DISCLAIMER

The conclusions and recommendations presented in this report are those of AAAFTS and its contractors and do not represent the official positions and policies of the participating highway agencies. The maps prepared in the pilot studies and presented in this report are illustrative examples that provide useful information concerning the safety performance of the roadway system and are presented here solely to demonstrate the potential utility of usRAP. The specific maps presented in this report do not, by themselves, provide sufficient information to determine which roadways should receive priority for improvement. In determining improvement priorities, highway agencies consider many factors beyond those depicted on the maps in this report. Decisions regarding any improvements are based on detailed engineering studies that consider the improvement types most appropriate for specific road sections and the cost and anticipated effectiveness of those improvements. In response to recently established Federal legislation contained in Section 1410 of SAFETEA-LU, each state highway agency will be establishing its own criteria and procedures necessary to satisfy the identification of 5 percent of their public road locations exhibiting the most severe safety needs. This report does not constitute a standard, specification, or regulation.

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Section 1. Introduction

1.1 Background

The level of safety for motorists on U.S. roads varies widely. Controlled-access freeways, with no at-grade intersections or driveways, provide the highest level of safety among road types. Other safety enhancing features of roadways include medians, roadside clear zones, guardrails, median barriers, and intersection turn lanes. Highway agencies have limited funds for improving the safety features of roadways, so it is important that their investment decisions are made in a way that provides maximum benefits to motorists and to the public at large.

Roadway and roadside improvements will have a key role in improving the overall safety performance of the highway system. However, a key to understanding the nature of safety on the highway system is to recognize that, while every crash occurs on some road segment, this does not imply that the design or operational characteristics of that road segment are necessarily the cause of those crashes. While driver and vehicle factors contribute to the causation of many more crashes than road factors, risk maps of the road system can help to identify roadways where there are opportunities to improve safety.

Currently, there is no systematic road assessment program in North America to inform motorists of the level of safety on the roads they travel or to help auto clubs and others provide informed advice to highway agencies on needs for safety improvement. However, such a program does exist in Europe. The European Road Assessment Program (EuroRAP) was developed by European motoring clubs to evaluate the safety of roads using two methods: a synthesis of available crash statistics summarized by crash location and a road safety review based on the design features of specific roadway sections. Under the latter scheme, road sections are given a rating from one to four stars, with four stars representing the “safest road.” A similar program, known as AusRAP, has been initiated in Australia. The results of both EuroRAP and AusRAP have been presented in the form of risk raps and star rating maps of the roadway system.

The AAA Foundation for Traffic Safety (AAAFTS) has initiated a pilot program to test the technological and political feasibility of instituting a U.S. Road Assessment Program (usRAP). This work has been funded by AAAFTS and the FIA Foundation for the Automobile and Society. The pilot program will examine the various technological barriers—are appropriate data available and how should those data be aggregated? The pilot test will also examine political barriers—will highway agencies cooperate with such a program and can liability concerns be overcome? This pilot program will focus attention on the need for highway safety improvement and start a national dialogue on the issue. There is concern that crash investigations and road safety data in many jurisdictions are not adequate to support comprehensive analyses of road safety features. The national dialogue should help create public support for higher funding to upgrade data systems and make road safety improvements.
The usRAP pilot program is very timely given recent Federal highway safety program requirements in Section 1401 of the Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). A provision in Section 1401 requires that states, as a condition for obtaining Federal funds from the Highway Safety Improvement Program (HSIP), must submit an annual report to the U.S. Secretary of Transportation describing at least 5 percent of locations with the most severe safety needs, and an assessment of remedies, costs, and other impediments to solving the problems at each location. The Secretary is required to make these reports available to the public on the U.S. Department of Transportation web site and through other means. The risk maps prepared in the usRAP pilot program represent an effective tool that could be used to identify 5 percent of the roadway system with the greatest safety needs. usRAP maps may also be an effective tool for identifying roadway sections eligible for improvement as part of the SAFETEA-LU high-risk rural roads program.

