availability of grants for engineering treatments from DfT for example.

4.3.3 A proactive screening tool for UK local authorities

A number of proactive approaches have been developed independently that are based on the assessment and identification of road infrastructure related risks by video survey or direct inspection for use on rural road networks.

iRAP Star Rating is the most comprehensive and most widely used system of this kind. This project is based on the client's assessment, after consultation with local authority staff, that iRAP Star Rating may be too expensive to consider conducting across all local authority rural roads. Currently iRAP's advice for non-SRN roads is to use their reactive Risk Mapping approach to identify problem stretches then use their demonstrator tool to identify specific deficiencies at spot locations.

A fully proactive screening system for non-SRN rural road could be developed based on the available international research. This would be specifically designed for the requirements of UK local authorities and the resources typically available to them in terms of staff and data. The system would include "low effort" screening focused on assessing a limited number of the most frequent infrastructure and general safety problems that are common on rural roads. It could be developed to be particularly suited for use on local authority rural road networks which may have low vehicle flow levels.

Recommendation 3

- Develop a risk based inspection/video survey approach/system specifically for UK local authorities with low data and effort requirements.

This approach would allow practitioners to adopt fully the recommended Safe System proactive approach for rural road safety management, which can specifically target Vulnerable Road Users' safety issues.

Developing such a system, rather than using currently available systems means it could be produced to fit the target end users' needs better. It could be tailored to use available crash data and also road state and inventory systems which are currently used by local authorities. Access to this system for local authorities could also be cheaper if developed by DfT compared to commercial offerings. Sufficient research currently exists to develop this system, but it could be improved as better UK experience on measure effectiveness is collected.

Flow and speed information and detailed asset data are unlikely to be available for many of the lower flow rural roads however but the system could be developed to deal with these issues.

This system would be relatively expensive to develop from scratch. This would include research of the issues and consultation with practitioners, followed by design of the basic methods for network inspection and screening, linking of countermeasures to identified issues, piloting and developing the software. The software should include economic appraisal (requiring the development of CMFs which could be obtained from international studies if good UK estimates are not available), and evaluation.

Some training would be required to ensure networks are screened properly and the software is applied properly by staff.

This approach will still need experienced engineers to develop the detailed design programmes of measures and it may be more difficult for practitioners to understand the basis for the proactive approach compared to more familiar reactive methods. It is also possible that this system will identify programmes of treatment which cannot generally be afforded within available authority budgets.

4.3.4 Guidance manual for practitioners Local Authorities

Developing guidance materials which could be available as a downloadable manual and a web portal would be a relatively cheap option. This could provide detailed technical information on a wide range of approaches; both reactive and proactive, from which practitioners can choose the most appropriate depending on the data, staff capacity and resources they have available.

Recommendation 4

- Clear and comprehensive guidance material on new reactive approaches and best practice for proactive approaches.

This guidance should be developed based on in-depth consultation with local authority staff and analysis which will identify the precise areas of rural road safety management where personnel have most difficulties. The development would require thorough review to understand the typical resources and data systems available to local authorities for the management of safety through engineering so that the material can be most useful and appropriate.

The guidance material would introduce the concepts of managing risks proactively at the route or network level. It could detail how to apply iRAP Risk Mapping and Star Rating for example. The content could also set out good reactive practices for identifying road sections using the typical crash data analysis tools available to most local authorities.

However, there may be low take-up by practitioners and the reader would require reasonable technical experience and a good general understanding of safety engineering approaches in order to use this material most effectively.

The project cost would be moderate.

4.3.5 Use of a pre-existing models

The application of a currently available proactive or an existing reactive model may be a cost effective approach since the cost of development has already been covered. However, this report identified that there was insufficient information available to clearly recommend a specific model which is likely to be cheap and easy to apply by local authorities that is also proven to be effective.

A solution to this problem is that a number of the most promising models identified could be tested in a controlled trial which would enable their relative performances to be better compared.

Recommendation 5

- Field testing pre-existing systems and approaches

It is recommended that six of the models identified from the analysis for this report could be tested against each other on the same stretches of road.

The results of using each approach could be compared with the results from a detailed road safety inspection approach which would provide the most accurate benchmark for evaluation purposes.

The six main models that should be tested are:

- iRAP Star Rating
- IASP
- NetRisk
- SURE
- iRAP Risk Mapping
- North Yorkshire Route Assessment Tool

The six models were chosen based on the scores they obtained from the review process and also the impression of how cost-effective they might be given the lack of good evaluation. The list was chosen to reflect a range of the broad approaches available to give good contrast.

This field testing would have the benefit that the actual manpower resources, costs and data required could be compared on a fair basis.

The quality and value of the outputs, such as how relevant the identified problem sections are and, where applicable, the quality and cost effectiveness of programmes generated could be compared to thorough and intensive manual inspection of the trial roads by a group of experts.

There is a high likelihood that all of the six selected models will be available for this test.

This particular study would be extremely useful to identify practical approaches that would be beneficial to UK local authorities; it would be a ground breaking piece of research of great international interest.

The project would be relatively expensive.

4.3.6 *Recommendations priority and likely effectiveness*

The first recommendation (development of sets of SPFs for rural roads) is relatively low cost and its impact would likely be moderate to medium in terms of improving safety practices if funded alone. However it is recommended that this project is funded as a priority since it is fairly low cost. The development of the UK rural road SPFs is also required in order that recommendation 2 could be fully developed.

Recommendation 2 is the development of standard tools for the robust evaluation of countermeasure effectiveness and better economic appraisal. The accumulated information of how different measures perform in terms of reducing crashes and casualties and how cost-effective the different approaches are would be used to develop a national standard list of recommended solutions for given safety problems.

Recommendation 2 is relatively costly but could have a significant impact since the outputs could be used to improve or enhance the current reactive practices (crash data analysis based) which many local authority approaches use to identify problem stretches. It could also improve the choice of solutions in conjunction with existing reactive screening approaches. It is recommended that these first two recommendations are funded as a priority.

Recommendation 3, which is the development of a new low effort proactive network screening and safety management system for local authority rural roads, is a more speculative suggestion. Indications are, however, that a lower effort proactive method similar to iRAP Star Rating and the IASP system could be extremely valuable. This is because the range of the typical safety risk problems on lower standard rural roads is fairly limited thus the system would need to score a limited range of road features. The benefit of recommendation 3 is that it would permit local authorities to adopt a real proactive approach to risk management especially on roads which have high risks but low crash occurrence (e.g. where flows are low). The screening tool system and software produced for recommendation 3 could be linked to the systems produced for recommendation 2 to produce a comprehensive system.

Recommendation 4 is the production of guidance on best practice for using existing reactive and new proactive approaches to manage safety on rural roads. Although relatively cheap, the likely impact in terms of tangible improvements in safety performance could be relatively low. This is because uptake would require better knowledge on the part of the staff accessing the information in order for them to apply it, whereas the other recommendations are generally developing systems and applications that should make doing analysis and getting better safety outcomes easier. However, this recommendation could be performed in conjunction with the development of recommendations 1, 2 and 3 which would all require research into best practices as part of their development processes.

Recommendation 5 is the field testing of a range of the most promising proactive and reactive models identified and reviewed by the project. This option has a high upfront cost for the funder but might result in savings overall since it should identify a cost effective pre-existing method (or methods) that could be effectively applied by local authorities which would not require the high development costs of a bespoke system. It is hard to place a priority level on this recommendation in comparison to the others, since it is about better understanding how the possible existing models may really perform in the field as this information is currently missing.

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Appendix A Road Safety Model Summaries

A.1 High-Risk Rural Roads Guide

Model:	**High-Risk Rural Roads Guide**
Country:	New Zealand
Developer:	NZTA
First released:	2011
Model type:	Risk-based and crash history
Format:	Text-based guidelines which references several established road safety models

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
££	£££	£	★★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	X	✓	-	✓

Summary

The High-Risk Rural Roads Guide (HHRRG) is a guidance document which was prepared by the New Zealand Transport Agency (NZTA) and released in 2011. The guide is one of the flagship initiatives of 'Safer Journeys 2020', the New Zealand government's current road safety strategy.

The guide was created to provide a level of consistency of approach to safety amongst road authorities in New Zealand. It outlines six methods which can be used to identify high-risk road sections on a road network and recommends which method is most suitable given the available data. The guide also provides an extensive list of countermeasures including details of how and when to apply each solution, as well as their cost and effectiveness.

Using the guidance contained in the HRRRG, a very comprehensive road safety management approach can be achieved, depending on availability and quality of a range of road and crash data.

Background

The HRRRG recognises the Safe System approach to road safety which was officially adopted by the New Zealand Government in 2010. The guide's aim is to address two of the four key components of the Safe System, 'Safer Roads and Roadsides' and 'Safe Speeds'. The guide also identifies the three main rural road crash types (run-off road, head-on and junction crashes); it provides extensive guidance on how to improve road safety effectively by understanding and targeting these crash types.

Description of the model

The guide begins with a discussion of key crash issues on New Zealand rural roads and then introduces six methods to identify the high-risk sections of the road network, which use:

- the national Crash Analysis System (CAS)
- Road Asset Maintenance Management (RAMM)
- Road Infrastructure Safety Assessment (RISA)
- KiwiRAP Risk Maps
- KiwiRAP Star Rating Risk Maps
- KiwiRAP Assessment Tool (KAT) Star Rating and Road Protection Scores

The choice between which of the six methods is most suitable is largely dependent on the availability to data. A decision flowchart is given in the document which outlines the ideal scenarios for selecting each screening method together with details about how to apply each method.

CAS and RAMM are both databases which include detailed crash history information with links to a range of data sets. A process is provided to guide the reader to undertake a network wide screening using this crash data. RISA outputs can also be used if available. There are also several outputs from KiwiRAP which have different benefits and the process for utilising each is provided.

The HRRRG contains an extensive list of road safety countermeasures which covers 40 pages in the appendix of the guide. For each countermeasure, details regarding the situations where it is suitable, implementation issues, crash reduction potential, other benefits, cost, and treatment life are given.

Data requirements

The HRRRG does not have any specific data requirements but rather requires that the reader understands the quality and availability of several sources of data. All New Zealand authorities have access to CAS and/or RAMM which will allow them to undertake the more manual, reactive methods. A large proportion of the New Zealand strategic road network has had a recent KiwiRAP assessment done which can be accessed online if permission has been secured.

Prioritisation of high-risk sections

The HRRRG outlines six approaches that may be used to identify high-risk road sections. These include a mix of proactive and reactive approaches

Identification of road safety defects

The HRRRG cannot be effectively used to identify specific road safety defects.

Generation of potential treatments

The HRRRG contains a very comprehensive list of road safety countermeasures which are well supported by references to related reports and guidelines. The list is divided into five treatment philosophies which range from ‘Safe System Transformation Works’ to ‘Site-specific treatments’.

The reader will require a significant amount of road safety engineering experience to make effective use of the extensive information in the guide.

Economic appraisal

The economic aspects of the HRRRG are quite limited. Indicative costs levels are indicated as between one '$' (low cost) and three '$$$' (high cost) so full economic appraisal is not possible using the information supplied. Benefits are given as crash reduction percentages and treatment lives are provided for every countermeasure. Other non-economic benefits are also listed.

The HRRRG tends to focus on the strategic level and provides guidance for developing, prioritising and funding road safety infrastructure and speed management programmes.

Monitoring and evaluation

The HRRRG document has a whole section on monitoring and evaluation. It stresses the importance of this stage and provides several items of guidance and gives examples on how to monitor and evaluate road safety treatments effectively.

Software requirements

The guide can be downloaded online as a Portable Document Format (PDF) file which should be compatible with any computer.

Licencing

The guide is available free online and is easy to locate with a simple web search. Many of the data sources referred to in the guide require special permissions. The databases CAS and RAMM which are national crash and asset management databases respectively are generally available to any New Zealand road operators by request. KiwiRAP results can be accessed online after creating an account.

References

NZTA (2011). *High-risk rural roads guide* (Version 1). Wellington: NZ Transport Agency.

Assessment criteria	Star rating	Justification
Main benefits	★★★	The HRRRG is a comprehensive guidance document dedicated to rural road safety. It provides flexibility by recommending several methods, depending on availability of data. If using the guide exclusively in practice, applying treatment selection and economic analysis will be challenging. The guide endorses and outlines effective evaluation and monitoring.
Quality of model design	★★★	The guide is very thorough in two key areas - identifying high risk sections and providing guidance on treatment options. The guidance on economic appraisal is high level and is not so helpful for real world application.
Ease of use	★★	The HRRRG is well structured and easy to read. Some road safety engineering experience is required to interpret the content and apply effectively.
Considers various road user groups	★★★	A section discusses vulnerable road users and provides the reader with guidance on how to manage issues specific to motorcyclists, cyclists and pedestrians.
Quality of economic appraisal	★★	The benefits of many treatments are not quantified but instead labelled as low, medium and high cost. This allows users to undertake only a limited economic consideration of treatment options.
Evaluation and monitoring included	★★★	The guide dedicates a chapter to monitoring and evaluation of road safety treatments. Several worked examples are included.
Validation of methodology/strength of literature base	★★★	Based on a strong research base and references several well established methods used extensively in New Zealand such as KiwiRAP.
Data requirements/cost	★★★★	No data is specifically required, however in order to fully utilise the guide, data from one or more will be required. Many of these data options are freely available to New Zealand Local Authorities. It is flexible on the issue.
Human resource requirements/cost	★★★	The guide is quite straightforward but does require some road safety engineering experience to interpret some aspects.
Software/licencing requirements/cost	★★★★★	No specific software or licencing requirements.
Intellectual property considerations	★★★★★	Guide is freely available and is well supported by references to research literature.
Development potential	★	No information was found regarding plans to update the HRRRG. The guide is expected to serve New Zealand road operators for the entire Safer Journeys 2020 period.
Ease of modification for use in UK	★★	The HRRRG was produced specifically for a New Zealand however a lot of the content remains valid for the UK. HRRRG could serve as a valuable blueprint for creating a similar guide for the UK.

A.2 Manual for Selecting Safety Improvements on High Risk Rural Roads

Model: **Manual for Selecting Safety Improvements on High Risk Rural Roads**
Country: United States of America
Developer: Federal Highway Administration Office of Safety
First released: 2014
Model type: High-risk roadway features and severe crash history
Format: Guidance manual

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£	£	£	★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	✓	-	-

Summary

The Manual for Selecting Safety Improvements on High Risk Rural Roads (HRRR) is applicable for roadway segments of any length, with or without curves, and for intersections on two-lane rural collector and local roads.

The manual is primarily intended to assist an agency in understanding the effectiveness of various possible safety improvements for high risk rural roads to assist them in the treatment selection process.

There are a large number of safety treatments available which can potentially treat safety problems on these roads so it can be challenging for practitioners to identify the most effective treatments to implement when funds are limited. Agencies can use this manual to obtain a range of key information about infrastructure-based treatments that are relevant for rural roads. These data include the effectiveness or benefits, cost-effectiveness performance, and the suitability of different treatments for specific situations. It also gives the implementation costs of measures and annual or recurring maintenance costs.

The manual builds upon established methodologies for reactively and proactively addressing safety issues, the manual encourages network, corridor level, and site-specific implementation of treatments to reduce more severe crashes on lower flow, rural roads. The manual also includes overviews of safety program management, potential funding sources and funding processes which are specific to the USA. It also contains decision-making tools for selecting appropriate safety treatments for specific crash types and roadway characteristics.

Background

The safety assessment methodology presented in the manual was developed specifically for two-lane rural roads with low daily flow volumes which are indicated to be less than 8000 vehicles per day.

The cost and effectiveness information is based on survey responses from state, local and tribal agencies that have implemented treatments in rural settings and also national publications of evaluation results.

The manual provides straight-forward processes that are easy to follow. Flowcharts and written guidance provide sequential guidelines for conducting the safety assessment analysis process. It also outlines specific components of the overall analysis processes such as crash diagnostics and economic analyses.

Data requirements

The manual provides suggestions for the data that should be collected or analysis that should be done (such as crash type, crash frequency, crash severity) and also guidance on public input, and the roles for maintenance and law enforcement personnel in the processes of assessing treatment effectiveness.

The manual requires minimal data that is likely to be available within an agency's existing management inventories and databases. The minimum recommended data elements required are:

- crash type (road departure, right-angle),
- crash location type (segment, intersection, curve),
- crash severity (total or fatal plus injury),
- environmental characteristics (lighting, weather);

Also additional helpful data for identifying risk factors:

- traffic volumes,
- roadway features (number of lanes, shoulder type and width, speed limit), and
- intersection features (number of approaches, skew angle, turn lanes, type of control).

Prioritisation of high-risk sections

The HRRR safety assessment process ultimately results in a short, prioritised list of candidate safety treatments for the selected site or network roadway feature. The manual recommends these treatments serve as the starting point for a safety project study that would ultimately select the final countermeasure to be implemented and the deployment level. It is recommended that these project studies investigate relevant factors such as road capacity, driving laws and regulations, and the area context or land use.

The interim output from the process is the identification of the most common crash types at site-specific locations or high-risk roads stretches. This is information that can also be useful during strategic highway safety planning processes at a regional or national level. The manual can also be used solely for generating a list of potential treatments and their applicable deployment locations to address rural road safety issues.

Generation of potential treatments

Tables for treatments given in ten main categories provide a substantial amount of information giving cost, effectiveness and a benefit-cost ratio for each measure. The ten treatment categories are color-coded to help the user to easily identify the required section. The treatment categories include roadway features such as bends, intersections, and pavement markings. It also has a non-motorised user category that addresses pedestrian, bicycle, equestrian, and wildlife issues. The manual also provides additional information sources to help US users identify safety infrastructure funding sources.

Economic appraisal

The manual provides guidance for conducting an economic analysis that ultimately produces a prioritized list of treatments for a given location or network approach. The manual recommends using simple benefit to cost analysis, cost-effectiveness, or net annual benefit methodologies, but does not provide instruction or a software tool to actually conduct the analysis. While the installation costs and crash reductions may not equate to the experience in the UK, the benefit-cost ratio will be useful to identify treatments that have a positive return on investment and are worthy of consideration.

Monitoring and evaluation

The manual recommends conducting evaluations of implemented treatments to determine if they have actually been effective and this information is intended to indicate if the same treatments should be used for similar situations. It does not provide detailed guidance for conducting an evaluation.

Software requirements

The guidance manual is intended for use in conjunction with the typical crash data computer software programs available to agencies and the general processes for retrieving data and performing analyses.

Licencing

There is no cost involved with obtaining the manual since it can be downloaded from the Federal Highway Administration’s website.

References

FHWA. 2014. Manual for Selecting Safety Improvements on High Risk Rural Roads. http://safety.fhwa.dot.gov/hsip/hrrr/manual/. U.S. Department of Transportation, Federal Highway Administration.

Assessment criteria	Star rating	Justification
Main benefits	★★★	Suitable for rural roads, identifies at-risk locations, works with minimal data, assists with identification of relevant countermeasures, provides prioritized list of projects, provides guidance for data to collect for performance evaluation; not very detailed guidance for all the steps needed; not process orientated.
Quality of model design	★★★	Fairly comprehensive model, identifies and prioritizes rural road safety issues, provides guidance for economic appraisal and performance evaluation; not so good on suggesting solutions.
Ease of use	★★★	Provides easily understood guidance, references to consult, and examples that assist with use; better results if user has good general safety knowledge.
Considers various road user groups	★★★	Planning process is applicable for crash types related to special user groups but no particular focus on VRUs
Quality of economic appraisal	★★	Provides general guidance for conducting economic appraisal but does not provide the spreadsheet to perform the appraisal.
Evaluation and monitoring included	★★	Manual recommends conducting evaluations but provides little guidance on how to this.
Validation of methodology/strength of literature base	★★	A few evaluations of systemic improvements have been conducted and they show crash reduction has been achieved.
Data requirements/cost	★★★★★	Tool is flexible for use with available data or data can be collected if desired.
Human resource requirements/cost	★★★★★	Tool designed to be flexible to agency staffing capabilities and available data.
Software/licencing requirements/cost	★★★★★	Tool is a free download, MS Excel desirable for economic appraisal.
Intellectual property considerations	★★★★★	Available to public on FHWA website.
Development potential	★★★★	Adaptable to local agency preferences and data capabilities.
Ease of modification for use in UK	★★★★	Adaptable to different types of roads, guidance leads toward identification of countermeasures appropriate for the user's agency.

A.3 Systemic Safety Project Selection Tool

Model: **Systemic Safety Project Selection Tool**
Country: United States of America
Developer: Federal Highway Administration Office of Safety
First released: 2013
Model type: High-risk roadway features and severe crash history
Format: Guidance manual

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£	££	£	★★★★	★★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	✓	-	-

Summary

The Systemic Safety Project Selection Tool (Tool) sets out a process for incorporating safety planning into traditional safety management processes. First published in 2013, the Tool builds upon current safety management practices for identifying roadway safety problems and implementing safety improvement measures. The Tool increases a transportation agency's analytical techniques and approaches beyond current single site analysis to a wider safety approach by enabling an agency to perform a network wide evaluation to identify roadway attributes that are associated with locations which have increased crashes. The process enables an agency to proactively address highway safety concerns.

Crashes on rural roads often account for a high percentage of the total severe crashes in a region, but these crashes are generally dispersed or the occurrence of specific treatable crash types is low at individual locations. The low density of crashes typically makes it difficult to identify clearly defined safety issues or locations of concern using the traditional hot spot analysis process based on crash plot patterns. A further challenging aspect of the low-density of crashes is that these frequently occur on roads that are part of the local system so there may not be robust crash, geometric, and volume data to assist with identifying the locations of concern. The problem of low-density crashes is often viewed as a primarily rural issue, but similar situations can exist in urban areas, such as crashes involving motorised vehicles and vulnerable road users.

The analysis outlined in the Tool can be used across the board by transportation and government agencies at all levels and by transportation planning organisations to plan, implement, and evaluate safety programs and projects that best fit their capabilities and needs. The Tool provides a step-by-step process for conducting network safety analysis; considerations for determining the balance between implementing site-specific safety improvements and longer road section safety improvements; and a mechanism for quantifying the benefits of safety improvements implemented through a network approach.

Background

In the process of developing Strategic Highway Safety Plans, State Departments of Transportation determined that a focus on reductions in road fatalities and serious injury crashes in their states rather than in all injury crashes would require tackling local rural roads, where a significant proportion of severe crashes occur. However, the low-density crash situation on low-volume rural roads presents challenges to improving safety through traditional reactive planning processes. In recognition of this, the Tool presents an innovative methodology to proactively address safety on road systems with little to no documented crash history by identifying risk factors. Risk factors are determined by identifying contributing factors to severe crashes based on many locations across the roadway network. For intersections risk factors may include presence of driveways, skew angle and distance to the previous intersection. Segment risk factors may include curve density, curve radius, presence of driveways or intersections, and vertical curves. The Tool is applicable for road segments of any length, with any number of curves, and intersections.