Midwest Research Institute (MRI) has managed the pilot program for AAAFTS with assistance from the Center for Transportation Research and Education (CTRE) at Iowa State University and the participation of an advisory panel of key stakeholders. A sufficient amount of the assessment will be completed in several test jurisdictions to demonstrate not only the feasibility but also the utility of such a program. This report presents the initial results of the usRAP pilot program, including the results of pilot studies conducted in Iowa and Michigan.

1.2 Objectives

The primary objectives of the potential usRAP program are to:

- reduce death and serious injury on U.S. roads rapidly through a program of systematic assessment of risk that identifies major safety shortcomings, which can be addressed by practical road improvement measures.
- ensure that assessment of risk lies at the heart of strategic decisions on route improvements, crash protection, and standards of route management.

The objectives are identical to the objectives of the ongoing EuroRAP and AusRAP programs.

As envisioned, usRAP would be implemented as a cooperative effort by highway agencies and auto clubs to accomplish the important objectives presented above. At the heart of the usRAP concept is that highway agencies need the support of auto clubs and the general public to make the case for investments to bring about a substantial reduction in highway crashes. Better information on the safety performance of the roads the motoring public travels should create additional dialogue and public debate on road safety, something that is sorely needed, which in turn can create support for greater investment in highway safety and can help to target those investments to the locations with the greatest need.
1.3 Pilot Program Activities

The purpose of the pilot program is to assess the technical and political feasibility of instituting a usRAP. The pilot program began in May 2004 and has continued through the submission of this report. The pilot program has included the establishment of a usRAP advisory panel, a review of existing road assessment programs and related activities, the conduct of pilot studies in Iowa and Michigan, the identification and assessment of key issues related to potential usRAP implementation, and the development of recommendations for future usRAP activities. A second phase of the pilot program began in March 2006 and will involve pilot studies in additional states.

1.4 usRAP Advisory Panel

This pilot program has been conducted under the guidance of an advisory panel of key stakeholders representing highway agencies, auto clubs, and other interested organizations. The members of the advisory panel are:

- Kevin Bakewell, Auto Club South, Tampa, Florida
- Gregory Cohen, American Highway Users, Washington, DC
- John Daly, Genesee County Road Commission, Flint, Michigan (representing the National Association of County Engineers)
- Michael Griffith, Federal Highway Administration, McLean, Virginia
- Michael Halladay, Federal Highway Administration, Washington, DC
- Dale Lighthizer, Michigan Department of Transportation, Lansing, Michigan
- Richard Miller, Auto Club Group/AAA Michigan, Dearborn, Michigan
- Keith Sinclair, American Association of State Highway and Transportation Officials (AASHTO), Washington, DC
- Bruce Smith, New York State Department of Transportation, Albany, New York (representing the AASHTO Standing Committee on Highway Traffic Safety)
- Ed Stoloff, Institute of Transportation Engineers, Washington, DC
- Thomas Welch, Iowa Department of Transportation, Ames, Iowa

AAAFTS, the advisory panel and the research team, very much appreciates the contributions to this pilot program made by John Dawson of EuroRAP; Daniel Tessier of the Canadian Automobile Association; and Mr. Jeffrey Bagdade of the Auto Club Group/AAA Michigan.
1.5 Organization of This Report

The remainder of this report is organized as follows. Section 2 presents a review of existing road assessment programs and related initiatives. Section 3 presents the results of the usRAP pilot studies conducted in Iowa and Michigan. Section 4 discusses key issues for usRAP implementation and Section 5 presents specific recommendations for usRAP implementation resulting from this pilot program. Section 6 discusses potential next steps in the usRAP program. Appendix A presents the preliminary usRAP Road Protection Score (RPS) criteria used in the pilot studies.
Section 2. Existing Road Assessment Programs

The usRAP pilot program is intended to assess the feasibility of adapting the road assessment programs undertaken in other countries to U.S. conditions. This section of the report reviews work under way as part of the European Road Assessment Program, the Australian Road Assessment Program, and the International Road Assessment Program. This section also reviews related U.S. efforts.

usRAP may be similar to these ongoing programs in some respects and may differ in others. However, the usRAP assessment begins with an evaluation of these ongoing programs.