Description of the model

The Tool is a guidance manual for use in conjunction with an agency’s existing computer software programs and processes for retrieving crash data and performing analyses. There is no cost for obtaining the Tool since it can be downloaded free from the Federal Highway Administration’s website. The Tool provides step-by-step guidance that is supplemented with graphics, real-world examples, and helpful hints to guide the user through the process. The process is not complex to follow and explains how the outcome of a step feeds into the next process. References to relevant national resources are also included to enhance an agency’s ability to complete each step as thoroughly as possible.

Data requirements

The Tool requires a minimal amount of data such that it is already likely to be available within an agency’s existing asset or maintenance management inventory. The minimum recommended data elements needed are:

- system type (local/state),
- crash type (road departure, right-angle),
- facility type (freeway, arterial),
- crash location type (segment, intersection, curve),
- location characteristics (topography, intersection elements);
- additional helpful data for identifying risk factors:
  - volumes,
  - roadway features (number of lanes, shoulder type and width, speed limit),
  - intersection features (number of approaches, skew angle, turn lanes, type of control).

While the network planning process produces useful results with these minimal levels of data, greater information supports a more refined identification and prioritisation of safety improvement projects. This flexibility provides the ability to “calibrate” the Tool in terms of input data.

Prioritisation of high-risk attributes

The four-step systemic safety planning process results in the identification of at-risk locations (those with infrastructure road safety deficits) based on the comparison of the actual conditions of segments, curves, and intersections to a set of characteristics identified from crash data associated with the locations where the crashes actually occurred.

Identification of potential treatments

The Tool leads the user through the generation of potential treatments to address the safety issues at locations based on risk features. While the Tool gives useful outputs with the completion of each step in the process, the main outcome is the development of a safety project for each identified at-risk location along a road system. The process specify effective, low-cost countermeasures and a few higher-cost countermeasures for each crash type (such as lane departure, angle or head-on). The prioritised individual projects makes up the systemic safety program for the agency.

Economic appraisal

The Tool provides guidance for conducting an economic appraisal using a benefit-cost analysis methodology. The benefit represents societal cost savings due to a reduction in crashes and the cost represents installation and operations costs. The methodology incorporates service life, interest rate, maintenance costs, and traffic growth rates to provide the ability to calculate the benefit-cost ratio for the life of the countermeasure. The Tool suggests that a spreadsheet is useful for this, but does not provide this resource.

Monitoring and evaluation

Guidance for monitoring and evaluation is also provided. The Tool provides suggestions for data to collect based on suggested performance measures and recommends a three-level process to conduct the evaluation. The Tool identifies several simple as well as advanced statistical techniques that are appropriate for conducting the evaluation, but does not provide this resource.

References

Preston, H., Storm, R., Dowds-Bennett, J., Wemple, B. July 2013. Systemic Safety Project Selection Tool. http://safety.fhwa.dot.gov/systemic/fhwasa13019/. Federal Highway Administration, Office of Safety, Washington, DC

Assessment criteria	Star rating	Justification
Main benefits	★★★★	Suitable for rural roads, identifies at-risk locations, works well for prioritising sites that experience fewer crashes across a roadway network, assists with identification of relevant countermeasures, provides prioritized list of projects, provides guidance for data to collect for performance evaluation.
Quality of model design	★★★★	Comprehensive model which identifies and prioritizes rural road safety issues, provides guidance for economic appraisal and performance evaluation.
Ease of use	★★★	Provides easily understood guidance, references to consult, and examples that assist with user. Tools and approach are straightforward and can be accomplished with minimal training. Maximum results are achieved with some background and experience in selecting appropriate countermeasures and economic assessment for project prioritisation.
Considers various road user groups	★★★	Planning process is applicable for different crash types related to special user groups but not a key focus.
Quality of economic appraisal	★★	Provides general guidance for conducting economic appraisal but does not provide the spreadsheet to perform the appraisal.
Evaluation and monitoring included	★★	Tool recommends a three-level process to conduct the evaluation and suggests simple and advanced statistical techniques for conducting the evaluation.
Validation of methodology/strength of literature base	★★	A few evaluations of systemic improvements have been conducted and they show crash reduction has been achieved. Some comparisons to usRAP have been conducted and agencies continue to monitor program effectiveness from the Systemic Safety Project Selection Tool.
Data requirements/cost	★★★★★	Tool is flexible for use with available data or data can be collected if desired.
Human resource requirements/cost	★★★★	Tool designed to be flexible to agency staffing capabilities and available data – easy to use, but personnel with greater knowledge can make better use.
Software/licencing requirements/cost	★★★★★	Tool is a free download, MS Excel desirable for economic appraisal.
Intellectual property considerations	★★★★★	Available to public on FHWA website.
Development potential	★★★★	Adaptable to local agency preferences and data capabilities; new tools will probably come out to support approach; training is available.
Ease of modification for use in UK	★★★★	Adaptable to different types of roads, guidance leads toward identification of countermeasures appropriate for the user's agency; UK Crash modification factors would be desirable but are not required to apply the systemic safety analysis approach.

A.4 iRAP Risk Mapping

Model: **iRAP Risk Mapping**
Country: Global
Developer: EuroRAP
First released: 2002
Model type: Crash history-based
Format: Microsoft Excel template with technical support available via email

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
££	££	££	★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	X	X	-	-

Summary

The European Road Assessment Programme (EuroRAP) developed Risk Mapping as a method of indicating levels of safety on road networks using crash history information. Risk Mapping was then adopted by the International Road Assessment Programme (iRAP) and provides a complimentary tool to the proactive iRAP Star Rating approach.

Risk Mapping is a reactive approach and is a relatively cheap and easy exercise providing that reasonable quality crash and traffic flow data is available. It produces two main output types; both presented as colour coded strip maps where the relative levels of safety are indicated by different colours. The risk maps are used as a highly visual, high impact method to indicate unsafe routes and roads which are understandable by both the public and decision makers. Detailed tabular information can be used by road operators as a more precise information source for identifying problems.

The first output type is 'Individual Risk' which refers to the risk level for each road user on a section of road. This essentially plots the fatal and serious casualty number for a three year period divided by length and traffic flow for each road section.

The Second key output is the 'Collective Risk' which indicates the risk experienced by the road users as whole on the road sections. This approach plots the fatal and serious casualty number for a three year period divided only by the length for each road section.

Both outputs are useful in very different ways and can help inform the road safety management decisions made by road operators.

Risk Mapping can only be used to identify and prioritise high-risk road sections on a road network. EuroRAP recommends using the iRAP Road Safety Toolkit to analyse those routes and sections which have the highest identified risk.

Background

EuroRAP was formed in 1999 as a sister programme to the European New Car Assessment Program (EuroNCAP). While EuroNCAP addressed the issue of safer vehicle engineering design, EuroRAP focussed on safer road infrastructure, another pillar of the Safe System philosophy. EuroRAP aimed to reproduce the highly successful EuroNCAP approach which encourages consumer pressure to drive car producers to make cars safer.

The first Risk Mapping pilot trial was in 2000-2001 and included roads in Great Britain, Sweden, Netherlands and Germany. In 2002 risk maps for the British trunk network were first made publically available; since then these have been updated regularly.

iRAP Risk Mapping has been undertaken in several European countries; however iRAP's alternative product 'Star Rating' has found more widespread success globally as it does not require detailed crash data and is a proactive approach to road safety.

Description of the model

iRAP Risk Mapping has a well-defined formal procedure. A licence must be obtained and sample data sent to EuroRAP for review and EuroRAP can provide support during all stages of the analysis process.

1. The first step is to gather data for the network.
2. Then the road network is defined, including identifying which parts of the network are urban or rural.
3. The network is then subdivided into sections. The recommended minimum length of a section is 5 kilometres for single carriageway roads and 10 kilometres for dual carriageway roads.
4. Crash data is assigned to the road network. Crashes must be assigned to each RAP section, typically using Geographical Information System (GIS) software. A 3 year period for crash data is recommended, although a longer period may be used if crash numbers are low. Ideally the target is to have a minimum of 20 Killed and Seriously Injured (KSI) crashes on a section in order to obtain a statistically reliable crash rate estimate. Crashes are also divided into various user types (car, motorcyclist, heavy goods and other) and various crash types (pedestrian/cyclist, junction, run-off, head-on and other) so that results may be reported on specific user types, crash types or combinations of the two.
5. Traffic flow data is assigned to the road network. Guidance is provided on how to do this process manually, but typically traffic flow data will already be assigned to the road network by operator organisations.
6. The Individual Risk rate is expressed as KSI crashes per billion vehicle kilometres travelled and the Collective Risk rate is expressed as KSI crashes per kilometre per year.
7. The reporting process is very strict to permit global benchmarking and clear guidance is provided regarding how to present the findings. Risk rates are assigned to one of five risk bands from Low (green) to High (black) and results are often shown as a colour coded map, produced using GIS software which includes a Google Maps base layer.

Data requirements

The three key data requirements are:

- Crash data
- Traffic flow data
- Road network information

iRAP Risk Mapping only considers KSI crashes, which are generally well reported in crash databases (as opposed to slight injury and property damage crashes). Crash data should have accurate map coordinates identifying where the crashes occurred or must already be assigned to the road network.

Individual Risk cannot be calculated without traffic flow data. The process of assigning flows based on sparse spot traffic flow counts is a challenging task and ideally traffic data that has already been assigned to the road network should be used.

The road network should be available in a GIS format to allow results to be readily displayed on maps.

Prioritisation of high-risk sections

iRAP Risk Mapping provides information which can be used to identify and prioritise high-risk road sections. Collective Risk is generally the more useful measure for road funding purposes and reducing the KSI toll on the road network. This is because this measure best indicates where most crashes occur and hence where the best saving potential may be which is what drives favourable economic appraisal and returns.

Individual Risk can be very useful for educating road users about the chance they face of being in a crash when using particular the roads on the network; the information is intended to allow them to plan their journeys and choose the safest practical route.

Identification of road safety defects

iRAP Risk Mapping does not identify specific road safety defects however an experience road safety engineer may be able to identify possible defects from patterns in the road user type and crash types indicated in a road section.

Generation of potential treatments

iRAP Risk Mapping does not offer treatments but recommends that the iRAP Road Safety Toolkit is used for this purpose.

Economic appraisal

iRAP Risk Mapping can be used to perform a very simple economic appraisal exercise called 'crash cost mapping'. A cost is assigned to each crash based on the severity and road type of the crash. These costs are then summed by road section and reported on a map. The same five colour bands are used but are equally distributed across the network so that the top 20% of road sections are black and the lowest 20% are green. Average annual crash costs per kilometre can also be produced.

Monitoring and Evaluation

Risk Mapping is undertaken regularly for performance tracking of the UK major road network. This regular assessment allows for some simple before and after comparisons.

Software Requirements

The software requirements for iRAP Risk Mapping are minimal. The Risk Mapping template is in a Microsoft Excel format and does not utilise macros. GIS software is required for mapping the results.

References

Marden, J. (2013). RAP Road Risk Mapping Manual: Technical Specification (RAP-RM-2.1). Brussels: EuroRAP.

Assessment criteria	Star rating	Justification
Main benefits	★★★	Method is very straightforward and data requirements are achievable for many UK Local Authorities. iRAP recommends using the Road Safety Toolkit to identify treatment options and undertake economic appraisal.
Quality of model design	★★	Only designed to be a tool to identify and prioritise high–risk sections in a reactive manner. When used in conjunction with the iRAP Road Safety Toolkit and Star Ratings, a more comprehensive model is achieved.
Ease of use	★★★★	The Risk Mapping template is easy to follow and iRAP will provide support to licence holders.
Considers various road user groups	★★★	Pedestrian crashes are one of five key crash types which are analysed and so Collective Risk and Individual Risk are often reported for pedestrians separately. VRU groups are otherwise not given particular attention.
Quality of economic appraisal	★★	Crash cost mapping is a crude method of presenting the cost of killed and serious injuries on the road network but this is not an actual economic appraisal.
Evaluation and monitoring included	★★	Risk Mapping is undertaken on the UK major road network as a form of evaluation. This regular assessment allows for some simple before and after comparison.
Validation of methodology/strength of literature base	★★★	Based on sound statistical principles, validated to some extent through comparison of bands with iRAP Star Ratings.
Data requirements/cost	★★★★	Crash data is readily available for every local authority. Traffic flow data is less consistently available but should be available for most strategic roads. GIS data is commonly available.
Human resource requirements/cost	★★★★	The Risk Mapping template is very straightforward to follow. Some competency with GIS software is required for reporting results; most Local Authorities will have a GIS trained person on staff.
Software/licencing requirements/cost	★★★★	Risk Mapping requires Microsoft Excel and GIS software. Both programs will be already frequently utilised in Local Authorities.
Intellectual property considerations	★★★★	iRAP Risk Mapping is a commercially available product. A low-cost licence needs to be purchased and the developer's request that data is sent to them for checking and so they may provide technical support.
Development potential	★★	The model is a not configurable however the user can adjust the risk bands in the Risk Mapping template to achieve more suitable outputs for their network.
Ease of modification for use in UK	★★★★★	iRAP Risk Mapping was developed in the UK and is applied frequently to UK roads.

A.5 Users' Safety on Existing Roads (SURE)

Model: **Users' Safety on Existing Roads (SURE)**
Country: France (Germany)
Developer: Service d'Etudes Techniques des Routes et Autoroutes, Highways Department, Road Safety and Traffic Directorate, France
First released: 2004
Model type: Reactive with some inspection
Format: Guidance

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	£££	£££	★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	X	✓	-

Summary

Users' Safety on Existing Road (SURE) is a methodology which was developed in France and Germany specifically to improve the effectiveness of the safety infrastructure improvement of longer road stretches of roads. The model takes the form of a series of defined methods to guide the practitioner through largely reactive processes to identify and prioritise the road stretches which have the best economic potential for crash savings from engineering improvements. SURE is a form of Network Safety Management.

Background

In 2002 the French President (President Chirac) greatly increased the priority of road safety because the level of deaths and injuries was regarded as being far too high. This greater government focus resulted in strengthened laws and in a fast-tracked action plan of counter-strategies and spending on the issue.

SURE was developed as one of the strategy measures. SURE is a joint German and French initiative and is based on the German "Guidelines for Safety Analysis of Road Networks", which is abbreviated as ESN and was developed in 2003. The French approach "User Safety on the Existing Road Network" (which is abbreviated as SURE) was developed by Sétra from 2002 to 2004 and was first field tested on a number of roads in 2004.

Although developed for national roads, the authors indicate it can be adjusted for application on other road types.

Description of the model

The most original aspect of the SURE model is that the selection and ranking of road sections for further analysis and treatment is based wholly on their economic potential for improvement. This means the sections where it is estimated the greatest savings or benefit levels can be achieved are targeted first for treatment.

To achieve this, routes are divided into consistent sections which have the same main cross sectional road features and flow levels. Sections should be about 10km in length, and 3km as a minimum. The advantage of using relatively long sections is that these should have greater crash numbers occurring, so the underlying issues which contribute to the safety problem should be clearer based on an analysis of larger samples.

The cost of the crashes (cost per kilometre) on these sections is calculated and can be plotted using GIS systems with colour coding for severity level. Using crash costs instead of numbers effectively weights the analysis by the severity level since crash costs are defined by the severity.

The expected crash cost per kilometre on a range of the main road cross sections which have good engineering features ("best practice design") needs to be derived. The difference between the actual crash cost per kilometre on the roads being tested and the ideal lower cost on the same road type with best design is used to prioritise the lengths. The greater the difference in the costs, the higher the priority since these sections should have the greatest potential for achieving savings through treatment with the best economic returns.

If the "ideal" crash cost density for a cross section with the high standard design is not known, the road lengths with the highest costs can be prioritised in descending order.

The methodology seeks to identify and understand the road design or engineering deficiencies by analysing the crashes in families which are likely to have the same or related underlying causation mechanisms which relate to the aspects of the physical road features.

The method aims to create greater consistency in approach between authorities in improving safety through engineering treatments; it emphasises there should be good consultation and involvement from all stakeholders in the safety.

Data requirements

Crash data with good coordinates for a three to six year period needs to be available. Six years of data is reported to be required for doing the analysis on lower volume roads. Broad road cross section types and flow data for sections is needed.

Prioritisation of high-risk sections

The priority sections for further in depth crash analysis and inspection are identified by their crash cost density and how this differs from a similar road which has the best engineering design features.

Identification of road safety defects

The main defects on sections are identified by analysing the crash records in a "Haddon diagram" type approach which considers the factors which are involved in causing the crash and affect the severity in different time phases (driving stage, accident stage, emergency stage, collision stage).

Generation of potential treatments

Programmes of treatments are developed on a manual basis and are shaped by the crash analysis and any inspection that has been done.

Economic appraisal

Information on the general effectiveness of a range of treatments types is available; appraisal is done using a cost effectiveness basis.

Monitoring and evaluation

There is strong emphasis on monitoring and evaluation but no specific software or methodology is set out.

Software requirements

GIS software and crash database systems are required.

References

Ganneau, F., & Lemke, K. (2008). Network safety management-From case study to application. *Roads-Paris-*, *338*, 24.

Chambon, P., & Ganneau, F. (2005). SURE (Users' Safety on Existing Roads): A New Method Implemented In France To Improve Safety On Existing Roads. *Proceedings 2005, Strasbourg, France 18-20 September 2005-Transport Policy And Operations-Traffic and Transport Safety-Network Safety Assessment*.

Brannolte, P. U., & Münch, A. (2009). Software-based road safety analysis in Germany. In *4th IRTAD Conference, Seoul, Korea* (pp. 207-218).

Assessment criteria	Star rating	Justification
Main benefits	★★	Strong emphasis on screening the network on the basis of the potential for improvement, a clear method for identifying the problems using crash analysis and inspection. Economic appraisal is built in to some extent (cost effectiveness), there is an emphasis on evaluation but no clear methodology is suggested and no specific software or solution is provided.
Quality of model design	★★★	Covers some of the steps very well but others are less well defined.
Ease of use	★★	Requires judgement and knowledge about roads and flows to create the homogeneous sections which could be difficult due to variation. Getting the ideal crash cost per KM is likely difficult. Most stages required to identify treatments etc. are manual.
Considers various road user groups	★★	No clear focus on VRUs but can be taken into account.
Quality of economic appraisal	★★	Primarily cost effectiveness focussed.
Evaluation and monitoring included	★★	Evaluation is recommended but methodology is not set out clearly or specified in detail.
Validation of methodology/strength of literature base	★★	The screening approach is interesting but not clear that it has been validated specifically to check it effective; other approaches are sound.
Data requirements/cost	★★★	Requires good flow data and ideally inventory data to classify road sections to identify consistent sections plus crash data.
Human resource requirements/cost	★★★	Requires considerable judgement/experience to screen and then action the sections which are identified by the screening method. Time consuming.
Software/licencing requirements/cost	★★★	Require GIS system to plot crash cost density plus crash data analysis.
Intellectual property considerations	★★★★	Published information is available on the approach and main idea The main idea is the screening based on crash costs per KM.
Development potential	★★★	The systems generally take the form of guidance and cover a range of tasks used in other methods; these could be developed to some extent.
Ease of modification for use in UK	★★★	This could be adjusted for UK rural roads reasonably easily; main task is identifying GIS methods for plotting cost density and getting the cost per KM for best design cross sections.

A.6 Regional Road Safety Explorer

Model: **Regional Road Safety Explorer**
Country: Netherlands
Developer: SWOV
First released: 2001
Model type: Crash data
Format: GIS and simpler computer versions

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	££££	££	★★	★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
X	X	-	✓	✓

Summary

Regional Road Safety Explorer is abbreviated as RRSE in English; it is abbreviated as VVR in Dutch for Verkeersveiligheidsverkenner Voor de Regio. RRSE is an initiative developed primarily by the Netherland's Institute for Road Safety Research (SWOV) and was aimed at improving the ease of identifying effective programmes of safety measures which have clear, casualty reduction targets linked to specific countermeasures. It was developed specifically for the use of authorities at the regional rather than the national level within the Netherlands. As it is aimed at the regional rather than the national level it has some very relevant aspects and aims for the current project. It also takes a different approach from most other models reviewed and is included for these reasons for a full summary write-up. This is despite it being relatively limited in its overall comprehensiveness and not being a model targeted to managing safety on specific routes. There is also only limited information available on the model available in English.

RRSE is primarily a tool for planning effective safety programmes in order that casualty reduction targets can be achieved on a more scientific basis. To do this RRSE estimates the expected reductions in casualties for a range of possible countermeasures and approaches which include specific infrastructure or engineering measures. It is reported that it is designed primarily to be operated at the regional level but with recent developments it can also be operated at specific sites or road stretches depending on the available data.

The system was used extensively in 2008 in the regions of Haaglanden (region The Hague) and Arnhem-Nijmegen. The system has also been developed as a proof of concept for use in neighbouring Flanders which is in Dutch speaking Belgium.

Background

The driving force for the development of RRSE was the decentralisation of government which give increasing responsibility for road safety to the regional authorities in the Netherlands. RRSE was designed to make the development of regional or local safety plans more specific (quantifying safety instead of basing plans on qualitative assessment) and more effective by making estimates of the casualties that should be saved by implementing a variety of road safety measures. In this way a detailed programme of measures could be developed by local authorities that should achieve a defined casualty reduction in a given time frame. This was particularly useful to assist the Regions in designing and funding programmes that should have achieved the national targets that were set for them for reducing casualties.

Development

There have been a range of variants based on RRSE since its original development in the early 2000s. It was originally developed with the computation being performed in MS Excel Spreadsheets.

It was then developed further by SWOV, in conjunction with private companies and government departments, as a full software product which is linked to GIS (VVR-GIS 3.0). The move from MS Excel was done to make it easier to manage and update the algorithms and data required. It is reported that the VVR-GIS 3.0 version can assist with decisions of what measures to implement at the local site level as well as at the regional level providing that national road maintenance survey data and flow data is available for the road.

The VVR-GIS 3.0 data requirements are fairly heavy and more recently a simpler version has been developed (VVR-2009) for use on lower volume roads. VVR-2009 goes back to the original calculation method of the earliest version of VVR and was developed for the use by local authorities on networks for which there is less infrastructure/asset data available. VVR-2009 cannot be operated at the level of individual sites or road stretches to help develop engineering safety solutions and programmes.

Description of the model

All the RRSE versions have the same basic approach.

The model works by establishing the road safety situation in a base year in terms of fatalities, casualties and crashes occurring in a reference year. Casualty/crash rates per road segment and junction category are needed. Estimated traffic growth per road class is also required.

The base case number of crashes and casualties by severity is calculated for the reference and future years using this information for the “do nothing” scenario.

The models include information on the known effectiveness of a range of possible measures which was derived from international research sources. The user indicates the intensity of application of the available measures and the model estimates the savings in future years which should result.

The following figures are estimated for the end year:

- Road fatalities and serious casualties occurring and the predicted savings in numbers over the base year figures
- Road length (predicted construction) and traffic levels
- Casualty savings due to specific infrastructural interventions per road category
- The costs of the measures

The VVR-GIS 3.0 version also does cost-benefit analysis at the regional or individual site level. The simpler versions do cost benefit analysis at the regional or sub regional level.

Evaluation

There has been no formal evaluation of the programme, however the users found that the data requirements were too expensive and the list of measures which was included was too limited. It has not been used since 2009.

Data requirements

The simpler versions require detailed numbers of injury collisions, also fatalities, serious injuries and slight injury numbers across the network. The road network is divided into road lengths separately by functional type. Any plans to change road types or build new lengths, together with their predicted traffic growth over the time frame considered, are also required.

In addition, the VVR-GIS 3.0 requires detailed information on the road infrastructure from the Dutch national maintenance data set which is only available for strategic national road. VVR-GIS 3.0 needs information on the layout of road sections and junctions and also the flows on the different elements.

Software requirements

MS Excel or bespoke software linked to GIS.

References

Assessing the impact of road safety policy measures in Flanders: modelling approach and application, RA-MOW-2011-025, C. Ariën, E. Hermans, S. Reumers, S. Daniels, G. Wets, T. Brijs, Onderzoekslijn Beleidsorganisatie en -monitoring

http://imob.ifolks.be/sites/default/files/RA-MOW-2011-025.pdf

RIPCORD-ISEREST-Deliverable-D2.doc: Accident Prediction Models and Road Safety Impact Assessment: recommendations for using these tools, Workpackage No. WP2 Deliverable No. D2, Rob Eenink, Martine Reurings (SWOV), Rune Elvik (TOI), João Cardoso, Sofia Wichert (LNEC), Christian Stefan (KfV)

http://www.transport-research.info/Upload/Documents/201003/20100318_175121_45402_ripcord_d02_road_safety_impact_assessment.pdf

De Verkeersveiligheidsverkenner gebruikt in de region, R-2005-6, Ir. S.T.M.C. Janssen

http://www.swov.nl/rapport/R-2005-06.pdf

Assessment criteria	Star rating	Justification
Main benefits	★★	Provides a method for having more quantifiable road safety plans and strategies.
Quality of model design	★★	Not a very comprehensive model, provides a method for strategy selection and also for some evaluation/monitoring.
Ease of use	★★★	Relatively straightforward to use but does require some engineering safety knowledge.
Considers various road user groups	★	Doesn't explicitly account for VRUs but some counter-measures it lists will.
Quality of economic appraisal	★★★	Economic appraisal is included in model.
Evaluation and monitoring included	★★★★	Evaluation is a key strength of the model.
Validation of methodology/strength of literature base	★★	Only very limited checking has been done.
Data requirements/cost	★★★	Requires a significant road inventory data for the advanced version. Other versions require less but give less detailed outputs.
Human resource requirements/cost	★★	Requires significant time to acquire and apply the data needed to run the model.
Software/licencing requirements/cost	★★★★	Minimal, SWOV may share this pro bono.
Intellectual property considerations	★★★	Developed by SWOV who may be willing to allow open access to the product.
Development potential	★★	The list of measures and strategies included could be expanded, however all development seems to have halted on this currently.
Ease of modification for use in UK	★★★	Some localisation of the measure costs and effectiveness would be required.

A.7 Route Analysis Tool

Model: **Route Analysis Tool**
Country: United Kingdom
Developer: North Yorkshire Council and Jacobs
First released: 2012
Model type: Reactive – Crash analysis based
Format: MS Access/GIS

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	££	£££	★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	X	X	X	X

Summary

North Yorkshire County Council (NYCC) identified a need to develop a technically sound method to identify and prioritise those longer sections of road which have higher crash occurrences.

There was also a desire to incorporate risk into the safety analysis by taking flow into account when screening for safety problems but had difficulty due to a lack of good volumetric data on many rural roads. A system was also wanted which would avoid problems of sample bias (regression to the mean).

Any new method needed to include statistical rigour and be a defensible methodology based on sound techniques to identify longer sections with safety problems. This was to make the screening task more systematic and comprehensive.

The approach adopted was to use the GIS spatial method (the Getis and Ord G.I. statistic) in order to identify longer link or route sections with statistically elevated crash occurrence.

The G.I. approach generally identifies clusters which are significantly denser or more pronounced than those surrounding the cluster and this has been used to identify road crash hotspots previously. However, its use to identify link sections required some development.

Background

The G.I. approach is available in some GIS packages as a function; however, these could not be used to identify link sections.

North Yorkshire collaborated with their partner consultants Jacobs to develop the statistical methodology into a software system. This was done in MS Access using Visual Basic 6 to programme the required algorithms. This development permits data input and analysis output to the council's in-house GIS system (MapInfo). The GIS system assigns the crash data to the link sections and can display the results on maps.

Description of the model

The model identifies link sections (typically between 500m to 1.5KM) which have statistically higher crash occurrence than surrounding sections. Screening is done separately for the main road network classes; that is, for 'A' roads, 'B' roads and 'C' roads separately because the average risk levels differ too greatly between these road types to run the analysis together.

The models can be applied to crash numbers per kilometre or crash rate per vehicle kilometre which takes flow into account. The model can be run separately for crashes involving vulnerable road user groups such as motor cyclists or older drivers.

The model effectively emulates a "moving window" analysis, which assesses the number of crashes in different sections in comparison to surrounding sections up to a cut-off distance for the other sections to be considered in the comparison and for generation of the G statistic. The cut-off distance is set by the user and corresponds to the length which is likely to include road sections which will be reasonably similar to the section being tested. In rural areas this will be long since roads are fairly consistent but in urban areas where road characteristics can change frequently this should be shorter.

A value of the G statistic is estimated for each individual section; if surrounding sections have high G values, then the values in the section between them is increased using a weighting factor specified by the user.

After running an analysis all the G scores are listed and those that have significantly higher G scores can be identified. These can be plotted on maps with colour banding so that longer sections with high GI statistics can be identified.

The method is used to identify routes with generally consistently high and consistent crash occurrence since these will get generally higher G scores rather than short sections with much higher crashes than the surrounding sections. In this way the method is suited to identify longer sections or routes rather than individual hotspots.

Data Requirements

Typically three years of crash data are used to perform the analysis. The system can use the council's maintenance management information which is available in the GIS system to access flow data.

Prioritisation of high-risk sections

The model can prioritise longer sections of road which warrant investigation and possible treatment. This can be done on the basis of G statistic scores which take into account severity of crashes which better accounts for the total cost of crashes in sections.

In order to make the tool more accessible and overcome the problem of output interpretation, which is not immediately straightforward, NYCC and Jacobs have produced a training manual for its practical application. This has been used to roll out the tool amongst the Council's road safety engineering team. The G.I. scores are given a z statistic score which indicates if the score is significantly different from other scores.

Experience and development

Since the tool was first developed, it has undergone an iterative process of refinement and although there remains scope to improve it further, NYCC considers it has evolved to the point where it can now be used for casualty reduction purposes. Further refinements are expected such as making analysis of sub categories of crashes such as motorcyclist KSIs easier. Use of the tool has been approved through the Council's democratic process.

North Yorkshire County Council has been using the Route Analysis Tool this year (2015) and is generally pleased with the results. It has added a useful dimension to compliment and extend beyond hotspot analysis that they are still doing.

Software requirements

The system runs in MS Access linked to an in-house GIS package (MapInfo).

Licencing

North Yorkshire County Council own the rights to the model as developed but have helped promote its wider application and the use of route analysis to help reduce casualties more widely, through presentations at professional institution seminars and at local universities. The Council would be happy to continue with this promotion role.

References

This summary was developed after discussion with staff from North Yorkshire County Council and Jacobs.

Assessment criteria	Star rating	Justification
Main benefits	★★	Mainly for screening longer sections and prioritising these.
Quality of model design	★★★	Very comprehensive model, lacking evaluation/monitoring of effectiveness in practice.
Ease of use	★★	Some interpretation is required by the user.
Considers various road user groups	★★	Designed to be run separately for VRU crashes groups.
Quality of economic appraisal	★	None.
Evaluation and monitoring included	★	None.
Validation of methodology/strength of literature base	★★★	Based on a well-developed spatial analysis approach which works well for other related analysis.
Data requirements/cost	★★★	Uses data readily available from systems already developed.
Human resource requirements/cost	★★★★	Can generate priority sites relatively easily.
Software/licencing requirements/cost	★★★	Developed in-house essentially.
Intellectual property considerations	★★★	Based on publicly available research.
Development potential	★★★	Could be developed further to refine outputs and make interpretation easier. Other statistical distributions could be tested applied.
Ease of modification for use in UK	★★★★	Developed in the UK and used here already.

A.8 PTV Visum Safety

Model: **PTV Visum Safety**
Country: Worldwide
Developer: PTV Group
First released: 2014 (Version assessed)
Model type: Mix of risk-based and crash history
Format: GIS based transport planning software with safety module

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	£££	£££	★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	X	✓	X

Summary

PTV Visum Safety is a safety model developed by the German company PTV Group. It is an extension of their core Visum product which is primarily a network transportation management system. It has been used by several road authorities around the world including Transport for London (TfL). The software has three modules and was initially released as a method for the identification and analysis of hot spot clusters sites (referred to as blackspots by PTV) but it has been further developed to include a network safety management tool and a risk based model for the assessment of future scenarios. The models used for some of the network level (macroscopic) modelling are suited for urban conditions but it is indicated in their literature that the system can be used in inner urban settings and for route studies in non-urban areas.

PTV Visum can be used to identify hot spots or for route studies using historic crash data. Crash data can be imported from separate databases or the PTV Vistad software can be used for recording crash data directly. PTV Visum Safety has been used with STATS19 database in the UK. It is possible to identify suspected crash hotspots or longer sections with elevated crashes; these are given ranking scores weighted by crash severities. A set of characteristics such as numbers, location, turning movements, can be used to define potential hot spots. A three level categorisation can be assigned to reflect high, medium and low crash occurrences to enable heat maps to be produced which indicates the location of more severe problems based on colours shown on the routes.

The software can also be used at a network level to aid in strategic planning by providing a prioritisation of hazardous road sections in the network. This element of the software enables mapping of crash locations by attributes such as severity, crash type and proximity to intersections that enables a broad understanding of factors that may contribute to the incident occurrence; this is used to rank and plan solutions. The search parameters can be amended to focus on particular crash themes or different types of road users.

The software can be used to undertake a high level risk assessment of existing infrastructure and also to appraise proposed infrastructure changes by applying a standardised valuation method. The model uses Swiss crash prediction models that are applied for different main road types (dual carriageway, divided or undivided etc.); by combining these with traffic volumes a risk assessment can be made for the network, or for individual links. Based on these choices the model will predict crash rates (per link type and per kilometre) and then potential accident costs to compare and evaluate different scenarios. This allows an assessment of how variation in network features, such as changes in traffic flow, new infrastructure, control systems, land use and turning movements, may affect crash costs. This is a very high level assessment process and does not make use of an inventory of current road side conditions or hazards; but it will consider elements such as speed (if this is part of the APM parameter), intersection types and control methods. There has been no validation of the risk assessment component of the software within the UK nor it is known how relevant the Swiss model would be for UK roads but the software does allow different accident prediction models to be used so there is the potential for localisation of these. Newcastle University are currently working with PTV to develop accident prediction models for use in the software.

Background

PTV Visum Safety is a module of the PTV Visum software which is primarily used for traffic analysis and forecasting by means of GIS-based data management. PTV Visum models all road users including pedestrians and cyclists and interactions for networks and also travel demand based on predicted traffic flows. PTV Visum Safety integrates with the main PTV Visum model and uses the traffic flow and demand data for various elements of the safety analysis, but can be used on a stand-alone basis.

Description of the model

PTV Visum Safety is a complex system and is described as comprising of three modules:

- Black (hot) spot management (BSM) – Allows the ability to detect, edit and analyse crash cluster sites based on historic crash patterns. Cluster sites are identified using heat (density) maps or automatic searches with user defined parameters to define cluster thresholds.
- Network Safety Management (NSM) – Allows safety planning based on the network level safety situation. This considers historical crash data, traffic volume and some road infrastructure data and ranks road segments in terms of the riskiness of sections and crash severity whilst specifying the crash saving potential.
- Road Safety Impact Assessment (RIA) – Allows a strategic level risk assessment of existing and future infrastructure with the use of a simple crash prediction model. The model uses traffic volumes (and inherent infrastructure safety) to allow comparison of various scenarios to calculate expected changes in costs due to crashes.

Input data

The model requires crash history data and traffic volume data for each road section analysed. Furthermore, to make use of the RIA module a PTV Visum traffic model is required to predict traffic flows is required. On top of this a main road type categorisation and the control type at intersections has to be provided to use the default Swiss crash prediction model. Custom models may use additional information such as: traffic speeds (signed and operational); land use interactions; intersection types; turn movements (banned and permitted); gap acceptance at un-signalised intersections; and link classification (including journey distance), in addition to main road type categorisation.

Prioritisation of high-risk sections

The identification and prioritisation of sites can be undertaken by using the BSM or NSM modules of the software. This will require the use of historic crash data, imported from a Police database source, and is either site specific or at the network level depending on which module of the software is used.

Identification of road safety deficits

The RIA module can be used to undertake a risk assessment of various proposed infrastructure enhancements. This uses crash costs and crash rates per link type per kilometre to compare different scenarios with the aim of improving the overall risk level of a road length or network. The model can provide a ranking based on predicted accident Benefit to Cost Ratio for the various types of infrastructure improvements proposed.

Generation of potential treatments

PTV Visum Safety can analyse the effects of different user defined scenarios and infrastructure changes but the available literature does not indicate that the model will provide specific recommendations for potential treatments.

Economic appraisal

The NSM element of the software applies a Benefit to Cost Ratio (BCR) approach where costs of construction or traffic control measures can be analysed and compared with the predicted crash savings based on relevant crash costs entered by the user. BCR analysis can also be performed using the RIA module for different designs of new constructions.

Calibration of the model

The RIA uses a crash prediction model derived based on Swiss roads and data; this can be configured to other existing or specifically developed local models and relationships for different countries/road types.

Use of the model

The software has been used throughout the world including North America, China, Middle East, Thailand, UK and in a number of European Cities. From the case studies available, the most use has been made of the BSM element of the software but the other two elements have been used, with Transport for London making use the NSM component to identify strategic level actions. There was no evidence found on the validation of the RIA module but it is understand that Newcastle University are performing analysis of this system, but this work is not yet complete and the outcomes are unknown at this time.

Software requirements

PTV Visum Safety is a GIS-based software package. The developers specify the recommended system requirements for the software as Microsoft Windows 7 (64-bit) with at multi core processer Core with 8 to 32 GB of RAM and a hard disk of 1,000 GB Serial ATA III, although for the For the software itself 2 GB of free hard disk space should suffice. A suitable graphics card is also necessary and it is not recommended that on-board graphic cards use shared memory.

Licencing

PTV Visum Safety is a publically available product and can be purchased from the PTV Group who have offices in the UK. PTV Visum Safety can be purchased as a stand-alone product or an add-on module for an existing PTV Visum licence. The cost of a single licence for PTV Visum is dependent on the size of the traffic model and is split into zones, nodes and links and will vary for each authority. The costs for the software are not publically available.

References

Laufer, J. (2014) (26th ARRB Conference – Research driving efficiency Sydney, New South Wales 2014). Network Management and the forecast of accident blackspot locations

PTV Group (2014) (Company presentation, Road Safety Analysis with PTV Visum Safety) Road infrastructure Safety management

Farhan, M. Faruque, S. Mohammed, A. Osman, S. Al-Jabari, O. Almojil, A (2014) (World Academy of Science, Engineering and Technology International Journal of Social, Behavioural, Educational, Economic and Management Engineering Vol:8, No:9, 2014)
A Technical Perspective on Roadway Safety in Eastern Province: Data Evaluation and Spatial Analysis

Rahman, M. Transport Planner, PTV Asia Pacific (2014). Identifying and Mitigating Traffic Accident Settings: A Smart Management Approach

PTV Group (2014). PTV Visum Safety: A comprehensive Tool for the Analysis of Crash Data

PTV Group (2014). PTV Visum Safety in the Province of Arezzo: Road Safety in the Planning Process

Assessment criteria	Star rating	Justification
Main benefits	★★★	Good BSM module and NSM will allow quick identification of high risk links. The RIA module does not seem extensive as other two modules and is the most recently developed.
Quality of model design	★★	Allows identification on microscopic and macroscopic levels and will allow comparison of changes to the network by use of a simplistic model but does not generate treatments or allow evaluation. The RIA is not as extensive as other models assessed and does not appear to require asset survey so not clear how comprehensiveness / useful this module will be.
Ease of use	★★★	Once sufficiently trained on the use of the software it is not essential to have detailed safety engineering knowledge. However, there is an initial steep learning curve for VISUM.
Considers various road user groups	★★	Will allow search of users groups for identification of high risk sites. It is not clear if comparisons and assessment will provide information at this level of detail.
Quality of economic appraisal	★★★	Economic appraisal is included in model but specific; details are unclear. The system can perform BCR for two of the models.
Evaluation and monitoring included	★★	Nothing included to systematically undertake any before/after monitoring and evaluation.
Validation of methodology/strength of literature base	★★	A number of case studies have been produced by PTV and users. In most instances those found have been largely based on BSM module but some anecdotal evidence of benefit of other modules.
Data requirements/cost	★★★	Requires good level of traffic data and access to historic crash database. No apparent need for asset survey.
Human resource requirements/cost	★★★	Staff will be required to undertake training on the use of the software. 3 day basic and advanced training courses are available for PTV Visum in the UK.
Software/licencing requirements/cost	★★★	The PTV Visum software and PTV Visum Safety module will need to be purchased. Yearly maintenance subscription costs are also likely.
Intellectual property considerations	★★★★	None, this is a publically available software for purchase.
Development potential	★★★★	Software is relatively new and continued development and additions are likely.
Ease of modification for use in UK	★★★	The BSM and NSM have already been used in the UK and no modifications are required. The RIA module uses Swiss crash prediction model so suitability of use on UK roads will need to be considered. The software does allow different crash prediction models to be used.

A.9 Safety Analyst

Model:	**Safety Analyst**
Country:	United States of America
Developer:	Federal Highway Administration and participating state and local agencies, currently sold and supported by the American Association of State Highway and Transportation Officials (AASHTO)
First released:	2008
Model type:	Proactive, Network screening and project prioritisation
Format:	Software

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	££££	£££££	★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	✓	✓	✓

Summary

Safety Analyst is a set of software tools for use by state and local highway agencies for highway safety management. Safety Analyst implements analytical procedures to assist staff in the decision-making process and develop and manage system wide programmes of site-specific improvements. It has the aim of enhancing highway safety cost-effectively. The software automates procedures to assist highway agencies in implementing the main steps of the highway safety management process.

Safety Analyst was developed as a cooperative effort by the Federal Highway Administration (FHWA) and a number of participating States and local agencies.

Background

Safety Analyst supports Part B of the Highway Safety Manual. The transportation safety management process involves six main steps, which are: network screening, diagnosis, countermeasure selection, economic appraisal, priority ranking, and countermeasure evaluation. Safety Analyst supports all of these functions at a national or regional level.

Data requirements

The Safety Analyst software tools require access to a database of roadway characteristics, traffic volume, and crash data for an agency's road network. Many of the data elements required for Safety Analyst are readily available to highway agencies, but it requires some effort to assemble other data elements that may be needed. Safety Analyst includes a data management tool to help users import and manage these data. While many additional data elements are desirable for Safety Analyst and may be evaluated, the minimum set of data elements required includes:

- Roadway Segment Characteristics Data
- Intersection Characteristics Data
- Ramp Characteristics Data
- Crash Data

Prioritisation of high-risk sections

The network screening tool identifies sites with potential for safety improvement for example:

- Sites with higher-than-expected crash frequencies,
- Sites whose crash frequencies as expected, but which nevertheless have sufficient crashes that may potentially be improved cost-effectively.

In addition, the network screening tool can identify sites with high crash severities and with high proportions of specific crash or collision types. The network screening algorithms focus on identifying spot locations, but also include the capability to identify extended route segments.

Identification of road safety deficits

The diagnosis tool is used to analyse the nature of safety problems at specific sites and generates summary statistics and collision diagrams. It is also used to conduct statistical tests for particular sites to identify predominant and over-represented collision patterns.

The diagnosis tool also guides the user through appropriate office and field investigations to identify particular safety concerns. Engineering and behavioural factors are used in the diagnosis of safety issues. This step identifies specific crash patterns of interest and a list of safety concerns that may potentially be treated by countermeasures.

Generation of potential treatments

The countermeasure selection tool assists users to choose treatments to reduce crash frequency and severity at sites. The user can select treatments from lists of countermeasures stored in the software. The countermeasure selection tool suggests candidate countermeasures based on the diagnosis step output. Single or multiple countermeasures can be selected.

Economic appraisal

The economic appraisal tool performs cost benefit analysis of potential countermeasure(s). Default construction cost are provided within this tool, but these can be modified by the user. A comprehensive range of economic appraisal is available including from simple cost effectiveness to full cost benefit analysis.

The priority ranking tool generates ranked list of sites and proposed improvement projects based on the benefit and cost estimates determined by the economic appraisal tool.

Countermeasure evaluation

The countermeasure evaluation tool provides users with the ability to conduct before-and-after evaluations of implemented safety improvements. The tool can account for problems such as regression to the mean and changes in traffic flows.

Calibration of the model

UK specific safety performance functions would be needed. UK crash modification factors would be beneficial.

Software requirements

Software Requirements: Windows XP or better on an entry level PC.

Database Servers are optional; but recommended for major deployments.

Data storage requirements depend on the size of the inventory, traffic, and crash data. For example, a data set of 25,000 road segments, 46,000 intersections, 1.4 million crashes, and 9 years of traffic data requires less than 1.5 GB of disk space for a locally held database.

Licencing

The software is available for licencing as an AASHTOWare product. This AASHTOWare Safety Analyst licence is available to agencies located outside the United States if they have associate-international membership of AASHTO. The International workstation licence is $15,000 annually and the international site licence is $25,000 annually. This licence includes up to 24 hours of engineering support and some minimal data management support which is via a bi-weekly webinar. Additional support can be purchased.

References

AASHTOWare. Safety Analyst. http://www.safetyanalyst.org/index.htm. American Association of State and Highway Transportation Officials.