2.1 European Road Assessment Program (EuroRAP)

EuroRAP is an international not-for-profit organization formed by motoring organizations (auto clubs) and highway agencies throughout Europe to work together for improvements to the safety of Europe’s roads. It is the sister program to EuroNCAP, a safety program that crash tests cars and assigns them star ratings for safety. More information about EuroRAP can be found at www.eurorap.org.

The goal of EuroRAP is to provide safety ratings for roads across Europe. This will generate consumer information for the public and give road engineers and planners vital benchmarking information to show them how well, or how badly, their roads are performing compared with others, both in their own and other countries. EuroRAP is also committed to forging a partnership between all agencies with responsibility for road safety.

Objectives

The primary objectives of EuroRAP are to:

- reduce death and serious injury on European roads rapidly through a program of systematic assessment of risk that identifies major safety shortcomings which can be addressed by practical road improvement measures
- ensure that assessment of risk lies at the heart of strategic decisions on route improvements, crash protection, and standards of route management

Assessment Protocols

EuroRAP is using three assessment protocols:
• **risk mapping** to document the risk of death and serious injury crashes and show where risk is high and low
• **star ratings** based on inspection of roads to examine how well they protect users from crashes and from deaths and serious injuries when crashes occur
• **performance tracking** compares the safety performance of roads over time to identify roads where safety has been substantially improved and roads that show a consistent need, over time, for safety improvement

EuroRAP considers that both risk mapping and star ratings are needed to present a complete picture of the safety of a given road section, including the level of safety that the road has achieved and the extent to which it is equipped to protect the road user. Countries participating in EuroRAP differ in their level of interest in and reliance on those two protocols; all participants are potentially using both protocols, but some appear to assign a higher priority to risk mapping, as based on documented system performance, while others prefer star ratings which are directly sensitive to specific roadway design features. The performance tracking protocol is being implemented as countries that have already developed initial risk maps add additional years of crash data to those maps. Each of these assessment protocols is assessed further below.

**History and Current Status**

Conceptual planning for EuroRAP began in 2000. A pilot program was carried out in 2002 and resulted in publication of the *EuroRAP Pilot Phase Technical Report* in May 2003. The first full year of implementation has been carried out in 2003 and is complete with the publication in May 2004 of the *EuroRAP I (2003) Technical Report*. Activities in 2004 were considered the second full year of EuroRAP I implementation. Planned activities for 2005 and 2006 are being termed EuroRAP II.

The pilot program in 2002 included the development of risk maps for rural primary roads in Britain, the Netherlands, Sweden, and Catalonia (the province of Spain where Barcelona is located). A conceptual approach to a Road Protection Score (RPS), on which star ratings could be based, was also developed as part of the pilot program.

The first year of implementation in 2003 included refinement of risk maps for Britain, the Netherlands, Sweden, and Catalonia, and the development of risk maps for Italy. The conceptual approach for RPS rating was developed into a more complete methodology and that methodology has been applied to 60 routes in seven countries.

In 2004, EuroRAP activities were also underway in Austria, Finland, Germany, Ireland, Northern Ireland, and Switzerland. In particular, Ireland, Northern Ireland, and Switzerland developed risk maps in 2004. Britain and Sweden are also updating their risk maps. Germany is beginning a pilot program of RPS inventories and Sweden is implementing a very extensive program of RPS inventories that is expected to cover 5,000 mi (8,000 km) of roadway this year.
In 2005, EuroRAP activities have expanded to 18 countries, including Austria, Belgium, Croatia, Czech Republic, Finland, France, Germany, Great Britain, Iceland, Ireland, Italy, Netherlands, Norway, Slovakia, Slovenia, Spain, Sweden, and Switzerland. In December 2005, a publication entitled *From Arctic to Mediterranean: First Pan-European Progress Report* presented the results of activities to date in each of these countries.

**Selected Road Networks**

EuroRAP has made a decision to focus their initial efforts on the rural primary road networks. This decision was made because a majority of fatal and serious injury crashes occur outside of urban areas and because data for primary rural roads were more complete and more accessible than for urban roads and for rural secondary roads.

The goal of initial EuroRAP implementation in each country is to select a network of rural primary roads on which at least 30 percent of nationwide fatalities occur. In most European countries, this includes all rural roads under the jurisdiction of the national highway agency (freeways plus major intercity routes), plus a wider set of rural roads under the jurisdiction of regional or provincial highway agencies. The national highway network typically includes a mix of freeways, multilane divided or undivided highways, and two-lane highways. The majority of the regional or provincial highway networks considered are two-lane highways. The road networks initially selected for EuroRAP include 14,000 mi (22,400 km) in Britain, 2,200 mi (3,500 km) in the Netherlands, 5,300 mi (8,500 km) in Sweden, and 2,100 mi (3,400 km) in Catalonia.

**Road Section Lengths**

Road sections used in EuroRAP typically average around 12 mi (20 km) in length. EuroRAP guidance is that section boundaries should be chosen such that sections typically experience at least 20 fatal or serious injury crashes in three years. This implies that the shorter homogeneous roadway segments typically found in roadway inventory databases should be combined.

As an example of the determination of road section lengths, in Britain, EuroRAP has generally sought a minimum roadway section length of 3 mi (5 km), with longer sections where appropriate. To achieve this, shorter road segments that do not meet the desired minimum section length or crash frequency guidelines were combined using the following target criteria:

- the combined segments had the same road number (for simplicity of bookkeeping)
- the combined segments were adjacent to one another
- the combined segments were part of the same network (national or regional)
• the combined segments had similar ADTs (differences up to 10,000 veh/day were accepted)

The criteria produced many sections of mixed design types. However, even after combining segments, a number of sections shorter than 3 mi (5 km) in length and/or with fewer than 20 fatal and serious injury crashes in three years remained. Such sections have been retained in the EuroRAP database, recognizing that their crash rates would be more variable than sections that meet the target criteria.

In populous countries such as Britain, the target criterion of 20 fatal and serious injury crashes in three years per section could be met in most cases. However, in Sweden, where traffic volumes are lower, the route segments chosen experienced an average of only five fatal and serious injury crashes in three years.

Road Design Categories

Various EuroRAP countries have used the following categories to classify rural road sections by road design type:

• freeways
• other divided roads
• mixed design roads
• four-lane undivided roads
• 2+1 roads (two-lane highway with continuously alternating passing lane)
• two-lane roads (perhaps classified by pavement width)
• other roads

Crash Severity Levels

The primary crash severity level addressed in EuroRAP includes both fatal and serious injury crashes. Fatal and serious injury crashes are considered together because both severity levels are considered unacceptable outcomes for collisions. Furthermore, consideration of fatal crashes alone would unnecessarily restrict the average crash frequency per site and make results more variable. There are also some concerns that differences in the definition of a fatal crash between European countries (i.e., based on the maximum elapsed time between the crash and death) could bias results if fatal crashes alone were used. In EuroRAP’s approach, it is likely that victims who survive an extended time period after the crash and then die would still be classified as serious injuries and, therefore, would still be included in risk mapping.

Some countries are using all injury crashes, rather than just serious injury crashes, in implementing EuroRAP. This is done either because serious and minor injury crashes cannot be separated in available data (e.g., Italy) or because average crash frequencies per section are so low that larger crash sample sizes are considered desirable (e.g., Ireland).
It should be noted that EuroRAP statistics are based on fatal and serious injury crashes, not the number of persons fatally or seriously injured. The occurrence of multiple fatalities or injuries in a single crash is an issue that has been raised for consideration by EuroRAP’s benefit-cost working group (see below).