Assessment criteria	Star rating	Justification
Main benefits	★★★★	Suitable for rural roads, accounts for regression to the mean; complex and expensive though.
Quality of model design	★★★★	Six modules address network screening, diagnosis, countermeasure selection, economic appraisal, priority ranking, and countermeasure evaluation. Does not have site specific crash prediction capability.
Ease of use	★★★	User interface is easy to learn and input data to get results quickly; some States found it difficult to get their data into it as datasets extensive
Considers various road user groups	★★	Network screening and countermeasure selection for various users is feasible, however limited data is available for bicycles and pedestrians VRUs not a key focus area.
Quality of economic appraisal	★★★★	Cost effectiveness (countermeasure cost per crash reduced), benefit–cost ratio (ratio of monetary benefits to countermeasure costs), or net benefits (monetary benefits minus countermeasure costs).
Evaluation and monitoring included	★★★★	The countermeasure evaluation tool provides users with the ability to conduct before-and-after evaluations of implemented safety improvements. The tool can account for problems such as regression to the mean and changes in traffic flows.
Validation of methodology/strength of literature base	★★★	Not really up and running in a lot of locations yet, some indication that major user perform well but this is not definitive.
Data requirements/cost	★★★	Intended to work with typical state current data sets but issues with spatial aspects make this difficult to upload. Data can be collected if required.
Human resource requirements/cost	★★	Requires a robust data set and IT support to configure the software for network screening; training recommended.
Software/licencing requirements/cost	★	$15,000 per single-user licence. $25,000 per workstation licence.
Intellectual property considerations	★★★	Software can be purchased and supported by AASHTO and consultants.
Development potential	★★	Little opportunity to modify the methodology; some groups working on interface.
Ease of modification for use in UK	★★	The models are based on crash history in US, which may not be directly applicable to UK. The software has the ability to be calibrated for specific roadway networks. Unclear if calibration can work for UK conditions well.

A.10 17-38 Spreadsheets for Applying the Highway Safety Manual Predictive Methodology for Rural Two-Lane, Two-Way Roads

Model: **17-38 Spreadsheets for Applying the Highway Safety Manual Predictive Methodology for Rural Two-Lane, Two-Way Roads**
Country: United States of America
Developer: National Highway Cooperative Research Program
First released: 2010
Model type: Reactive, Accident Predictive Models
Format: Microsoft Excel based software (macro-enabled)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
££	££	£	★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	X	X	X	X

Summary

The American Association of State Highway and Transportation Officials (AASHTO) introduced the Highway Safety Manual (HSM) to provide a quantitative safety decision tool for transportation officials to assist with planning, designing, operating, and maintaining their roads. AASHTO recognised that the success of the HSM would in part depend on practitioners having access to the tools and knowledge necessary to implement the methodologies set out in it and to interpret the output appropriately. One solution to this requirement was the development of Excel spreadsheets that have the HSM predictive method equations integrated within them. A spreadsheet was developed for rural, two-lane roads (see HSM Chapter 10). The user inputs the characteristics of a number of road features which are required and the spreadsheet gives estimates for predicted average crash characteristics (numbers and severity) expected on rural two-lane, undivided roads. The spreadsheet can also give results for divided or undivided multilane rural roads. The estimates can be derived for existing road conditions but also for a range of changes that are being considered during planning.

Background

The spreadsheet gives analysis results for link segments and for intersections separately. The results for individual sections are summed to estimate the predicted average crash frequency, severity, and collision types for a rural road corridor or network. The methodology covers all crash types except collisions between a pedestrian and a bicyclist.

The estimates for the predicted average crash frequency for each road segment are based on the site-specific geometric design features present, roadway features, and traffic volumes. The calculations were developed from Generalised Linear Modelling equations that were derived from relationships between crash data distributions and a range of geometric designs, features, and traffic volumes.

Data requirements

Use of the spreadsheets is straight-forward and easy. The user can input local characteristic parameter values which are required by the equations or they can rely on the default values given in the spreadsheet that are based on representative sites.

For segment analysis, the user is required to enter the section length and the average daily traffic volume. The road segment data required includes elements such as the number of lanes and their widths, shoulder type and width, passing lanes, and the presence or absence of lighting. The presence or absence, or number, or length given for these features as appropriate will influence the estimated crash numbers.

The road feature and geometric data is generally available from official datasets or can be identified from online mapping sources such as Google Earth™ or Google Street view; the information can also be obtained during a site visit.

For the intersection analysis, the user is required to input average daily traffic volumes for all main roads, the type of control (e.g. signal or stop), and the number of approaches. In addition the intersection analysis requires details such as the skew angle, turn lanes, and lighting.

The spreadsheets provide the opportunity to enter a calibration factor that accounts for differences between the States and specific locations where the regression models were developed and the jurisdiction where the methodology is being applied. The HSM explains how to determine the value of the calibration factor.

The output gives total accidents, fatal and injury, and property damage only crashes per year in tables that are suitable for inserting into other documents to present the results.

A useful feature is the ability of the spreadsheet to give the better long-term estimate for expected crash number for a segment or for a junction based on the actual observed number of crashes and the Empirical Bayes regression estimate which takes account of the large random element in crash occurrence.

Some states have customised the excel spreadsheets to provide an improved user interface; included output charts and graphics and added additional functionality. Specifically states have added regional calibration factors and countermeasure selection and benefit-cost modules.

Software requirements

Microsoft Office 2003 Excel is required.

Licencing

AASHTO provides the spreadsheet files free of charge on its website.

References

NCHRP. 2010. NCHRP 17-38 Spreadsheets for Applying the Highway Safety Manual Predictive Methodology for Rural Two-Lane, Two-Way Roads. National Cooperative Highway Research Program. American Association of State and Highway Transportation Officials.

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http://www.idot.illinois.gov/assets/uploads/files/transportation-system/manuals-guides-&-handbooks/safety/hsip%20spreadsheet%20tool%20user%20manual.pdf

Ohio Department of Transportation. 2014. Economic Crash Analysis Tool (ECAT)

http://www.dot.state.oh.us/Divisions/Planning/ProgramManagement/HighwaySafety/HSIP/Pages/ECAT.aspx

Assessment criteria	Star rating	Justification
Main benefits	★★	Suitable for rural roads, accounts for regression to the mean; rigorous approach and research behind it even if application is limited.
Quality of model design	★★	Designed for the singular purpose of predicting average annual crash frequency for design evaluation purposes: does it well though.
Ease of use	★★★	User interface is simple, most users are already familiar with use of Excel spreadsheets – some States have developed extensions to make it easier to use and increase functionality.
Considers various road user groups	★★	Methodology includes predictions for crash types except pedestrians and bicyclists collisions; more research underway.
Quality of economic appraisal	★	Spreadsheets do not perform economic appraisals.
Evaluation and monitoring included	★	Monitoring and evaluation are not included.
Validation of methodology/strength of literature base	★★	Models were developed through rigorous multistate statistical analysis. Models were completed at different times and research continues to evolve. Overall, 17-38 spreadsheets have improved decision making.
Data requirements/cost	★★★★	Spreadsheet is flexible for use with available data or data can be collected if desired but ideally needs flows.
Human resource requirements/cost	★★★★	Spreadsheets can be used with existing agency staffing and available data but judgement needed to interpret outputs.
Software/licencing requirements/cost	★★★★★	Spreadsheet is a free download.
Intellectual property considerations	★★★★★	Available to public on AASHTO website.
Development potential	★★★	Some opportunity to modify the methodology as new research comes out for other measures; States have provided better interfaces.
Ease of modification for use in UK	★★★	The models are based on crash history in US, which may not be directly applicable to UK; requires Safety Performance Functions to be developed.

A.11 HiSafe: Companion Software to the Highway Safety Manual

Model:	**HiSafe: Companion Software to the Highway Safety Manual**
Country:	United States of America
Developer:	Digiwest, LLC
First released:	2010
Model type:	Reactive, Accident Predictive Models
Format:	Software

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	££	££££	★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	X	✓	✓	X

Summary

The American Association of State Highway and Transportation Officials (AASHTO) introduced the Highway Safety Manual (HSM) to provide a data based safety decision tool for transportation officials for planning, designing, operating, and maintaining their road facilities. The HSM allows designers and planners to evaluate a variety of design decision trade-offs such as implementing narrower lanes and wider shoulders; meaning that safety can become part of the practical design process and /or least cost planning analyses. It allows for safety to be quantitatively assessed, improving transportation decision making.

To make application of the HSM processes easier and more convenient for practitioners, Digiwest developed HiSafe. HiSafe is user friendly software that computerises the HSM predictive equations including those developed for rural, two-lane roads (see HSM Chapter 10). Regression equations which relate a range of road characteristics to crash occurrence have been developed; this methodology permits estimates of the predicted average crash frequency, crash severity, and collision types for rural two-lane, two-way roads where a range of conditions are known and are covered by the regression equations. These equations are the same as the 17-38 HSM Sheet incorporated in the NCHRP 17-38 Spreadsheet described in another summary in this report. Again this software tool allows the safety assessment of the current situation and planned changes (physical features that are being considered during a planning phase) for a defined future time period. HiSafe provides the crash reduction for specific selected intersection and segment safety treatments and has the ability to provide a benefit to cost ratio economic appraisal.

Background

The software allows users to estimate the predicted or expected average crash frequency, severity, and collision types for a rural roadway facility or network. As per the NCHRP 17-38 Spreadsheet the methodology includes estimates for all crash types except those between a pedestrian and a bicyclist.

Data requirements

The user can input real data values collected for the actual road segments which they wish to model or default parameter values that are representative for similar sites can be incorporated into the regression models.

The user is required to enter segment length and average daily traffic flow for a segment analysis. The roadway segment variables for which CMFs are given in HiSAFE include the number of lanes and their width; shoulder type and width; passing lanes; and lighting.

The intersection variables for which CMFs are given include elements such as skew angle; turn lanes; and lighting.

For the intersection analysis, the user is required to input average daily traffic flow for both roads, type of control (signal or stop), and the number of approaches.

The required roadway features and geometric data should be available from agency records and online mapping sources such as Google Earth™. These can also be obtained during a site visit.

Issues such as systematic differences in police crash reporting and recording rates, and the general terrain type can affect the performance of the SPFs. Calibration factors which correct the SPFs for differences between where they were calculated and where they are being applied can be estimated and HSM provides instructions on developing these factors.

Crash prediction methodology

The estimates for the predicted average crash frequency for each site are based on the site-specific geometric design, roadway features, and traffic volumes. The calculations rely on Safety Performance Functions (SPFs). These are simple regression equations that were developed for the relationship between crash data and variation in section length and traffic volumes. The different relationships were calculated for a range of main site types (e.g. rural undivided, rural multilane divided etc.) over a range of flow levels.

HSM uses a range of Crash Modification Factors (CMFs) to modify the predicted crashes per year estimated by the SPFs. The approach builds up equations that will estimate expected crashes at locations when the user inputs the values in the relationship equations.

The output gives results separately by total crashes, fatal and injury, and damage only crashes per year in tables that are suitable for inserting into other documents to present the results.

Assessment of treatments

In addition to the predictive equations, HiSafe has built-in countermeasures to assess impacts of various segment and intersection treatments.

For intersections, HiSafe will evaluate the impact of modifying an intersection skew and convert stop control to signal control. For segments, the impact of safety for varying treatments can be analysed - including centreline rumble strips; modify horizontal curve; lane width adjustments; roadway lighting; adding or widening paved shoulders; improved roadside design; shoulder rumble strips; improved super elevation; and vertical alignment changes. For both intersection and segment improvements users may add a customised crash modification factor if they have some basis for doing this.

Users have the ability to add customized crash modification factors. Users should use caution when selecting treatments and their effectiveness. The FHWA CMF Clearinghouse is a valuable resource for obtaining appropriate CMFs.

Economic appraisal

HiSafe provides a basic benefit – cost ratio assessment. The BCA analysis requires users to input the cost and service life of potential treatments.

Licencing

HiSafe can be downloaded as a free 21 day trial and costs $500 per single licence.

References

Digiwest, LLC. 2010. HiSafe v3: Companion Software to the Highway Safety Manual. http://hisafe.org/.

Assessment criteria	Star rating	Justification
Main benefits	★★★	Suitable for rural roads, accounts for regression to the mean; rigorous approach and research behind it even if application is limited; includes limited countermeasure evaluation and economic appraisal.
Quality of model design	★★★	Designed primarily as a crash frequency prediction tool with some ability to assess impacts of safety treatments and develop an economic appraisal.
Ease of use	★★★★	User interface is simple, easy to learn and input data to get results quickly.
Considers various road user groups	★★	Methodology includes predictions for crash types except pedestrians and bicyclists collisions; more research underway.
Quality of economic appraisal	★★★	Basic BCA can be performed.
Evaluation and monitoring included	★	Monitoring and evaluation are not included.
Validation of methodology/strength of literature base	★★★	Models were developed through rigorous multistate statistical analysis. Models were completed at different times and research continues to evolve. Overall, predictive methods have improved decision making.
Data requirements/cost	★★★	Limited data requirements or data can be collected if desired.
Human resource requirements/cost	★★★★	Spreadsheets can be used with existing agency staffing and available data.
Software/licencing requirements/cost	★★	$500 per single-user licence.
Intellectual property considerations	★★★	Trial version available for download, software can be purchased on website.
Development potential	★	Some opportunity to modify the methodology as new research comes out for other measures.
Ease of modification for use in UK	★★	The models are based on crash history in US, which may not be directly applicable to UK; requires SPFs to be developed.

A.12 Interactive Highway Safety Design Model (IHSDM)

Model:	**Interactive Highway Safety Design Model (IHSDM)**
Country:	United States of America
Developer:	Federal Highway Administration
First released:	2000 (current version 2014)
Model type:	Proactive, Crash Prediction Models for Identifying Site Specific Improvement Potential
Format:	Software

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	££	£	★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	X	X	X	X

Summary

The Interactive Highway Safety Design Model (IHSDM) is a suite of software analysis tools used to evaluate the effects of geometric design options on highways. IHSDM provides estimates of the expected safety and operational performance of a highway's design and checks existing or proposed designs against relevant standards. Results of the IHSDM support decision making in the design process. Maximum benefits are achieved when using IHSDM for making design decisions because the safety assessment is combined with design consistency and policy adherence modules lending itself to the design exception process.

Background

The IHSDM currently includes six evaluation modules (Crash Prediction, Design Consistency, Intersection Review, Policy Review, Traffic Analysis, and Driver/Vehicle). The Crash Prediction Module computerises the HSM predictive equations including those developed for rural, two-lane roads (see HSM Chapter 10). Again this software tool allows the safety assessment of the current situation and planned changes (physical features that are being considered during a planning or design phase) for a defined future time period.

Data requirements

The user can input real data values into the regression models which have been collected for an actual road segments which they wish to model or there is the option to use default parameter values that are representative for similar types of sites.

The user is required to enter segment length and average daily traffic flow volume for a segment analysis which is required for the Safety Performance Function calculation. In addition there is a requirement to input data detailing a number of the roadway segment variables include the number of lanes and their width, shoulder type and width, the presence of passing lanes and lighting. These features all have Crash Modification Factors associated with them in the model.

For the intersection analysis, the user is required to input average daily volume for both roads, type of control (signal or stop), and the number of approaches.

The intersection variables for which Crash Modification Factors are given include elements such as skew angle, turn lanes, and lighting.

The required roadway features and geometric data should be available from agency records and online mapping sources such as Google Earth™. These can also be obtained during a site visit.

Methodology

The software estimates the predicted average crash frequency, severity, and collision types for a rural road corridor or network. The methodology covers all crash types except collisions between a pedestrian and a bicyclist.

The estimates for the predicted average crash frequency for each road segment are based on the site-specific geometric design features present, roadway features, and traffic volumes. The calculations were developed from Generalised Linear Modelling equations that were developed by deriving the relationships between crash data distributions and a range of geometric designs, features, and volumes.

The output give results separately for total crashes, fatal and injury, and damage only crashes per year in tables that are suitable for inserting into other documents to present the results.

The software has a variety of input options to improve usability. Output tables and graphics are helpful for comparing analysis output of multiple corridors of sets of improvements.

Calibration of the model

IHSDM has a facility that has the ability to develop calibration factors based on site data. The calibration factors adjust the safety performance function results to account for regional differences.

Software requirements

The minimum Windows computer system requirements to run IHSDM are as follows:

- Software
    - Recent Windows Operating System, XP or better up to Windows 7
    - Web Browsers: Firefox, Netscape Navigator, or Microsoft Internet Explorer
- It will run on an entry level PC

Licencing

IHSDM is free to download and there are many options for obtaining free technical support. Technical support can be obtained through the help line, support e-mail, training courses (in-person or webinars), case studies, documentation, frequently asked questions, and an online problem report/change request form.

References

FHWA. 2015. Interactive Highway Safety Design Model (IHSDM v 10.1.0). https://www.fhwa.dot.gov/research/tfhrc/projects/safety/comprehensive/ihsdm/. U.S. Department of Transportation, Federal Highway Administration.

Assessment criteria	Star rating	Justification
Main benefits	★★	Software started as a rural road analysis tool, accounts for regression to the mean; rigorous approach; includes modules to consider adherence to policy and design standards; includes calibration capability and multiple methods for inputting data.
Quality of model design	★★	Designed for the purpose of evaluating adherence to design and policy standards and realising the impact of design decisions on the predicted average annual crash frequency.
Ease of use	★★★	User interface is user friendly, requires some training.
Considers various road user groups	★★	Methodology includes predictions for crash types except pedestrians and bicyclists collisions; more research underway.
Quality of economic appraisal	★	Does not perform economic appraisals.
Evaluation and monitoring included	★	Monitoring and evaluation are not included.
Validation of methodology/strength of literature base	★★	Models were developed through rigorous multistate statistical analysis. Models were completed at different times and research continues to evolve. Overall, IHSDM has been useful for demonstrating design decision trade-offs related to crashes.
Data requirements/cost	★★★	Data requirements are the same as the 17-38 spreadsheets, however, additional data is required for use with the design standard and policy modules. CAD and Microstation files can be used as input files.
Human resource requirements/cost	★★★★	Usable with existing agency staffing and available data.
Software/licencing requirements/cost	★★★★★	Free download.
Intellectual property considerations	★★★★★	Available to public on the IHSDM website.
Development potential	★★	Some opportunity to modify the methodology as new research comes out for other measures; FHWA leads the software development and upgrades and would need to be involved in customisation.
Ease of modification for use in UK	★★	The models are based on crash history in US, which may not be directly applicable to UK; requires SPFs to be developed; Standard and policy modules would needed to be updated to reflect UK criteria.

A.13 iRAP Star Rating

Model: **International Road Assessment Programme (iRAP) Star Rating**
Country: International
Developer: Road Safety Foundation (UK registered Charity)
First released: 2006
Model type: Risk-based
Format: Various data collection standards and Excel/web based

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££££	££££	££££	★★★★★	★★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	✓	✓	✓

Summary

International Road Assessment Programme (iRAP) established 'Star Rating' as a way to develop large and cost-effective programmes of infrastructure safety improvements for road networks. The Star Rating programme has an ambitious global remit to be a key tool to reduce significantly global road deaths and serious injuries. This is to be achieved through the implementation of major programmes of safer road infrastructure improvement on longer higher risk routes where they are most needed. By the end of 2015 an estimated 550,000km of road had been assessed across 60 countries.

The method is primarily based on recording the main key physical elements that are present on roads and which are known to have effects on road safety. These key road features are each given an attribute score which relates to how likely a severe injury would be from that feature. For example, curves can be manually assessed as being very severe, severe, moderate or slight. The scores assigned are used to estimate the overall level of risk for various road user groups (pedestrians, motorcyclist, bicyclists and vehicle occupants) that results from using the road environment.

The Star Rating process is comprehensive. It requires detailed scoring of a range of physical features over every 100m length of a road that is being rated. Other data such as vehicle speeds and flow data (for a range of road users) for both junctions and links are also required. Where full economic analysis of improvement options is required additional information outlining the number of fatalities across the network and a breakdown of these by the main crash types is needed; as are economic parameters.

Trained personnel score the severity of road features for each 100m section and this assessment is used to calculate the Star Rating for sections which can range from one (poor) to five (safest). The Star Rating is grouped over longer sections and then displayed on colour coded route maps so that road quality can be visualised better.

The Star Rating process is scalable; spot Star Ratings can be undertaken using the Demonstrator tool which is available at http://vida.irap.org. This can provide a means of indicating how safe a particular point is for pedestrians, cyclists, motorcyclists and vehicle occupants. The breakdown of risk by likely crash type is provided and the possible effect of different remedial treatments on the star rating can be explored. Where economic evaluations are required the road scoring information is also used to develop Safer Road Investment Plans (SRIPs). These are major programmes of infrastructure upgrades to correct systematic defects at the network and route level. A library of countermeasures is included in the iRAP software (ViDA) and these are selected for locations based on triggers that relate to the particular safety deficits identified from the scoring process.

Fatality estimation assigns the known number of fatalities on the whole network across the assessed roads in line with the calculated risk levels. This information is then used to estimate the fatality reductions that may be obtained from implementing the specific SRIP measures. This in turn feeds into the process of economic appraisal for the different elements of the SRIP.

iRAP is Safe System based and takes account of the safety of vulnerable road users. It develops Star Ratings and SRIPs separately for pedestrians, bicyclists and motorcyclists in addition to those for vehicle occupants.

Background

iRAP is an umbrella organisation for the different global Road Assessment Programmes; it is a UK registered charity operating in 70 countries. Activities undertaken in the UK are overseen by the Road Safety Foundation, which is also a UK registered charity.

The aim of the iRAP Star Rating of roads is to produce a comprehensive, proactive approach to manage safety better on road networks. A key driver was to develop a methodology which could be used in a wide range of countries without the need for detailed crash data in order to produce iRAP Risk Maps or to use other reactive approaches.

Star Ratings grew out of an earlier EuroRAP risk model which assessed the protective characteristics of roadside features present. These Road Protection Scores (RPS) were scored from a drive-through survey. The early EuroRAP RPS process considered only the safety of car occupants and produced ratings of roads on a four-star scale. Piloting was completed in 2002.

Personnel from research organisations in the US, UK, Australia, and Malaysia were originally involved in developing the iRAP methodology; technical input has since expanded with other organisations from other countries now also involved. There have been three main versions of the 'iRAP Model' which is the fundamental structures of the equations which are used to relate the scored features to the risk level. The current main version in use is 3.02, some regional RAPs continue to use previous versions to maintain consistency with previous results and because they consider earlier versions still fit their needs.

iRAP introduced an assessment of the likelihood of crashes in addition to the protectiveness of road elements. iRAP also introduced a five star rating scheme.

Description of the model

Where a network level assessment is required, the first stage of an iRAP Star Rating is to source an existing video survey (e.g. asset or inventory survey; Google) and undertake a detailed road survey which entails collecting asset inventory information for the network which is to be assessed. Scoring is then done for a maximum of 78 road features. In practice a smaller number (about 50) of elements are generally applicable to each road. Road feature scoring is currently primarily video based. However scoring has been combined with the physical drive-through survey method by a two-person team in the past and this may still be a viable methodology on simpler roads; and the walking or cycling based assessments may be appropriate for smaller lengths.

The video recording is typically done by an instrumented vehicle which generally has forward and backward facing cameras, although assessments can be made via video collected by portable forward facing cameras systems. The distance between, or length of, some road elements are required so the images need to be calibrated to enable accurate lengths to be measured. The vehicles also carry accurate GPS receivers which can record the precise location and also information such as the arc of bends during the survey.

The features are scored from the video images by trained personnel who ideally have some road engineering background; this process can be subcontracted to iRAP accredited companies which can make the process cheaper. Increasingly, scoring can be done automatically from GIS based survey data for a large number of the required attributes making the assessment process quicker and cheaper.

The scored data is then used to produce the Star Ratings for road sections expressed as a score from one star (poor) to five stars (safest).

Data requirements

The scoring process requires road inspection data which is collected through high quality, wide angle view video mounted on an instrumented vehicle with GPS location integrated in the video frames. The road attributes are scored primarily from the video record, although some features such as curve severity can be scored from GPS records.

There is no prescribed set method to perform road inspection and scoring providing that the quality of the output is high.

85th percentile and mean traffic speeds are required for all links being assessed. Categorised Average Annual Daily Traffic is needed as well as traffic flows on minor arms at junctions. Some challenging data that are required include categorised pedestrian flow ranges along and across roads and also bicycle flows along roads; some proxy methods have been developed to derive these values from land-use information where counts are not available.

Prioritisation of high-risk sections

An iRAP Star Rating Score identifies the risk in 100m sections of roads however it is a route or network level tool and it is designed to identify general problems over longer lengths. The individual 100m risk scores are represented on maps averaged or smoothed over 3km sections in rural areas and 1km sections in urban areas. The Star Rating system reflects the typical international practice of recognising the best performing category as 5-star (green) and the worst as 1-star (black).

Identification of road safety defects

The specific defects in road sections are identified based on their severity scores.

Generation of potential treatments

The iRAP ViDA software is used to generate the Star Ratings and has a series of trigger values set which relate to the risk scored for the various individual road elements. If the overall risk in a section is high, the software suggests countermeasures which are appropriate for the sources of risk from a library of around 90 measures.

The software produces indicative solutions which feed into the SRIPs. The actual final programme of detailed solutions must be developed by experienced engineers, but this will be heavily influenced by the suggested SRIP.

Economic appraisal

The SRIPs are economically evaluated programmes. The ViDA software distributes the known number of fatalities across the network in proportion to the overall risks which have been identified during the assessment. The measures suggested in the SRIPs have costs (implementation and on-going maintenance) and effectiveness levels for reducing fatal and serious casualties. These values are brought together to generate the Benefit to Cost ratios.

Monitoring and evaluation

iRAP has an in-built evaluation monitoring capability. The reduction of risk across the network can be assessed by re-scoring the road, typically after three to five years, once safety investment has been applied. However, this monitoring process does not specifically assess decreases in fatalities and serious casualties, which could be done where data is available, to check whether they are in line with the predicted reductions.

Software Requirements

Some specialised GIS system linked to the video footage for scoring, MS Excel for holding and checking the scoring data, access to the free web based ViDA software which is required. The Star Rating data can be linked to local bespoke asset or road state management software where required.

Licencing

Access to ViDA is free for Star Ratings and very cheap for economic analyses and open to all relevant organisations.

References

ViDA http://vida.irap.org

Star Rating Demonstrator https://vida.irap.org/en-gb/demonstrator

iRAP Methodology Fact Sheet # 1 Overview http://www.irap.net/en/about-irap-3/methodology

iRAP Star Rating Policy Fact Sheet http://www.irap.org/en/about-irap-3/research-and-technical-papers

Engineering Safer Roads Star Rating roads for in-built safety http://www.eurorap.org/engineering-safer-roads-star-rating-roads-for-in-built-safety

Assessment criteria	Star rating	Justification
Main benefits	★★★★★	The iRAP Star Rating covers all the main steps for managing safety at the network level. It includes sophisticated and sound research to manage risk relatively easily and clearly.
Quality of model design	★★★★★	iRAP Star Rating is probably the only model that covers all the main route safety management processes including a strong element of evaluation.
Ease of use	★★★	Generally the method is easy to apply once scoring is done; it is a useful planning tool at the network and corridor level. The Vida software is somewhat complex and not entirely straightforward to operate. Experienced road safety engineers are required to develop detailed counter measure plans.
Considers various road user groups	★★★★★	iRAP does explicitly consider road safety issues specific to motorcyclists, pedestrian and cyclists in addition to vehicle occupants.
Quality of economic appraisal	★★★★★	BCRs are easily generated for the SRIP programme elements; users can vary costs/CMFs.
Evaluation and monitoring included	★★★★	Evaluation is based on re-assessment and re-scoring the risk, to identify any changes after improvements were made. This is not given five stars because the evaluation does not explicitly measure casualty reductions where this could be done.
Validation of methodology/strength of literature base	★★★★	Based on rigorous research, some efforts have been made to confirm that Star Rating relate to crash costs/KM; some expert review has been performed.
Data requirements/cost	★★	For full surveys iRAP requires extensive high quality video, the detailed scoring of a large range of elements, also an extensive range of good quality flow and speed data and costs for measures. For local level assessments lower cost options exist that simplify the process.
Human resource requirements/cost	★★	Scoring requires training to do assessments well; it can be out-sourced. Running ViDA requires training. Detailed engineering designs still need to be developed by experienced staff.
Software/licencing requirements/cost	★★★★	Varies: Third-party asset software and GIS software to manage video scoring is generally required; access to iRAP. ViDA software is free and access fairly open.
Intellectual property considerations	★★★	iRAP are a charitable organisation and are open about the research that has gone into developing the model. Use of the algorithms and detailed methodology is not permitted without clear consent from iRAP.
Development potential	★★★★★	iRAP encourages innovation and expansion of the methodology and also wider use of the data required to run the Star Rating. The programme benefits from the ideas and contributions from partners across the world.
Ease of modification for use in UK	★★★	More suited to higher volume roads; However pilots of Star Rating have already been run using iRAP on road sections in two UK Local Authority areas. Star Ratings of Designs, Schools and Public Transport Hubs highlight some lower data applications and potential for local authorities.

A.14 NetRisk Rating Tool

Model:	**NetRisk Rating Tool**
Country:	Australia
Developer:	ARRB Group & Roads Alliance
First released:	2006
Model type:	Risk-based
Format:	Microsoft Excel based software with purpose-built form which can be imported into video rating

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	££	£££	★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	-	X	X	X

Summary

The NetRisk Rating Tool is a road safety risk assessment model developed in Australia by the Australian Road Research Board (ARRB) in collaboration with the Roads Alliance[3]. The rollout of the model commenced in 2006. The NetRisk Rating Tool, formerly known as the Road Network Safety Assessment (RNSA) tool, was designed to enable the relatively rapid assessment of infrastructure and features on a road network while calculating a risk score that is accurate enough to be used as the basis to prioritise road sections and intersections for further investigation.

The relatively low number of road features included on the rating form used for the assessment suggests that the output is not as comprehensive as that produced by alternative models such as the International Road Assessment Programme iRAP; however the trade-off is that the rating process is faster and requires fewer resources.

The NetRisk Rating Tool is the first step of a two-step NetRisk process. The second step is to use Road Safety Risk Manager (RSRM) to identify the appropriate road safety treatments and perform economic appraisal on these treatments.

[3] Roads Alliance is a strategic partnership between the Queensland Government Department of Transport and Main Roads (formerly Queensland Main Roads) and the Local Government Association of Queensland to oversee the network of 'Local Roads of Regional Significance'.

Background

By the mid-2000s, many Australian road authorities had adopted the Safe System approach to road safety which puts less emphasis on reactive approaches and more on proactive approaches to manage safety. In addition, a change in national law at that time meant that authorities were now legally required to identify where risks were located on their roads.

NetRisk addresses the requirement for a proactive risk-based approach to network screening and was developed for local road authorities in Queensland, Australia. Its chief purpose is to assist with the safety management of their minor strategic roads, which are equivalent to B and C roads in the UK. The rating form for the NetRisk Rating Tool was designed to be simple, with only a limited number of road features requiring to be rated. This makes the NetRisk Rating Tool a cheaper alternative but broadly similar to models such as AusRAP/iRAP.

Description of the model

The NetRisk Rating Tool is used to rate the presence and condition of a range of road elements from a video of the network. The rating process commences when the road's main type is selected, this automatically brings up a form containing only the road elements relevant to that particular road class. Road elements are rated over 100 metres sections and the worst case (highest risk) within that 100 m section is recorded.

The tool uses different rating forms for five main road types:

- Urban intersection
- Urban mid-block
- Rural intersection
- Sealed rural mid-block
- Unsealed rural mid-block

The rating forms are relatively short and simple. There is a maximum of 15 road features that require scoring within any 100 m section. Buttons can be checked on the electronic rating form, to carry over unchanged ratings to the next 100 m section so only the changes in the road environment from section to section need to be noted.

The primary output is a 'Network Risk Score'. Typically this score ranges from around 0 (low-risk) to 20 (high-risk) for mid-block sections and 0 to 30 for intersections. This is the sum of the weighted risk for each of the road features and this is calculated for every mid-block section and intersection on the roads that has been assessed. The Network Risk Score can be used to compare the overall risk at locations regardless of road type. Intersections typically receive higher scores than mid-block sections and rural roads typically receive higher scores than urban roads. As a result, Network Risk Scores are generally ranked within their road types.

The NetRisk Rating Tool contains a set of 'safety triggers' programmed into the model. These trigger scores are customisable and can be used to produce a list of sections where the safety risk level has exceeded the set threshold level. The specific hazard that has contributed most to the heightened risk is also identified.

The primary benefit of using adjustable safety trigger levels is that some authorities might only have the available funds to treat the most severe locations on their network as opposed to focussing on improving the overall risk of extended stretches of road.

Data requirements

The minimum data requirement is a video record of each road which is to be assessed. If there is no recent video record for the network, a survey will need to be commissioned to collect the images required. Ideally the video data should include spatial information such as chainage (accurate start and end distances) and satellite Global Positioning System (GPS) coordinates for the precise location of each video image.

A weather rating based on annual rainfall data is also required for the model. A value can be estimated if specific local rainfall data is not available.

Prioritisation of high-risk sections

The primary purpose of NetRisk Rating Tool is to identify the highest risk sections in a road network. The model is designed to allow the user to assess sections relatively quickly and easily by minimising the number of road features which require a rating. The developers chose only to include those road features which most greatly contribute to serious crash outcomes on rural roads, as identified from their research on the topic.

Identification of road safety defects

The output of NetRisk Rating Tool can be used to identify road safety defects on the network but this aspect is quite basic. Further inspection of identified high risk locations using software such as RSRM is recommended to gain a better understanding of the defects to allow the correct treatments to be chosen.

Generation of potential treatments

The output (highest risk locations) must be assessed by another method such as RSRM to identify and select potential treatment options.

Economic appraisal

The NetRisk Rating Tool cannot be used for economic appraisal. An additional model or method must be used. RSRM is commonly used in conjunction with NetRisk for this purpose.

Monitoring and evaluation

The model does not include any facilities for conducting monitoring and evaluation of any schemes which are implemented as a result of running the model.

Software requirements

A NetRisk Rating Tool has minimal requirements, just a georeferenced video of roads and media player software however all known analyses identified have been undertaken scoring using ARRB’s Hawkeye Processing Toolkit. This software has an integrated image viewer screen connected to a centralised database, allowing for the straightforward review of video survey data. NetRisk rating forms are imported to the Hawkeye Processing Toolkit and for straightforward rating of the video survey data.

Licencing

Specific licencing information for the NetRisk Rating Tool was not found. The model is believed to have been informally superseded by the more recently developed Australian National Road Assessment Model (ANRAM).

NetRisk assessments were regularly undertaken for road networks around Australia between 2006 and 2012. Typically, ARRB Group undertook the assessment on behalf of the road authority using video data which was often purpose collected for the NetRisk assessment. In Queensland, Australia, road authorities were provided with the software and ARRB administered training and support to the authorities.

References

ARRB Group (2010). NetRisk rating guidelines version 2.1., (Unpublished internal document).

Deller, J. (2010). Road safety community partnership in Queensland, Australia. *Municipal Engineer*. 163, pp.225–232.

McInerney, R. & Doyle, N. (2006). Queensland Alliance road safety risk management: the complete solution. *In: 22nd ARRB Conference 29–2 October–November 2006, Canberra.*

Assessment criteria	Star rating	Justification
Main benefits	★★★	The NetRisk Rating Tool has a relatively fast and simple rating process. It cannot achieve a complete road safety outcome on its own as further assessment of high-risk sections must be done by other means.
Quality of model design	★★	Only designed to be a tool to identify and prioritise high–risk section and is effective at doing so. When used in conjunction with Road Safety Risk Manager, a comprehensive road safety model is achieved.
Ease of use	★★★	The NetRisk Rating Tool is straightforward and could be understood with some basic training.
Considers various road user groups	★★	The urban roads form contains a rating for pedestrian provision otherwise there are no other considerations for different road user groups.
Quality of economic appraisal	★	The NetRisk Rating Tool is not designed to undertake economic appraisal.
Evaluation and monitoring included	★	Does not contain function for monitoring or evaluation.
Validation of methodology/strength of literature base	★★	Based on fairly strong research base but some of this may be partly outdated compared to more recent models.
Data requirements/cost	★★★	Video data is required to undertake the assessment. A relatively low number of road features are assessed which makes the rating process efficient.
Human resource requirements/cost	★★★★	Does not require any significant extra labour resources however the user will require some training. A user guide is available and is very helpful.
Software/licencing requirements/cost	★★★	If ARRB Hawkeye software is used for video rating. A licence will need to be purchased. This software is moderately easy to use.
Intellectual property considerations	★★	Commercially available software that has been used extensively within Australia and New Zealand. Software has been used internationally. In these cases the NetRisk Rating Tool was used by the Australian-based consultant and not by the international authority itself.
Development potential	★	The NetRisk Rating Tool is considered to be superseded by more recent road safety models such as AusRAP and ANRAM.
Ease of modification for use in UK	★★★	The rating forms were derived specifically for Australian roads and these would have to be modified for the UK. The design and content of the process is logical and could be adapted relatively easily.

A.15 RANKing for European Road Safety (RANKERS)

Model:	**RANKing for European Road Safety (RANKERS)**
Country:	Europe
Developer:	CIDAUT & ERF
First released:	2008
Model type:	Risk-based with an applied factor for crash history
Format:	Suite of reports containing two tools, one of which benefits from specialised road inventory software

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	£££	££	★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	X	✓	-	X

Summary

RANKing for European Road Safety (RANKERS) was a comprehensive road safety research project to develop a suite of reports and tools to assist with road safety infrastructure decision making on non-urban roadways. The project was funded by the European Road Federation (ERF) and the majority of the project was delivered by Centro de Investigación y Desarrollo en Automoción (CIDAUT), a Spanish research and development organisation.

There were two main outputs of the project. The first was a tool used for identifying safety deficiencies on the road network and calculating a Road Safety Index (RSI) for each road section. The second was the 'Countermeasure Catalogue', a series of tables outlining various road safety countermeasures, ranked by cost and effectiveness.

The RANKERS tools, when applied effectively by an experienced road safety professional, could potentially achieve an outcome comparable to that expected of many of the more comprehensive road safety models reviewed in this report.

Background

The RANKERS project aimed to promote a proactive approach to road safety by considering the risk associated with various road features for decision making, rather than basing the assessment on the crash history. Roads are also assessed and managed in longer section lengths as opposed to short discrete locations.

The project involved extensive research to support the development and resulted in the publication of a very detailed literature review of road safety infrastructure countermeasures and their effectiveness. Based on this bank of knowledge, the RSI and Countermeasure Catalogue were designed and produced. A third output that was developed was an 'eBook' where users can look up specific road safety problem scenarios to find appropriate countermeasure options; it also gives academic sources detailing further information about each countermeasure.

The RANKERS project was completed in early 2008 and it was not possible to identify the extent to which the tools have been used in practice. The lack of information on use may be partly because most users of the tool are likely to be from non-English speaking countries. No information was found regarding any on-going development of the model and it is possible that the tools have not been updated since 2008.

Description of the model

The two main outputs of the RANKERS project can be applied together to create a relatively thorough road safety model.

The first RANKERS output is a methodology to identify road sections with safety deficiencies, with the other output being the calculation of the RSI. This calculation is based on the assessment of six 'infrastructure topics'. Each topic includes between one and seven questions. These topics are:

- Road alignment – 7 questions
- Junctions – 4 questions
- Overtaking – 5 questions
- Roadside – 1 question
- Pavement – 3 questions
- Road layout consistency – 4 questions

For every road section, each question is assigned a score between 1 (highest risk outcome) and 4 (little or no risk outcome). The definitions for each grade are prescriptive and listed on a rating form. The authors recommend using specialised road inventory software to view and rate the road images.

An average score is calculated for each infrastructure topic as well as an overall average score for the road section. All scores are assigned a colour according to the overall score, red (2 ≥ score >1), yellow (3 ≥ score >2) (-green) (4 ≥ score >3). The format for the reporting of RSI is very visually striking.

The RSI is adjusted for sections with a significant number of serious crashes by applying an accident correction factor. This has the effect of decreasing the RSI which will ensure these locations are treated sooner than other sections with comparable risk levels.

The second RANKERS output is the Countermeasure Catalogue. This catalogue contains over 100 road infrastructure treatments, grouped by the crash scenarios with their appropriate treatments.

The Countermeasure Catalogue can be used by road operators to guide them towards selecting the best possible treatment for the road safety issues which were identified when developing the RSI for each road section.

The road safety deficiencies for a road section are reviewed to determine which crash scenarios are most relevant to a road section. On this basis, the correct table in the Countermeasure Catalogue can be identified.

Each table of countermeasures contains several options of varying cost and effectiveness. Information contained in the table includes expected impact (crash avoidance or reduction of injury), effectiveness, costs (installation, operational and expected lifetime), ranking factor, and affected users.

The 'ranking factor', is a method that can be used to determine the relative cost-effectiveness of each treatment and allows for the ranking of treatments within RANKERS.

Data requirements

An assessment using the RANKERS tool requires detailed information about various road features at a network level. The most effective way to gather the majority of the required information is from video data for each road in the network. This video is rated against a set of criteria which is best done using specialised road inventory software.

It is best to have road maintenance data available so that the questions relating to pavement condition may be answered.

Fatal and serious injury crash history data is also required to calculate accident correction factors.

Prioritisation of high-risk sections

Prioritisation is achieved by calculating RSIs for each road section. While the rating form is quite complex and time consuming to complete, it only needs to be completed once for each 1.5-2 km section of road. This produces a time efficient but relatively imprecise set of results.

Identification of road safety defects

The RSI assessment process does not directly identify individual road safety defects. If the assessor is well prepared, they can keep a log of the location of specific road safety defects while completing the assessment. This may greatly increase the assessment time but this information would also be very valuable when selecting potential treatments later on.

Generation of potential treatments

The Countermeasure Catalogue can be used to guide the selection of potential treatments. There is somewhat of a disconnect between the Road Safety Index calculation and the Countermeasure Catalogue since the Road Safety Index is based on road infrastructure risk yet the treatments listed in the Countermeasure Catalogue are grouped by crash scenarios. Therefore the user must have a strong understanding of the how road safety infrastructure issues are linked to crashes in order to make the correct selection. Treatments may also be outdated as these were published in 2008.

Economic appraisal

The Countermeasure Catalogue includes an economic appraisal of sorts, but this is very limited. A ranking factor is provided for each treatment option that is based on a formula which considers both the cost and effectiveness of a treatment. A complete economic appraisal cannot be undertaken for each treatment option because often the benefit is listed as a qualitative description (e.g. either low, medium, high).

Monitoring and evaluation

Information regarding evaluation of the performance of RANKERS could not be found.

Software requirements

The only non-readily accessible software mentioned in RANKERS literature is a 'specialised road inventory software' which is in essence video viewing software which allows a rating form to be programmed into the software. This software is recommended and is not essential.

Licencing

RANKERS reports are publically available and presumably can be directly used or adapted by an authority if the developers are referenced appropriately. The developers should certainly be consulted if RANKERS is to be used for commercial purposes.

References

ERF et al. (2008). *Ranking of recommendations for road infrastructure safety* (D4.1). Brussels: European Road Federation.

Perandones, J.M. & Ramos, G. (2008). *Road Safety Index* (D4.2). Brussels: European Road Federation.

Ramos, G. et al. (2008). *Final Report* (D0.2). Brussels: European Road Federation.

Assessment criteria	Star rating	Justification
Main benefits	★★★	Prioritisation of high-risk sections is fast and straightforward. The visual representation of results is very striking. Selecting treatment options requires significant experience and economic aspects are weak.
Quality of model design	★★	Model assesses road sections and considers road engineering risk with crash history addressed by a correction factor. List of treatments is very rigid and economic appraisal is weak. No evaluation found.
Ease of use	★★	The structure of the assessment is very user friendly however it requires significant road safety knowledge to use RANKERS effectively.
Considers various road user groups	★★	RSI calculation contains no consideration for different road user groups. Countermeasure Catalogue contains some pedestrian specific treatment options.
Quality of economic appraisal	★★	Economic appraisal is limited. Treatment options are ranked according to an index. Benefit of some treatments cannot be calculated because benefit is provided in a quantitative format.
Evaluation and monitoring included	★	Monitoring and evaluation method is not included in RANKERS.
Validation of methodology/strength of literature base	★★	No external validation of methodology was found. RANKERS was founded on a large programme of research however this may be slightly outdated today.
Data requirements/cost	★★★	RANKERS is best assessed from video data of the road network which comes at a reasonable cost. Rating process is relatively fast as each question is assessed every 1.5-2 km.
Human resource requirements/cost	★★★	RANKERS assessment does not require any significant extra labour resources however the process requires more road safety knowledge/experience than alternative models.
Software/licencing requirements/cost	★★★★	RANKERS has no essential software requirements however specialised road inventory software to view images is recommended which may be costly.
Intellectual property considerations	★★★★★	Reports are publicly available.
Development potential	★	All outputs are published as text so may be amended readily. RANKERS appears to be a completed project and does not have any ongoing support from developers.
Ease of modification for use in UK	★★★★	The RSI calculation is straightforward and can be modified to suit local needs.

A.16 Identification of Hazard Location and Ranking of Measures to Improve Safety on Local Rural Roads

Model:	**Identification of Hazard Location and Ranking of Measures to Improve Safety on Local Rural Roads**
Country:	Italy
Developer:	University of Catania, EU funded
First released:	2007
Model type:	Proactive, Inspection based
Format:	Checklists and Software

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	££££	££	★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	X	✓	X

Summary

The project entitled "Identification of Hazard Location and Ranking of Measures to Improve Safety on Local Rural Roads" (IASP) was initiated specifically to develop a low cost but reliable method to identify risky sections of lower volume rural roads. The target roads are categorised as being undivided, with low/medium flow, with design speeds from 40KPH to 90KPH and 2 lanes per carriageway; they typically link between more important roads.

The authors note that a significant number of fatal and serious crashes occur on these routes but the crash data is too limited to enable traditional reactive analyses methods to identify the specific higher risk sections and the safety problems.

The project developed a methodology to estimate a Safety Risk Index (RI) based primarily on a Road Safety Inspection (RSI) approach.

The model makes use of "alignment design consistency models". It is noted by the authors that checks against design standards is not adequate alone to identify all the risks.

The guidance indicates that where crash data is available and there are enough incidents to identify hazardous sections this should be used; but the developed inspection method can be used in conjunction with the reactive analysis or on its own where crash data is inadequate.

The method is able to cover the key steps in the Safety Management process, from the identification of sections with safety defects, applying a proactive approach, to the appraisal and ranking of intervention alternatives.

Methodology

The Safety Risk Index is formulated by multiplying the risk components which are defined as:

- Drivers exposure to road threats Ef,
  - Which is proportional to section length and flow level
- Likelihood of a vehicle crashing, AFf,
  - Relates to the severity of identified risks scored by inspection
  - Design Consistency and Design Standards Checks
- Likely severity resulting from a collision, ASf.
  - Relates to features of roadside hazard identified through inspection, free flow speed and signed speed

$$\mathbf{RI = Ef \times AFf \times ASf}$$

The relationships between the road features and risk levels were derived primarily from available before and after study results in the international literature. Some of the required estimates of the safety effectiveness for some key road features were developed by applying more theoretical approaches where good before and after studies were not available.

Inspection regime

The inspection process requires three person teams in a vehicle; with a driver and 2 scorers (in the front and back seats). The scorers need to have a reasonable level of safety engineering knowledge.

Scoring is done within sections of constant length and roads are driven in both directions at moderate speed. 200 metre section length and a speed of 30 km/h are suggested by the authors for giving to the inspectors enough time to fill the checklist (200 metre will take 24 seconds to cover at 30 km/h).

A series of clear checklists are used to promote consistency and objectivity.

Eight key Road features which are consistently present on local rural roads and which have a strong bearing on safety risk are scored, these being:

- Accesses,
- Cross section,
- Delineation,
- Markings,
- Pavement,
- Roadside hazards,
- Sight distance,
- Signs.

The Safety of these specific features is ranked by inspectors as one of three states:

- High safety risk – 1
- Intermediate risk - 0.5
- Safe - 0.

In addition to the manual inspection scoring detailed above, the curvature of the road is reviewed against design standards using the recorded GPS track data. GPS is required in the vehicle to keep a track of the horizontal alignment of the road.

The scoring can also be done on tablet devices linked to the recorded GPS coordinates for the vehicles position which simplifies the process over the paper based method since the scorer do not need to note the start and end of 200m sections.

The inspectors fill the checklists by touching the screen of the tablet connected via Bluetooth to the GPS by using an Android app (Streetsheet). Once the acquisition procedure is concluded in both directions, the application merges data obtained in the forward path to those obtained in the return path.

Video is also recorded so that scoring can be checked and the inspectors' verbal comments are collected with the video. After the infield inspection, in the office the Data Analysis Module allows the inspection team to review the checklists and, supported by the video, to fill missed information or to correct errors before writing the inspection report.

Quite detailed information on real speeds is ideally required.

The inspection lists are used to identify specific and general safety issues; these are discussed between the team in a meeting and a programme of solutions is formulated and presented in a report.

Evaluation

The authors tested whether the RI was a good indicator of the actual risk by obtaining the statistical correlation between the RI values and the Empirical Bayes estimate of the numbers of crashes occurring within 30 road sections (around four to five kilometres long) for a 5 year period of data.

The authors used the Empirical Bayes (EB) estimates of crash numbers since this method is accepted to provide a more reliable estimate of crash frequency than the observed one; it provides a way to manage the large inherent variation in crash occurrence. The EB estimate of the expected number of crashes, which is based on the known Safety Performance Function type relationship to section length and traffic flow; is combined with the actual crash numbers occurring which produces a more reliable estimate not affected by the regression to the mean bias.

The authors indicated that there was a good correlation with R^2=0.87 which was highly statistically significant.

A similar validation study was recently carried out in Poland on a sample of about 180 km of two lane rural roads in the region of Krakow. A very good correlation was also found in this experiment between RI and crash frequency. This result is promising for the introduction of the IASP procedure in different countries.

Cost-benefit

The RI assessment has two basic applications. High-risk segments can be identified and ranked by the RI score. Specific safety issues that contribute more to lack of safety are pointed out by the accident frequency factor and the accident severity factor in order to give indications regarding more appropriate mass-action programs.

Recently the methodology has been extended to incorporate a module (SAFOPT) that does economic appraisal based on estimation of the reduction of risk rather than reduction in deaths and injuries and the associated costs. The RI generated is a quantitative measure, rather than the traditional qualitative Safety Inspection report; this makes it possible to perform a cost benefit analysis to help the road authority personnel to allocate any limited budget that is available for improvements optimally for Network Safety Management.

References

Cafiso, S., La Cava, G., Montella, A., Di Graziano, A., Pappalardo, G., & Taormina, S. (2007). *Identification of hazard location and ranking of measures to improve safety on local rural roads* (No. PROJECT TREN-03-ST-S07. 31286).

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http://www.dica.unict.it/users/dcafiso/IASP%20pdf/5_%20SIIV%2007.pdf

Cafiso, S., Kiec, M., Milazzo, M., Pappalardo, G., Trovato, F. (2014) Application of safety inspections for evaluation of two – lane regional roads in Poland", Archives of Civil Engineering - LX, 4, 2014 PP. 453 – 473, DOI 10.2478/ace-2014-0031

Assessment criteria	Star rating	Justification
Main benefits	★★★★	IASP is very simple easy to use and allows for rapid assessment of road hazards on the specific target rural low volume roads.
Quality of model design	★★	The model can identify hazardous road sections and specific issues can be identified from the inspection records; it focuses on the screening aspects primarily though and development of countermeasure programmes. This is very manual.
Ease of use	★★★★	Experienced inspectors are required to score the roads. Actual inspection method is very simple and relatively very few parameters are required to be scored.
Considers various road user groups	★	There is no indication that the method is specifically sensitive to the safety of VRU groups.
Quality of economic appraisal	★★★	Cost-benefit analysis can be undertaken; a disadvantage is that the benefit is presented in terms of risk reduction instead of in economic terms. Processes are quite manual.
Evaluation and monitoring included	★	No evaluation or monitoring is explicitly included.
Validation of methodology/strength of literature base	★★★	The authors had done some evaluation to check that the RI correlated with crash occurrence. It is unclear if the test applied was really sensitive enough or controlled enough variables to be definitive.
Data requirements/cost	★★★	The data requirements are fairly simple however the inspection requires 3 persons and experienced scorers driving road sections twice.
Human resource requirements/cost	★★	The collection of data is fairly challenging/time consuming and requires experienced road auditors to do scoring.
Software/licencing requirements/cost	★★★★	The system was developed by a university with EU funding. It is not a commercial venture and is scope to adapt it with the developers' participation is possible for minimal costs.
Intellectual property considerations	★★★★	The developers are open to assisting the development of the application for new countries.
Development potential	★★★	Development has occurred to computerise data collection for mobile devices and to extend the functionality to do some CBA, further development and refinement should be possible.
Ease of modification for use in UK	★★★	The system was developed for Italy but has been applied on a trial basis in Poland recently. The tool is ideal for Local Authorities in terms of data requirements and ease of use. Some adjustment of the road features scored may be required and for any parameters.

A.17 Road Infrastructure Safety Assessment (RISA)

Model: **Road Infrastructure Safety Assessment (RISA)**
Country: New Zealand
Developer: New Zealand Transport Agency
First released: 2007
Model type: Risk based model
Format: Microsoft Excel based software (macro-enabled)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	££££	££	★★	★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	X	-	X	X

Summary

RISA is a road safety model from New Zealand developed between 2002 and 2006, and it was fully in use between 2007 and 2011. The model was developed to allow highway authorities to understand the risk to road users from infrastructure and to prioritise funding on those sections of road where it is most required to improve safety.

The model was initially developed as a network risk assessment tool but can also be used to assess corridors. It is applicable only for rural sealed roads. RISA evaluates collected field data and then uses a formula to identify sections for improvement where the highway authority should focus effort in order to reduce the risk to road users. The formula and method was further refined to enable authorities to analyse the potential risk reductions that could be achieved by implementing various improvements by calculating the changed risk score.

RISA calculates the relative risk of each road assessed as 'Personal Risk', which is the risk to individual road users and 'Collective Risk', which is the risk to all road users. Personal Risk refers to crash rates taking flow into account and Collective Risk relates to the number of crashes per unit length. The Collective Risk can be combined with data on traffic volumes to provide a 'Network Risk' score that relates to the potential number of crashes on the network.

RISA is not a 'fully comprehensive' road safety model but may be combined with other methods which will generate road safety treatments and perform economic appraisal to create a more holistic road safety approach.

Background

RISA was developed as an evidence-based tool following on from experience with the safety auditing (inspection) of existing roads within New Zealand in late 1990s. The tool is based on world-wide research which relates individual infrastructure features and associated crash rates. The outcome of this research was the development of the risk factors for the identified features and these were validated for New Zealand conditions.

The RISA methodology does not consider existing crash data patterns on road sections and it is a proactive tool which takes into account risk which is determined by the road layout and infrastructure elements present. However, applying RISA can be a complex task that requires inspectors who are experienced in crash investigations and highway design to undertake the assessment.

Description of the model

The RISA system is a two stage process involving physical inspection followed by a desk-top analysis. A pre-stage involves comparing the safety performance of a road section against a benchmark road. This road is not special; it should have features common to rural roads in UK, whilst other features are uncommon, such as no roadside hazards.

The RISA data collection assessment is carried out by a team of three personnel who collect all the information by a visual inspection of the road; data is captured by completing field recording sheets manually. The selected route is driven 4 times, once in each direction at normal operating speeds and once in each direction at a slower speed to assess hazards.

Each assessor is assigned one survey form to complete for each road segment which is assessed. The forms are:

- Cross Section: Lane and shoulder widths and roadside hazards
- Alignment: Horizontal curves and delineation
- Surface and miscellaneous aspects: Surface condition, access ways and single lane bridges with priority working.

On completion of the assessment process the collected road data is entered in to an MS Excel workbook and macros validate the data and calculate the risks; the workbook produces a number of charts to illustrate the results.

Within the model, each feature is assigned a risk relative to the benchmark road's risk level, and this risk level is then multiplied by the extent or exposure of that feature. The model is simple in that it adds these values together which results in an overall risk score (per km or road) relative to the benchmark road. Traffic volume is combined with the risk scores as a set of bands (AADT bands) to create the Collective Risk - the predicted number of crashes.

The Collective Risk scores across all the roads are combined to create a Network Risk which represents the contribution that the road infrastructure features make to the number of crashes on the network; this can be used as a performance measure.

Junctions are treated differently from link sections of the road because research information was not available to build a risk model based on intersection engineering features. For junctions, RISA uses a compliance with good practice assessment for intersections that results in a pass or fail scoring. The assessment for intersections has two main focusses:

- Design issues (e.g. safe intersection sight distance)
- Maintenance Issues (e.g. quality of the road markings)

No attempt is made to combine link and junction assessments.

Data requirements

The precise number of road attributes for which data is collected is not known as the full guide manual is not available. The model also requires annual daily traffic volume data for each road section analysed.

Prioritisation of high-risk sections

The primary function of RISA is to identify high-risk sections of road in 1 kilometre sections. The outputs of the model are a number of risk ratings that are provided as individual mid-block Personal Risk for each of the three survey form themes. These are combined to create the personal risk scores for each road. The model will also calculate Collective Risk scores for each road and the Network Risk Number. Using the Macro workbook the user can easily identify road sections with different levels of risk and prioritise those stretches which have the highest risk rating.

A similar process to identify junctions that require safety attention can be undertaken. This is based on the safe intersection sight distance, the safety design assessment against best practice and the safety related maintenance assessment.

Identification of road safety deficits

RISA does not output specific deficits identified as part of the assessment process. The outputs provide overall risk scores for each kilometre of road.

Generation of potential treatments

RISA does not identify treatments for specific sections but predetermined treatments can be tested allowing the resulting reduction in risk rating to be estimated. The reduction in the network risk number acts a guide to determining the recommended treatments which are decided by experienced personnel to ensure that proposed changes are practical. The recommendations are aimed at a high level and are not location specific.

Economic appraisal

RISA does not undertake the economic appraisal of the potential treatments.

Calibration of the model

In order to undertake the analysis of roads within a network a benchmark road needs to be assessed to allow comparison. Once the benchmark road is established then for all future road lengths assessed the model will assign risk factors to the differences between the assessed road and the benchmark road. For use in the UK the risk factors will need to be evaluated and potentially altered.

Use of the model

RISA was fully operational between 2007 and 2011 and can still be used for assessment purposes but has been superseded somewhat by the development of KiwiRAP in 2011. RISA analysis was developed to be used by all Road Controlling Authorities in New Zealand.

Software requirements

RISA is an MS Excel workbook with macros enabled, thus the software requirements are minimal.

Licencing

RISA was funded by the NZTA with the intention that the developed model be used by New Zealand Road Controlling Authorities. No information was found about the cost of a RISA licence or the cost of completing a RISA analysis. At this point in time RISA is not a commercial product. Furthermore, the guidance produced by NZTA, NZTA (2008) Road Infrastructure Safety Assessment Draft Guidance is an internal document only.

References

England, J., Hannah, J., & Wilkiec, S. (2013) RISA: A case study of the crash reduction potential of RISA on local rural roads in New Zealand. Proceedings of the 2013 Australasian Road Safety Research, Policing & Education Conference 28th – 30th August, Brisbane, Queensland

Dr Appleton A. (4th IRTAD CONFERENCE 16-17 September, 2009, Seoul, Korea2009) Road Infrastructure Safety Assessment

Assessment criteria	Star rating	Justification
Main benefits	★★	Easy identification of roads with higher risk ratings for prioritisation.
Quality of model design	★★★	Not a comprehensive model. It will not generate treatments or undertake economic appraisal. Reduction in risk can be assessed by applying known treatments but does provide good methodology for the areas it was designed.
Ease of use	★★	Requires detailed road safety engineering experience to undertake the assessment.
Considers various road user groups	★	No information is detailed and no vulnerable user group focus is available.
Quality of economic appraisal	★	Does not undertake economic appraisal.
Evaluation and monitoring included	★	Does not perform evaluation and monitoring.
Validation of methodology/strength of literature base	★★★	Some evaluation has been undertaken. Review of before and after crash data that showed reduction in crash rates. Also shows good correlation between predicted and actual crash rates.
Data requirements/cost	★★★	Requires asset survey, exact number of variables to record unknown and ADT flow data.
Human resource requirements/cost	★★	Requires large commitment from staff with 3 experienced members of staff on site for the assessment process. 5km of road can be undertaken in 3 days, including data input.
Software/licencing requirements/cost	★★★★	Minimal; workbook macros; cost of licence unknown
Intellectual property considerations	★★	New Zealand government funded, unlikely to allow free use by other countries.
Development potential	★	Although still used in New Zealand it is likely that KiwiRAP will become the model / technique of choice so further development may not take place.
Ease of modification for use in UK	★★	Model is configured for roads in New Zealand. New risk factors will need to be calculated for UK rural roads. Data availability and overall cost may be prohibitive factors.

A.18 Road safety inspection and assessment

Model: **Road safety inspection and assessment**
Country: Worldwide
Developer: Various
First released: Not Applicable
Model type: This is a process as opposed to a model
Format: Site assessment followed by route specific recommendations

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
££	£££	£	★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	X	X	X

Summary

Road safety inspection (RSI) and assessment (RS Assessment) are established processes that can jointly be used to analyse a route to identify road safety issues and then to develop a list of potential appropriate treatments. The terminology or jargon for both of these processes varies around the world, for the purpose of this review the definitions are as set out in the African Road Safety Manuals published by the African Development Bank in 2014; this guidance was developed from reviewing a number of good practice manuals from around the world.

An RSI is an inspection of an existing road with the objective of identifying locations where aspects of the road environment which contribute to safety risk are deficient and require improvement. An RS Assessment is an intensive expert assessment of the safety features of an existing road, which is generally applied to sections identified by RSI.

The two processes are best used in tandem as it may not be possible to undertake detailed RS Assessment reviews of an entire road network. RSI is a high level review that should be undertaken across a significant proportion of the road network every three to five years. Once a high risk road section has been identified through an RSI, an RS Assessment can be undertaken in more detail to determine whether any of the safety risks detected can be treated. This approach has the benefit that it can be undertaken irrespective of the availability of good crash data.

RSI involves a systematic review of an existing road by driving and walking, preferably also making use of video, to identify hazardous features, faults and deficiencies in the road environment that may lead to road user injury. RSI is done using RSI Record Sheets and Prompt Sheets to record the findings and to standardise the methodology. It is a data collection exercise that can be undertaken by staff who are not experienced in Road Safety, however training is required to perform the task. The process generates a summary report which indicates where further action is required. Identified problem sections listed in the summary are then reviewed by staff with road safety experience who will develop a list of high priority locations where RS Assessment's need to be undertaken.

RS Assessment's involve experts undertaking an in-depth review of the safety of defined routes or sections directed by the RSI findings. The process aims to identify specific safety problems and to recommend viable and cost-effective remedial counter-measures. If the RSI utilised video data capture then a large proportion of the RS Assessment could be office based, although a site visit in certain circumstances may be warranted. The number of roads that are subjected to RS Assessment's will depend on the findings of the RSI process, also the available budget and the number of personnel available who are suitably experienced.

Input data

There is no requirement for any specific data to be available in order to perform the RSI and RS Assessment processes. The purpose of the processes are to identify hazards in situ along routes and there is no requirement to correlate these locations with historical crash data, traffic flow or any other forms of data.

Prioritisation of high-risk sections

The general recommendation is that all road types could or should be subject to RSI, though this could be limited to inspection of higher volume roads, roads of strategic importance or roads that are known to be higher risk from analysis of crash data. However, the process can be applied to all road types taking into account traffic flow and composition. The inspection process itself will highlight those routes and sections that require further investigation. During the RS Assessment process the safety expert can, using their judgement, assign a risk rating value based on the considered likelihood of high casualty severity for routes or specific locations identified.

Identification of road safety deficits

A formal report detailing specific road hazards and safety issues, supported with videos and photographs, is produced as the result of the RSI. An RSI is a standardised survey undertaken to collect fixed information relating to road characteristics (engineered and environmental features) of existing roads. This allows the identification of sections of road that warrant further road safety investigation. This is then followed by RS Assessment that is an in-depth review identifying the specific safety problems and recommending viable and cost-effective remedial measures.

Generation of potential treatments

The recommendation of suitable potential treatments will be developed by the road safety expert as part of the RS Assessment process. These can be applied to a route or at specific locations along a route. Expert knowledge is required to recommend suitable remedial measures but the use of tool kits listing measures (with the problems they solve and general effectiveness) could be used to assist in this process.

Economic appraisal

There is no set economic appraisal system recommended for use following road inspections or assessments. The safety expert can undertake appraisal but the choice of any method will be dependent on local / regional / national guidance and recommendations. Other models/systems could be used to cover this process.

Calibration of the process

A suitable RSI Record Sheet and RIS Prompt List will need to be developed for use in the UK fine tuned to the characteristics of different road types. No other calibration will be required.

Use of the process

RSI's and RS Assessments have been used in a range of forms for a number of years around the world. Development of standardised UK guidelines would be beneficial to complement the Road Safety Audit process.

Software requirements

The availability of a video camera (with GPS capability) and screen to review the video are the key requirements. Word processor software and spreadsheets are required to generate reports.

Licencing

There are no licencing issues with this process since there is no requirement for specific software to be used or purchased. Guidelines on the RSI and RS Assessment process could be made freely available downloadable from the internet.

References

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Assessment criteria	Star rating	Justification
Main benefits	★★★	No requirement for supporting data or purchase of expensive software. Inspection process can be undertaken by non-safety experts to reduce costs and will involve a detailed review of site conditions.
Quality of model design	★★	Does not automatically generate remedial measures or economic appraisal. The process is reliant on use of expert road safety engineer for development of remedial measures.
Ease of use	★★★	Once sufficiently trained in the inspection process, performing an inspection should be relatively straight forward. Performing the role required for the assessment process should not be difficult for experienced practitioner.
Considers various road user groups	★★★	Vulnerable users would be considered and included in Inspection Record Sheet and within the assessment process where issues are identified. Maybe dependent in some cases of viewing interaction on day of visit which is not guaranteed.
Quality of economic appraisal	★	No set or standard economic appraisal methodology. Would be dependent on individuals performing this task and collection of relevant data.
Evaluation and monitoring included	★	Not included specifically in approach.
Validation of methodology/strength of literature base	★★	There is not much evidence on the effectiveness of these techniques but one study in 2002 found that for road assessments, recommendations had a benefit to cost ratio ranging from 2.4:1 to 84:1.
Data requirements/cost	★★★★	No other data requirements or costs are required. However, the correlation with traffic volumes, speeds and historic crash data can be useful when developing remedial measures.
Human resource requirements/cost	★★★	Will require inspection team and safety expert(s) for the assessment process. Inspection should be undertaken every 3 to 5 years so requires continuous human resource to be available.
Software/licencing requirements/cost	★★★★★	None.
Intellectual property considerations	★★★★★	None.
Development potential	★★★	Proactive inspection approaches are relatively new with new guidance to be developed on an ongoing basis so there is the potential for further developments.
Ease of modification for use in UK	★★★★	The development of suitable Inspection Record Sheets and prompts is required. Otherwise the system can be implemented easily.

A.19 Australian National Risk Assessment Model (ANRAM)

Model: **Australian National Risk Assessment Model (ANRAM)**
Country: Australia
Developer: ARRB Group, funded by Austroads
First released: 2013
Model type: Risk-based and crash history
Format: Microsoft Excel based software (macro-enabled)

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££££	££££	££££	★★★★	★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	✓	✓	✓	X

Summary

The Australian National Risk Assessment Model (ANRAM) is a road safety toolkit from Australia. It was developed by the Australian Road Research Board (ARRB) with support from Austroads which is an Australian road research funding agency. It has been used by several Australian road authorities and the model is under continuous development. It is one of the most complex road safety models assessed in this report.

ANRAM uses a mix of risk rating and crash history to identify high-risk road sections. On road sections where traffic flow is relatively high, greater weighting is given to the crash history of that road section. On sections where traffic flow is relatively low, greater consideration is given to the level of risk related to the surrounding road infrastructure.

An International Road Assessment Programme (iRAP) assessment of the network is a prerequisite before ANRAM can be applied. The model uses the risk ratings of the existing road infrastructure from iRAP to calculate the number of crashes expected in a road section.

ANRAM then compares crashes history from a road section with the predicted number of expected crashes derived from existing Safety Performance Functions (SPFs). SPFs are simple relationships which give the number of expected crashes at different flow levels. There is a different SPF equation for each road type.

Background

ANRAM is the most recent high profile road safety model to be developed in Australia. The developers built on existing research and adapted several features from pre-existing road safety models, in particular AusRAP/iRAP and Road Safety Risk Manager.

ANRAM is a Safe System based method and only fatal and serious crashes are considered because these are the target for reduction. The Safe Systems approach aims primarily to reduce the possible forces which are exchanged when a crash occurs to levels below which serious injuries will not occur.

Between the years 2011 and 2012, ANRAM was used in all six Australian States. All standard road cross-sections used in the model were included in the trial and a total of 1,263 km of the Australian road network was assessed. The trial only included roads managed by the Australian State Road Authorities (SRAs); these roads are most comparable to the Highways England Strategic Road Network.

It is understood that ANRAM has not been used on significant lengths of lower volume local roads; and it has not been used outside Australia to date.

Description of the model

ANRAM is described in the available information as comprising of four modules, these being:

- Risk Assessment Module (RAM) – this computes a Star Rating Score (SRS) for every 100 m of carriageway for five crash types: Run-off road; Head-on; Intersection; Pedestrian; Other (mainly rear-end crashes)

  An SRS is derived for six standard road cross-sections which are: Rural undivided; Rural divided/freeway; Urban freeway; Urban divided; Urban undivided; and Urban local

- Crash Prediction Module (CPM) – this calculates the predicted number of fatal and serious injury crashes (Predicted FSI) for each road section based on existing Safety Performance Functions (SPF) for the road type and traffic volume

- Crash Validation Module (CVM) – this compares the Predicted FSIs with the observed number of fatal and serious injury crashes (Observed FSIs) as calculated from the crash history of the road section. An 'ANRAM FSI' value is calculated which is a weighted average of Predicted FSI and Observed FSI.

- ANRAM Toolkit – this is a database of countermeasures and guidance to assist users during review of the calculated crash risk on road sections, and in the assessment of sources of risk. It helps the user select appropriate treatments and gives information for the known effectiveness of the measures.

Data requirements

A complete AusRAP assessment is a requirement to produce the input data for ANRAM. However ANRAM only uses 42 measured (surveyed) road attributes of the maximum 72 attributes which can be collected for AusRAP, so a shorter assessment may be used. The model also requires crash history data and traffic volume data for each road section analysed.

Prioritisation of high-risk sections

A primary function of ANRAM is to identify high-risk sections of road. SRS values are calculated in ANRAM for each road section and these may be compared to determine which sections pose the greatest road safety risk based on their existing road features. Similarly, the ANRAM FSI values for different sections may be compared to determine which sections have the greatest likelihood of experiencing the greatest number of total FSI crashes based on existing road features and traffic volume.

Identification of road safety deficits

The ANRAM model contains risk factors for individual road features which are programmed into the model. These risk factors contribute to the overall risk score of a road section. Using the ANRAM toolkit, the user may wish to identify and address specific road safety deficits at specific locations; or plan to improve the overall risk level of a road length or network by improving general design issues along longer stretches.

Generation of potential treatments

The ANRAM Toolkit stores information on measurers which can be used to select appropriate road safety treatments. It also holds information on the potential impacts of these treatments, both for the reduction of risk and the economic benefit resulting from reducing fatal and serious crashes.

Several options are available for selecting a treatment or treatments. Some examples (from Austroads, 2014) are:

- a single treatment applied conditionally across the whole network
- multiple treatments applied to a selected route
- different treatments for different routes within one road network

The list of treatments and their costs can also be amended to suit the individual needs of a road authority.

Economic appraisal

The ANRAM Toolkit can be used to undertake an economic appraisal of proposed treatment options. A Benefit to Cost Ratio (BCR) approach is used that compares the benefit in terms of ANRAM FSI estimated crash savings against the cost of treatment listed in the toolkit.

Monitoring and evaluation

Information regarding evaluation of the performance of ANRAM could not be found.

Software requirements

ANRAM is a Microsoft Excel-based software package. The developers specify the system requirements for ANRAM v1.0 as Microsoft Windows 7 (32 or 64-bit) and Microsoft Excel 2010 or later, with security settings that allow macros to run. All files must be saved with an .xlsm file extension. The calculations in ANRAM are substantial and performance benefits greatly from increased processing power (Austroads 2014).

Licencing

ANRAM was funded by the Australian government with the intention that the developed model be used by Australian jurisdictions. No information was found about the cost of an ANRAM licence or the cost of implementing an ANRAM analysis. At this point in time ANRAM is not a commercial product.

References

Jurewicz, C. (2013). Australian National Risk Assessment Model: from vision to action. *In: Australasian Road Safety Research, Policing & Education Conference, 28–30 August 2013, Brisbane*.

Jurewicz, C. & Steinmetz, L. (2014). *Australian National Risk Assessment Model* (AP-R451-1). Sydney: Austroads.

Assessment criteria	Star rating	Justification
Main benefits	★★★★	Very comprehensive and sophisticated system which could be more user friendly.
Quality of model design	★★★★★	Very comprehensive model, lacking evaluation/monitoring of effectiveness in practice.
Ease of use	★★	Requires detailed road safety engineering experience to use, user guide and training can be provided.
Considers various road user groups	★★	Pedestrians will be considered as a separate road user group in future versions of ANRAM but the model is not currently calibrated for pedestrians.
Quality of economic appraisal	★★★★	Economic appraisal is included in model, a simplified Benefit-to Cost Ratio is provided for each treatment option but this should be investigated further by the user using the preferred method for the jurisdiction.
Evaluation and monitoring included	★	ANRAM does not appear to contain a function to monitor and evaluate treatments.
Validation of methodology/strength of literature base	★★★	Based on strong body of research and has built on elements from several well-established Australian road safety models. No independent check of the methodology was found.
Data requirements/cost	★	Requires a significant asset survey of 40+ variables rated from video every 100 m. Also good flow and crash data.
Human resource requirements/cost	★★	Requires large commitment from staff, possible additional staff and training time. Human resource requirements may be offset by outsourcing video rating task.
Software/licencing requirements/cost	★★	Minimal, MS Excel with macros, cost of licence unknown. Note that an AusRAP also needs to be undertaken.
Intellectual property considerations	★	Australian government funded, unlikely to allow free use by other countries.
Development potential	★★★★	On-going development programme by ARRB, users can add additional treatments if they wish.
Ease of modification for use in UK	★	Model is configured for main routes in Australia. New SPFs need to be calculated for UK rural roads. Data availability, overall cost and licencing challenges may be prohibitive factors.

A.20 Safety Network Evaluation Tool (SafetyNet)

Model:	**Safety Network Evaluation Tool (SafetyNet)**
Country:	New Zealand
Developer:	Abley & NZTA
First released:	2012
Model type:	Mix of risk-based and crash history
Format:	Web-based tool, input data is uploaded if recent data is not already contained on the website

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££££	£££	£	★★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
✓	-	X	X	X

Summary

Safety Network Evaluation Tool (SafetyNet) is a web-based road safety tool from New Zealand which combines the outputs of several road safety assessment methods into one comprehensive rating. The model was developed by Abley Transportation Consultants for the New Zealand Transport Agency (NZTA), which is responsible for managing the country's State Highway network.

SafetyNet requires input data from several sources and unless recent results are already available and are stored online, safety assessments may have to be undertaken and the results uploaded to the database, which will incur extra time and cost. Data sources include a mix of crash history based and risk-based methods, including the New Zealand Road Assessment Program (KiwiRAP) Risk Maps, KiwiRAP Star Ratings and crash performance indicators from the High-Risk Rural Roads Guide, published by NZTA.

SafetyNet is a very thorough method for identifying and prioritising high risk road sections. The software is based on Geographical Information System (GIS) components that allow the user to identify the sections of a road network that pose the greatest risk. The output of SafetyNet should then be reviewed in more detail by applying or using other road safety analysis methods such as the KiwiRAP Analysis Tool (KAT) which is recommended to be used in conjunction with SafetyNet for this purpose.

SafetyNet is currently being used extensively on the New Zealand State Highway network but it is also recommended for use on local roads where adequate data is available.

Background

In 2010, the New Zealand government implemented 'Safer Journeys' which was the country's road safety strategy for 2010-2020. This strategy is Safe System based and promotes a proactive approach towards identifying priorities for road safety investment.

SafetyNet was developed to solve an issue identified by NZTA which was how to prioritise treatment between two roads which were both identified as 'high risk' from KiwiRAP assessments. By taking account of six different safety performance indicators for a road section, more precise results are achieved.

Description of the model

SafetyNet combines six previously existing performance indicators to calculate an Investigation Priority Rating (IPR). These are:

1. Collective Risk (iRAP Risk Mapping)
2. Personal Risk (iRAP Risk Mapping)
3. Star Rating Road Protection Score (RPS) (iRAP Star Rating)
4. Injury performance indicator threshold for a 5km road segment (High-Risk Rural Roads Guide)
5. Fatal and serious injury indicator threshold for a 5km road segment (High-Risk Rural Roads Guide)
6. Injury performance indicator threshold for a 500m road segment (High-Risk Rural Roads Guide)

Each indicator has an assigned threshold value and a score of '1' is added when this is exceeded. If the threshold is not reached, a score of '0' is given. The threshold value for Collective Risk for example is greater than or equal to 'Medium-High'.

To calculate the IPR, each performance indicator is given an equal weighting except for Collective Risk which is assigned three times the weighting of the other indicators because this is the best indicator of where the greatest number of killed and seriously injured (KSI) casualties occur. IPR therefore has a maximum score of 8, and is presented in the same five-level system as KiwiRAP, these being:

- Low (5 stars) = 0
- Low – Medium (4 stars) = 1 or 2
- Medium (3 stars) = 3 or 4 (Collective Risk exceeds threshold)
- Medium – High (2 stars) = 4 (Collective Risk does not exceed threshold) or 5
- High (1 star) = 6 to 8

SafetyNet also provides a recommendation on the best 'treatment philosophy' and 'treatment strategy' to apply to the road section, based on information provided in the High-Risk Rural Roads Guide. The two treatment philosophies are:

- Proactive Treatment Strategy (greater weighting on risk-based indicators)
- Reactive Treatment Strategy (greater weighting on crash history-based indicators)

After selecting the desired treatment philosophy, the user can then consult the 'SafetyNet Treatment Strategy Matrix' to determine which broad approach is most likely to improve safety for the road section, based on the values of the performance indicators. If a Proactive Treatment Strategy is chosen, then a matrix with Collective Risk on the x-axis and Star-Rating RPS for the y-axis is consulted. If a Reactive Treatment Strategy is chosen, then Collective Risk is on the x-axis and Personal Risk is on the y-axis. The treatment strategies listed in the matrix are (ranging from the most expensive and radical, to the cheapest):

1. Safe System Transformation
2. Safer Corridors
3. Safety Management
4. Safety Maintenance

Data requirements

In the absence of pre-existing performance indicator data, to calculate each of the six performance indicators the following data is required:

- Crash history – the most recent complete 3 year data set is recommended. Data must have accurate map coordinates.
- Traffic flow – Annual Average Daily Traffic (AADT) for every road section, estimates may be used in the absence of real data but this reduces the accuracy of the results.
- Video record of the network – In order to code many of the fields required for calculating the iRAP Star Rating, video images for at least every 100 metres of road are required.

Prioritisation of high-risk sections

SafetyNet takes several well-established performance indicators which individually identify high-risk road sections and combines these into one single IPR. The user then has six other separate performance indicators from which they may make road safety decisions. Collective Risk (casualty density along routes) shows the true cost of the crash history to the community; Personal Risk normalises crashes by traffic flow (casualty rate per unit of traffic); Star Rating assesses the risk posed by the existing road infrastructure; and the three crash rate indicators from the High-Risk Rural Roads Guide provide different perspectives by assessing safety based on different crash severity and road section length combinations.

Identification of road safety defects

The SafetyNet IPR for each road section cannot be used to identify specific road safety defects however some of the performance indicators can provide the user with helpful information about the condition of the road network. In particular the KiwiRAP Star Rating and the injury crash rate for 500 metre intervals can identify specific locations with particular road safety problems.

Generation of potential treatments

SafetyNet does not generate potential treatments; however the SafetyNet Treatment Strategy Matrix can provide useful high-level information about the most appropriate road safety strategy to apply to each road section.

Economic appraisal

SafetyNet is not designed to undertake economic appraisal. Software such as KAT has been used in conjunction with SafetyNet for this purpose.

Monitoring and evaluation

Information regarding evaluation of the performance of SafetyNet could not be found.

Software Requirements

SafetyNet is an online tool. Users login via a website and can view SafetyNet results for all roads which have been already been assessed.

Licencing

SafetyNet was developed for NZTA and the New Zealand Local Authorities. It is not known what is required to apply the model outside of New Zealand.

References

Durdin, P. & Janssen, K. (2012). SafetyNET – breathing life into road safety analysis. In: Australasian Road Safety Research, Policing and Education Conference, 4–6 October 2012, Wellington.

NZTA (2011). *High-risk rural roads guide* (Version 1). Wellington: NZ Transport Agency.

Assessment criteria	Star rating	Justification
Main benefits	★★★	Refines the prioritisation of high-risk road sections. Presents the results automatically on high quality GIS maps. Can be costly if all indicators must be calculated from raw data.
Quality of model design	★★★★	Very comprehensive approach to prioritisation of high-risk road sections. Subsequent tools are required to find treatments and perform economic appraisal. KiwiRAP's KAT is recommended to analyse SafetyNet outputs.
Ease of use	★★★★	Model is easy to use. Outputs provide clear basis for decision making and GIS maps are easy to interpret. Calculating indicators from raw data requires technical skill.
Considers various road user groups	★★★	Several of the performance indicators consider different road user groups in their calculations. Results for different road user groups are not presented separately and the IPR is based on all road users.
Quality of economic appraisal	★	SafetyNet is not designed to undertake economic appraisal.
Evaluation and monitoring included	★	SafetyNet is not designed to undertake monitoring and evaluation.
Validation of methodology/strength of literature base	★★	Based a strong foundation of research. No validation of methodology could be found. SafetyNet is considered a more useful metric than KiwiRAP Collective risk by NZTA.
Data requirements/cost	★	The data requirements for SafetyNet are the most comprehensive of all road safety models in this report if all performance indicators are to be calculated from scratch.
Human resource requirements/cost	★★★	Greater time will be required if calculating indicators from raw data. KiwiRAP Star Rating in particular will take a long time. Once performance indicators are calculated, using the online GIS interface is straightforward.
Software/licencing requirements/cost	★★★★★	SafetyNet is web-based software and licences are free to all New Zealand authorities.
Intellectual property considerations	★	SafetyNet is a bespoke system developed specifically for NZ authorities.
Development potential	★★★	SafetyNet is under continual development in New Zealand, new indicator data are uploaded regularly but the process seems set in place now.
Ease of modification for use in UK	★★	The structure of SafetyNet could be adapted to the UK quite readily. EuroRAP could be used as alternative to KiwiRAP and the crash rates could be calculated. Developing the web-based software would require specialist help and a significant cost.

A.21 Road Safety Risk Manager

Model:	**Road Safety Risk Manager**
Country:	Australia
Developer:	ARRB Group / Austroads
First released:	2002
Model type:	Risk-based
Format:	Desktop-based software, data can be stored and accessed from an online portal

Costs			Star Ratings	
Data	Human Resources	Software / licencing	Comprehensiveness	Suitability for UK local authority rural roads
£££	£££	£££	★★★	★★★

Key processes of a road safety model				
Prioritisation of high-risk sections	Identification of road safety deficits	Generation of potential treatments	Economic appraisal	Monitoring and evaluation
X	✓	✓	✓	-

Summary

Road Safety Risk Manager (RSRM) is a risk management tool from Australia. It was developed by the Australian Road Research Board (ARRB) with support from Austroads (the main road research funding agency in Australia). The development of the RSRM started in 1998 and the software was commercially available from 2002. RSRM provides a user friendly interface to assess and manage the road safety issues on a road network. In terms of data requirements, RSRM is less resource-intensive than alternative models and is well supported with written guidance and training opportunities from ARRB.

RSRM was designed to allow for the quick assessment of individual road hazards and treatments. The developers claim this can take less than 10 minutes for each hazard. The model was also intended to assist road authorities prepare road funding submissions in a systematic manner.

RSRM is not a 'fully comprehensive' road safety model as it cannot be used to locate the hazards on the road network, this must been done using road safety inspection/assessment or risk-rating from video data.

Background

In 2001 the Australian High Court introduced a law which required all Australian road authorities to be able to prove that they have 'acted reasonably' to fulfil a duty of care for its road users. Authorities had to be able to prove that they had identified road safety hazards on their network and had developed a plan to prioritise the treatment of these hazards, with consideration of their budget constraints. Tools such as RSRM were developed in anticipation of, or as a response to, this change in the law.

Extensive research went into the development of RSRM which included a detailed investigation into which factors cause crashes on the road network. The research team concluded that the risk associated with a crash was based on three main components, exposure, likelihood and severity. The software was structured around these three elements.

Eight hundred and fifty road deficiencies were identified and grouped into over 60 different categories; in addition, appropriate treatment options were identified for each of these hazards. These are all incorporated into RSRM.

Initially, the RSRM software was created in a Microsoft Excel format. This version was trialled by several Australian road authorities for a period of 18 months and received favourable feedback. A more robust desktop-based software tool was subsequently released in 2002 and the software has been sold commercially since that time.

Description of the model

RSRM is structured around a logical risk management process. Risks are identified by considering the exposure, likelihood and severity associated with hazards on the road network. A relative risk score is calculated for each hazard and then a treatment is selected to reduce each risk; this treatment has an associated useful lifespan and cost. A Risk Reduction Cost Ratio (RRCR) is calculated which is expressed in 'units of risk reduction per dollar spent'. Treatment options can be easily prioritised by ranking them according to their RRCR values.

The RSRM software is logically set out and is user-friendly. A main menu contains a user manual, wizards to conduct a new investigation or review existing investigation, as well as functions to produce reports and to import or export results.

To conduct a new investigation the major steps are to:

- Enter investigation details
- Run the 'Hazard Wizard'
- Run the 'Treatment Wizard'
- Review the 'Hazard and Treatment Summary' page
- Run the 'Budget Scenario Analysis' tool
- Select from a list of reports such as the 'Multiple Hazard and Treatment Report'
- Export results to Microsoft Excel if necessary

Data requirements

RSRM has relatively fewer data requirements than many other models. Information regarding traffic volume, expressed as Average Annual Daily Traffic (AADT) is essential for determining the exposure of a risk. This AADT value may be estimated if no data are available from counts or surveys, however real data will produce a more accurate result.

Information regarding the location, type and severity of each hazard is the main data requirement. This information will assist the user when entering information regarding exposure, likelihood and severity of each hazard from which RSRM calculates a 'Hazard Risk Score'. Originally, this data was collected from a road safety inspection or assessment, however more recently software such as ANRAM, AusRAP and the NetRisk Rating Tool has been used to collect hazard information.

Prioritisation of high-risk sections

RSRM was not designed to identify and prioritise hazards and high risk sections. Additional processes are required to collect this information before RSRM can be utilised. At the time that the model was developed, road safety inspection was the predominant method for identifying hazards and for practical purposes, road safety professionals tended to focus on individual sites as opposed to longer road sections.

In more recent times, RSRM has been used in conjunction with other road safety models, most notably the NetRisk Rating Tool, which identifies hazards on a network more efficiently using video data as opposed to the more labour intensive field inspection.

Identification of road safety defects

The first process required in RSRM is referred to as hazard assessment. Identified hazards are logged into the software using a straightforward wizard and the model then calculates a relative risk score for each.

Generation of potential treatments

RSRM has a dedicated function for treatment assessment. The user inputs information into a wizard and the software guides the user towards selecting a suitable treatment which will reduce the risk of a hazard.

Economic appraisal

RSRM contains a straightforward and relatively robust economic analysis method. The model calculates a Risk Reduction Cost Ratio (RRCR) which is used for comparison between treatment options. In essence, it is a benefit to cost ratio, with the benefit being expressed in terms of the expected reduction in risk score due to an applied treatment.

RSRM is different to many of the alternative models because it does not quantify the benefit of a treatment in terms of number of crashes or fatalities and serious casualties saved. This could present a challenge to obtaining funding since the return on investment is a reduction in risk which cannot be readily measured in terms of monetary savings.

Monitoring and evaluation

RSRM offer a function for tracking the status of any safety issues and therefore 'closing the loop' if any action has been taken to address a safety issue. There was no specific mention of assessing whether these actions were affective. Reported feedback from users appears to be generally positive in terms of how helpful they found the software to be.

Software requirements

RSRM has minimal requirements and can be run on any reasonable modern computer. Results can be exported to Microsoft Excel to allow users to produce and edit reports or to add additional information. More recently RSRM has released a web-based front-end so that users may upload their network information to an online server and access this information from any location with web access.

Licencing

RSRM is a commercial product sold by ARRB Group and a licence for the software must be purchased. Support and training for the software is recommended and is an additional cost.

References

ARRB Group (2015). Road Safety Risk Manager: advancing safety and efficiency in transport through knowledge. https://www.arrb.com.au/admin/file/content2/c7/RSRM%20presentation.pdf

Hughes et al. (2012). Risk based prioritisation of remedial works identified through road safety audit. *In: 25th ARRB Conference, 23–26 September 2012, Perth*.

McInerney, R. (2001). The Road Safety Risk Manager: maximising road trauma reductions from engineering countermeasures. *In: Road Safety Research, Policing and Education Conference, 18–20 November 2001, Melbourne.*

Assessment criteria	Star rating	Justification
Main benefits	★★★★	RSRM is easy to use and allows for quick assessment of road hazards. It is also ideal for managing and tracking road safety problems. Originally designed to deal only with hot spots, it can now be used to assess longer stretches of road.
Quality of model design	★★★★	It identifies road safety problems, generates solutions for these and performs economic appraisal. It can be combined with other models such as the NetRisk Rating Tool to create a more comprehensive approach.
Ease of use	★★★★	The wizards make inputting the information very simple and straightforward. Some experience in road safety engineering is required to interpret results and make decisions.
Considers various road user groups	★★	RSRM does not produce results specifically for different road user groups but does consider road safety issues specific to pedestrian and cyclists.
Quality of economic appraisal	★★★	The method of economic appraisal is very logical and ensures that treatment options may be prioritised effectively. Benefit is presented in terms of risk reduction instead of in economic terms.
Evaluation and monitoring included	★★	The function to track the status of road safety treatments is a simple but limited method of monitoring and evaluation.
Validation of methodology/strength of literature base	★★★	Based on strong research and model is reviewed and updated every few years. No validation of methodology could be found. Feedback from users was generally positive.
Data requirements/cost	★★★	RSRM requires some form of data that locates and assesses details of the hazards on the road network prior to use. The most cost effective way to do this on a rural road network is from a video survey using a robust rating form/inspection sheet.
Human resource requirements/cost	★★★	RSRM is designed to assist road engineers in conducting one of the key tasks and if used correctly can lead to time/cost savings. Some training and time to familiarise staff with software may be required.
Software/licencing requirements/cost	★★★	Software is simple to install and run on any computer and relatively affordable.
Intellectual property considerations	★★	Fully commercial, used extensively within Australia and New Zealand. When used internationally, RSRM seems to have been used by the Australian-based consultant rather than the international authority itself.
Development potential	★★★	RSRM has been periodically updated by the developers to reflect current research and take advantage of newer technology such as online data access and storage.
Ease of modification for use in UK	★★★★	Models are derived for Australia and these would have to be calibrated for the UK but functions for modifying parameters exist. The tool is ideal for Local Authorities in terms of data requirements and ease of use.

Appendix B Star Rating Comparison Table

	Main benefits	Quality of model design	Ease of use	Consideration of various road user groups	Quality of economic appraisal	Evaluation and monitoring included	Validation of methodology	Data requirements /cost	Human resource requirements/ cost	Software/ licencing requirements/ cost	Intellectual property considerations	Development potential	Ease of modification for use in UK
HRRRG	★★★	★★★	★★	★★★	★★	★★★	★★★	★★★★	★★★★	★★★★★	★★★★★	★★	★★
HRRR	★★★	★★★	★★★	★★★	★★	★★	★★	★★★★★	★★★★★	★★★★★	★★★★★	★★★★	★★★★
SSPST	★★★★	★★★★	★★★	★★★	★★	★★	★★	★★★★★	★★★★	★★★★★	★★★★★	★★★★	★★★★
iRAP Risk Mapping	★★★	★★	★★★★	★★★	★★	★★	★★★	★★★★	★★★★	★★★★	★★★★	★★	★★★★★
SURE	★★	★★★	★★	★★	★★	★★	★★	★★★	★★★	★★★	★★★★	★★★	★★★
RRSE Explorer	★★	★★	★★★	★	★★★	★★★★	★★	★★★	★★	★★★★	★★★	★★	★★★
Route Analysis Tool	★★	★★★	★★	★★	★	★	★★★	★★★	★★★★	★★★	★★★	★★★	★★★★
PTV Visum Safety	★★★	★★	★★★	★★	★★★	★	★★	★★★	★★★	★★★	★★★★	★★★★	★★★
Safety Analyst	★★★★	★★★★	★★★	★★	★★★★	★★★★	★★★★	★★★	★★	★	★★★	★★	★★
17 - 38 Spreadsheet	★★	★★	★★★	★★	★	★	★★	★★★★	★★★★	★★★★★	★★★★★	★★★	★★★
Hi-safe	★★★	★★★	★★★★	★★	★★★	★	★★★	★★★	★★★★	★★	★★★	★	★★
IHSDM	★★	★★	★★★	★★	★	★	★★	★★★	★★★★	★★★★★	★★★★★	★★	★★
iRAP Star Rating	★★★★★	★★★★★	★★★	★★★★★	★★★★★	★★★★	★★★★	★	★★	★★	★★★	★★★★★	★★★
NetRisk	★★★	★★★	★★★	★★	★	★	★★	★★★	★★★★	★★★	★★	★	★★★
RANKERS	★★★	★★	★★	★★	★★	★	★★	★★★	★★★	★★★★	★★★★★	★	★★★★
IASP	★★★★	★★	★★★★	★	★★★	★	★★★	★★★	★★	★★★★	★★★★	★★★	★★★
RISA	★★	★★★	★★	★	★	★	★★★	★★★	★★	★★★★	★★	★	★★
RSI & RSA	★★★	★★	★★★	★★★	★	★	★★	★★★★	★★★	★★★★★	★★★★★	★★★	★★★★
ANRAM	★★★★	★★★★★	★★	★★	★★★★	★	★★★	★	★★	★★	★	★★★★	★
SafetyNet	★★★	★★★★	★★★	★★★	★	★	★★	★	★★★	★★★★★	★	★★★	★★
RSRM	★★★★	★★★★	★★★★	★★	★★★	★★	★★★	★★★	★★★	★★★	★★	★★★	★★★★

Appendix C Comparison of Technical Comprehensiveness Table

MODEL / Component	HRRRG	HRRR	SSPST	iRAP Risk Mapping	SURE	RRSE Explorer	Route Analysis Tool	PTV Visum Safety	Safety Analyst	17-38 speadsheet	HiSafe	IHSDM	iRAP Star rating	NetRisk	Rankers	IASP	RISA	RSI / RSA	ANRAM	SafeyNet	RSRM
Prioritisation of Sections for Further Review – Proactive Approaches																					
Collision Data:																					
by location +/- 50m	✓	✓	✓	n/a	n/a	n/a	n/a	✓	✓	✓	✓	✓	×	n/a	✓	✓	×	×	✓	✓	n/a
by severity	✓	✓	✓	n/a	n/a	n/a	n/a	✓	✓	✓	✓	✓	×	n/a	✓	✓	×	×	✓	✓	n/a
by vehicle/user type	✓	✓	✓	n/a	n/a	n/a	n/a	✓	✓	✓	✓	✓	×	n/a	×	×	×	×	✓	×	n/a
by crash type	✓	✓	✓	n/a	n/a	n/a	n/a	✓	✓	✓	✓	✓	✓	n/a	×	×	×	×	✓	×	n/a
Traffic Flow Data:																					
Volume (AADT/day/week/peak only)	✓	✓	✓	n/a	n/a	n/a	n/a	✓	✓	✓	✓	✓	✓	n/a	×	×	✓	×	✓	✓	n/a
totals only	×	×	×	n/a	n/a	n/a	n/a	×	×	×	×	×	×	n/a	×	×	×	×	×	×	n/a
by individual vehicle/user groups	✓	✓	✓	n/a	n/a	n/a	n/a	✓	×	×	×	×	✓	n/a	×	×	×	×	✓	✓	n/a
Road Attributes:																					
Road type (single/dual)	✓	✓	✓	n/a	n/a	n/a	n/a	×	✓	×	×	×	✓	✓	×	✓	✓	✓	✓	✓	n/a
Land use (rural/urban/residential/ Industrial/school)	✓	✓	✓	n/a	n/a	n/a	n/a	×	✓	✓	✓	✓	✓	✓	×	×	×	✓	✓	✓	n/a
Speed (posted/design/ operating)	✓	×	✓	n/a	n/a	n/a	n/a	×	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	n/a
Median (type/width)	✓	✓	✓	n/a	n/a	n/a	n/a	×	×	×	×	×	✓	✓	×	×	×	✓	✓	✓	n/a
Traffic Lanes (width/number)	✓	✓	✓	n/a	n/a	n/a	n/a	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	n/a
Shoulder (type/width)	✓	✓	✓	n/a	n/a	n/a	n/a	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	n/a
Roadside (severity/clear zone width)	✓	✓	✓	n/a	n/a	n/a	n/a	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	n/a
Horizontal alignment/curvature	✓	✓	✓	n/a	n/a	n/a	n/a	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	n/a
Vertical alignment/grade	✓	✓	✓	n/a	n/a	n/a	n/a	×	×	✓	✓	✓	✓	×	×	×	✓	✓	✓	✓	n/a
Super elevation/crossfall	✓	×	×	n/a	n/a	n/a	n/a	×	×	×	×	×	✓	×	✓	×	✓	✓	×	×	n/a
Surface condition (smooth/rough/ pot holed/skid resistance)	✓	×	×	n/a	n/a	n/a	n/a	×	×	×	×	×	✓	✓	✓	×	✓	✓	✓	✓	n/a
Intersection (type/control)	✓	✓	✓	n/a	n/a	n/a	n/a	×	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	n/a
Intersection sight distance	✓	✓	✓	n/a	n/a	n/a	n/a	×	×	×	×	×	✓	✓	×	✓	✓	✓	✓	✓	n/a
Intersection turn provision /channelisation	✓	✓	✓	n/a	n/a	n/a	n/a	×	×	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	n/a
Intersection frequency	×	×	✓	n/a	n/a	n/a	n/a	×	×	×	×	×	✓	×	×	✓	×	✓	×	×	n/a
Property access frequency	✓	×	✓	n/a	n/a	n/a	n/a	×	×	×	×	×	✓	×	×	✓	×	✓	✓	✓	n/a
Overtaking provision/sight distance	✓	×	✓	n/a	n/a	n/a	n/a	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	×	n/a
Signage (type/location/size/visibility)	✓	✓	✓	n/a	n/a	n/a	n/a	×	×	×	×	×	✓	×	✓	✓	✓	✓	×	×	n/a
Delineation (line marking guide posts, cats eye's)	✓	✓	✓	n/a	n/a	n/a	n/a	×	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	n/a
Tactile/audible devices (rumble strips)	✓	✓	✓	n/a	n/a	n/a	n/a	×	×	×	×	×	✓	×	×	×	✓	✓	✓	✓	n/a
Street lighting (present/location/type)	✓	✓	✓	n/a	n/a	n/a	n/a	×	×	✓	✓	✓	✓	✓	×	×	✓	✓	✓	✓	n/a
Speed management/traffic calming (by type of feature)	✓	×	✓	n/a	n/a	n/a	n/a	×	×	×	×	×	✓	×	×	×	✓	✓	✓	✓	n/a
Parking provision (allowed/prohibited)	✓	×	✓	n/a	n/a	n/a	n/a	×	×	×	×	×	✓	✓	×	×	✓	✓	✓	✓	n/a
VRU specific facilities (footway/cycle paths)	✓	✓	✓	n/a	n/a	n/a	n/a	×	×	×	×	×	✓	✓	×	×	×	✓	✓	✓	n/a
Prioritisation of Sections for Further Review – Reactive Approaches																					
Collision Data:																					
Specifies location +/- 50m	✓	✓	✓	✓	✓	n/a	✓	✓	✓	✓	✓	✓	n/a	n/a	n/a	n/a	n/a	n/a	✓	✓	n/a
Separates data by severity	✓	✓	✓	✓	✓	n/a	✓	✓	✓	✓	✓	✓	n/a	n/a	n/a	n/a	n/a	n/a	✓	✓	n/a
Seperates data by vehicle / user group	✓	✓	✓	✓	✓	n/a	✓	✓	✓	✓	✓	✓	n/a	n/a	n/a	n/a	n/a	n/a	✓	×	n/a
Separates data by crash type	✓	✓	✓	✓	✓	n/a	✓	✓	✓	✓	✓	✓	n/a	n/a	n/a	n/a	n/a	n/a	✓	×	n/a
Traffic Flow Data:																					
Volume (AADT/day/week/peak only)	✓	✓	✓	✓	✓	n/a	✓	✓	✓	✓	✓	✓	n/a	n/a	n/a	n/a	n/a	n/a	✓	✓	n/a
totals only	×	×	×	×	×	n/a	×	×	×	×	×	×	n/a	n/a	n/a	n/a	n/a	n/a	×	×	n/a
by individual vehicle/user groups	✓	✓	✓	×	×	n/a	×	✓	×	×	×	×	n/a	n/a	n/a	n/a	n/a	n/a	✓	✓	n/a

MODEL / Component	HRRRG	HRRR	SSPST	iRAP Risk Mapping	SURE	RRSE Explorer	Route Analysis Tool	PTV Visum Safety	Safety Analyst	17-38 speadsheet	HiSafe	IHSDM	iRAP Star rating	NetRisk	Rankers	IASP	RISA	RSI / RSA	ANRAM	SafeyNet	RSRM
Identification of Road Safety Issues																					
Proactive: specific defects																					
Site specific (+/- 50m?)	n/a	✓	✓	n/a	✓	×	n/a	n/a	✓	n/a	n/a	n/a	×	n/a	n/a	✓	n/a	✓	✓	n/a	✓
Route only (by km)	n/a	✓	✓	n/a	✓	×	n/a	n/a	✓	n/a	n/a	n/a	✓	n/a	n/a	✓	n/a	✓	×	n/a	×
Area only	n/a	✓	✓	n/a	×	×	n/a	n/a	✓	n/a	n/a	n/a	✓	n/a	n/a	×	n/a	×	×	n/a	×
infrastructure (barrier/bend/surface)	n/a	✓	✓	n/a	✓	✓	n/a	n/a	✓	n/a	n/a	n/a	✓	n/a	n/a	✓	n/a	✓	✓	n/a	✓
Junction specific	n/a	✓	✓	n/a	✓	✓	n/a	n/a	✓	n/a	n/a	n/a	✓	n/a	n/a	✓	n/a	✓	✓	n/a	✓
Road user specific	n/a	✓	✓	n/a	×	✓	n/a	n/a	×	n/a	n/a	n/a	✓	n/a	n/a	×	n/a	✓	✓	n/a	×
Speed related	n/a	×	✓	n/a	✓	✓	n/a	n/a	×	n/a	n/a	n/a	✓	n/a	n/a	✓	n/a	×	✓		✓
Reactive: crash patterns				n/a																n/a	
Site specific	n/a	✓	✓	n/a	✓	×	n/a	✓	✓	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Route specific	n/a	✓	✓	n/a	✓	✓	n/a	✓	✓	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Area wide	n/a	✓	✓	n/a	✓	✓	n/a	✓	✓	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Road user group	n/a	✓	✓	n/a	✓	✓	n/a	×	×	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Crash type (head on/side impact)	n/a	✓	✓	n/a	✓	×	n/a	×	✓	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Generation of Potential Treatments																					
Fixed list of treatment options included	✓	×	×	n/a	n/a	✓	n/a	n/a	✓	n/a	✓	n/a	✓	n/a	✓	n/a	✓	n/a	✓	n/a	✓
User can include additional (local) treatment options	×	×	✓	n/a	n/a	×	n/a	n/a	✓	n/a	✓	n/a	✓	n/a	×	n/a	×	n/a	✓	n/a	×
Treatments applied to individual locations	✓	✓	✓	n/a	n/a	×	n/a	n/a	✓	n/a	✓	n/a	×	n/a	×	n/a	×	n/a	✓	n/a	✓
Treatments applied to sections	✓	✓	✓	n/a	n/a	✓	n/a	n/a	✓	n/a	✓	n/a	✓	n/a	✓	n/a	×	n/a	✓	n/a	✓
Treatments applied unilaterally	×	✓	✓	n/a	n/a	✓	n/a	n/a	✓	n/a	✓	n/a	✓	n/a	×	n/a	✓	n/a	×	n/a	×
Develops generic treatment options	✓	✓	✓	n/a	n/a	✓	n/a	n/a	✓	n/a	×	n/a	✓	n/a	✓	n/a	×	n/a	✓	n/a	✓
Identifies detailed design solutions	×	×	×	n/a	n/a	×	n/a	n/a	×	n/a	×	n/a	✓	n/a	×	n/a	×	n/a	×	n/a	×
Allows for multiple treatments to be applied simultaneously	×	✓	✓	n/a	n/a	✓	n/a	n/a	✓	n/a	✓	n/a	✓	n/a	×	n/a	×	n/a	✓	n/a	×
Only considers single treatments	✓	✓	×	n/a	n/a	×	n/a	n/a	×	n/a	×	n/a	×	n/a	✓	n/a	×	n/a	×	n/a	✓
Economic Appraisal																					
Costs:																					
Treatment cost (fixed/variable)	×	✓	✓	×	×	✓	n/a	×	✓	n/a	✓	n/a	✓	n/a	✓	×	n/a	n/a	✓	n/a	✓
CMFs (fixed/user variable)	×	✓	✓	×	×	✓	n/a	✓	✓	n/a	✓	n/a	✓	n/a	×	×	n/a	n/a	×	n/a	×
Benefits:																					
Full economic terms (CBA/NPV)	×	×	✓	×	×	✓	n/a	✓	✓	n/a	✓	n/a	✓	n/a	×	×	n/a	n/a	✓	n/a	×
First Year Rate of Returns (FYRR) only	×	×	×	×	×	×	n/a	×	×	n/a	×	n/a	×	n/a	×	×	n/a	n/a	×	n/a	×
Calculates lives/casualties saved per unit cost (cost efficiency)	×	×	×	×	✓	×	n/a	✓	✓	n/a	×	n/a	×	n/a	×	×	n/a	n/a	✓	n/a	×
Calculates in non-economic terms (risk reduction)	✓	×	×	×	×	×	n/a	×	×	n/a	×	n/a	×	n/a	×	✓	n/a	n/a	×	n/a	✓

Notes:
RISA: The road attributes taken into account for the site assessment for RISA have been assumed as the formal list is not publically available. Assumptions based on literature and common attributes of similar assessments.

Appendix D Guidelines for completing the 'Relevance to UK Local Authorities' table

A 'Relevance to UK Local Authorities' table was completed for each of the Road Safety Models introduced in Appendix A. The guidelines below detail how the project team came to assign each Star Rating.

Below are the 13 questions contained in the table, a list of points to take into consideration when undertaking the assessment and an example of a 5, 3 and 1 star outcome for each question.

1. What are the main benefits of this system?

- Better identification of real problem locations
- The model is suitable for UK rural roads
- Takes into account regression to the mean of crash locations
- Identifies longer stretches and routes
- Identifies hot spots only
- Assists with identification of effective and relevant countermeasures
- Estimates realistic benefits to allow economic appraisal
- Promotes effective evaluation and monitoring

Star rating guide:

- Comprehensive system that will lead to better road safety outcomes – ★★★★★
- Assistance which makes some of the steps easier – ★★★
- System which assists with only one aspect or step – ★

2. How well does the model execute the functions for which it was designed for?

- Understand the purpose for which the model was designed
- Make subjective assessment of how effectively the model executes the functions for which it was designed.

Star rating guide:

- Achieves a high quality outcome for the features it was designed for – ★★★★★
- Does not achieve its intended purpose in one key area – ★★★
- Model is limited by design or does not effectively achieve its purpose – ★

3. Is the model easy to use?

- What level of training is required to efficiently use the method – so from layman to new graduate to experienced safety engineer with 20 years on the job
- How much training will be required to use the method – e.g. fully intuitive or is intense training necessary which requires a strong background in RS engineering?

- Is the output really simple but useful allowing actions to be developed or does any output generated require detailed interpretation, sense checking and a lot of further development by experienced personnel?

Star rating guide:

- A method that can be run by staff with limited road safety engineering experience – ★★★★★
- Graduate can use model after some specific training – ★★★
- A qualified road safety engineer with 10 years of experience required – ★

4. Does the model consider the various needs of each road user group?

- Considers the specific requirements for several different road user groups including drivers, pedestrians, pedal cyclists and motor cyclists
- Produces separate results for each road user group

Star rating guide:

- Considerable attention paid to specific needs of each road user group and results/star ratings produced separately for different road user groups – ★★★★★
- Some attention paid to differences of each road user group and pedestrian and/or cyclist specific features are included in the model – ★★★
- Model does not or cannot recognise different road users and outputs are not road user specific – ★

5. What is the quality of economic appraisal?

- A robust method of economic appraisal is included in the model
- Produces simple results like first year rate of return
- Calculates more sophisticated appraisal such as cost-benefit analysis

Star rating guide:

- Robust economic appraisal of all treatment options included in model – ★★★★★
- Economic appraisal of treatment options addressed in a simple or limited way – ★★★
- Model contains no economic appraisal of treatment options – ★

6. Does the model address the importance of monitoring and evaluation?

- Before/after analysis is an included function
- Guidance provided on how to undertake monitoring and evaluation

Star rating guide:

- Contains function to assist user in undertaking monitoring and evaluation – ★★★★★
- Contains guidance on how to undertake monitoring and evaluation but does not otherwise assist user with this tasks – ★★★
- Does not address monitoring and evaluation – ★

7. Is there any evidence that any validation of the model methodology has been attempted? Does the model appear to be based on strong, well-established literature?

- Before and after studies to show that model achieved the expected outcome
- Independent review of the quality of the model
- Based on a strong literature base
- Developed from pre-existing model

Star rating guide:

- Comprehensive, independent review undertaken, confirming casualty reduction and BCR was achieved – ★★★★★
- Any evidence of before/after analysis or otherwise based on a very we-established literature base – ★★★
- No evidence of any review undertaken, literature base is relatively weak – ★

8. What data is required to use the system? For data which is not already readily available, how could the data be collected and what would be the likely cost?

- Crash data only
- GIS mapping required
- Flow data required
- Physical infrastructure and road condition
  - Full geo-coded video survey required
  - Limited survey only of small number of attributes required

Star rating guide:

- Only crash data and other readily available data required– ★★★★★
- Simple, relatively cheap survey required of a small number of attributes – ★★★
- Full video survey including a large number of attributes measured at 100m intervals required – ★

9. What additional human resource allocations and costs are required to adopt the system?

- New staff required specifically for implementing and using this model?
- Existing staff can perform this tasks alongside existing tasks or replacing current tasks
- Costly asset surveys/fieldwork required

Star rating guide:

- System easily run and operated by existing staff – ★★★★★
- Significant additional labour hours dedicated to operate model – ★★★
- One or more additional full-time staff required – ★

10. *What are the hardware/software/IT/licencing requirements for the model?*

- GIS software required
- Crash data system/database access required
- Network development (links/junctions with characteristics/flows assigned)
- Specialist analysis from third party (e.g. Vida)

Star rating guide:

- MS Excel or other cheap/widely available package only required – ★★★★★
- Relatively cheap and easily installed/operated software – ★★★
- Costly limited software with low intuitive usability – ★

11. *Are there any intellectual property restrictions that would prevent us from adopting a similar approach?*

- Licence required for the process and software
- Clear IP rights owned by third party poses a commercial concern
- No access to the source code or model workings

Star rating guide:

- An freely available guideline or software – ★★★★★
- A proprietary system which is relatively straightforward to purchase – ★★★
- Can only be used by official agencies within a geographic region – ★

12. *Does the model show much potential to be built upon and developed even further? Does the developer frequently update the model?*

- Is the system black box and locked down
- Can it be largely configured for local conditions
- Is the system fully developable

Star rating guide:

- Completely open system that encourages local development, with strong developer support – ★★★★★
- Some opportunity to develop the model, minimal developer support – ★★★
- Completely locked black box system, model is final and will not be updated – ★

13. *What are the challenges towards or additional modifications required for the approach to be adopted in the UK?*

- Model has already been in use in the UK
- Model values are derived for very specific geographic region/country
- Model values are derived for very specific road types and conditions
- Language issues
- Available guidance to assist with implementation

- Appropriateness of the range of treatments for the UK
- Economics tied in to other countries standards

Star rating guide:

- Designed for roads equivalent to UK rural roads and can be adopted in the UK with relative ease – ★★★★★
- Model can be configured to suit UK rural roads with some challenges – ★★★
- Inflexible and designed for a different country/region – ★