Crash Locations

The analysis of safety measures for EuroRAP road sections requires that crashes attributable to specific road sections be identified. The ability to do this varies with completeness and accuracy of available crash data.

In most European countries, crash location data have been found to be reasonably complete and accurate. However, in Italy, approximately 30 percent of fatal and injury crashes had no location identifier information other than route number and province (i.e., route number and county in U.S. terms). The Italian auto club has proceeded with development of risk maps by allocating the unlocated crashes to road sections in proportion to the crashes on those sections on the same route number and within the same province for which specified locations are available.

Sweden has addressed the issue of treating crashes that occur at intersections where two EuroRAP road sections intersect by assigning half of the crashes to each of the intersecting road sections.

Risk Mapping

The first of the two EuroRAP assessment protocols is risk mapping for road sections. The EuroRAP approach to risk mapping is discussed in this section.

EuroRAP has used four risk measures based on observed crash history. Each measure has been computed for the road sections on the EuroRAP network, classified into five categories, and displayed on maps using color coding for the five categories. The four risk measures and their corresponding maps are:

- Map 1—fatal and serious injury crashes per km of road
- Map 2—fatal and serious injury crashes per billion veh-km of travel
- Map 3—ratio of fatal and serious injury crash rate per billion veh-km of travel to the average crash rate for similar roads
- Map 4—potential number of fatal and serious injury crashes saved per km in 3 years if crash rate per billion veh-km were reduced to the average crash rate for similar roads
All four maps can be prepared from a database that contains just four pieces of information about each road section:

- number of fatal and serious injury crashes that occurred on the road section in a specified time period
- road design type
- section length
- traffic volume (ADT)

Map 1 is considered useful because it presents the actual observed number of crashes per unit length (crash density).

Map 2 is considered the basic EuroRAP risk map because fatal and serious injury crashes per billion veh-km of travel are proportional to the risk of a fatal or serious injury to an individual motorist traveling through the road section in question.

Map 3 and 4 are useful because they compare the crash experience for particular road segments to their group average. Map 4, in particular, is intended as indicative of the safety benefit that could be achieved if a road section were improved.

Figures 1 through 4 present examples of EuroRAP Maps 1 through 4, respectively, for Britain. Each map uses four or five risk levels, which are color coded on the maps. Initially, it was intended to assign star ratings to roadway segments based on the categories used in Map 2. However, the use of star ratings in connection with risk maps was dropped and the star rating concept has been reserved for use with the second EuroRAP protocol, based on the RPS, as described below.

A primary goal of EuroRAP—documenting the risk to motorists traveling through particular road sections—is met by the preparation of Map 2 and tabulation of the data on which Map 2 is based. Beyond the display of risk to individual motorists, EuroRAP plans to use other measures such as those shown on Maps 3 and 4 to fulfill its other goal of taking a proactive approach to improvement of the level of safety for the road system as a whole (individual risk vs. collective risk to society as a whole). The road sections shown on Map 2 as having the highest crash rates are not necessarily road sections that would have a high priority for improvement. For example, in the data for the pilot program in Britain, the road section with the highest crash rate (i.e., the highest individual risk to motorists traveling through the road section) was a winding, low-volume road in the Scottish highlands. Improvement of such a road would be expensive and environmentally sensitive with little gain in terms of number of crashes reduced.
Figure 1. Example of EuroRAP Map 1—Fatal and Serious Crashes per km in Britain
Figure 2. Example of EuroRAP Map 2—Fatal and Serious Crashes per Vehicle-km in Britain
Figure 3. Example of EuroRAP Map 3—Ratio of Crash Rate per Vehicle-km to Rate for Similar British Roads
Figure 4. Example of EuroRAP Map 4—Potential Reduction in Fatal and Serious Crashes per km if Group Average Rates for Britain are Achieved
The other maps have been developed because of the concern that Map 2 does not lead directly to rational improvement priorities. EuroRAP considers that the four maps, taken collectively, can help to guide improvement priorities. In addition, current research is identifying the reduction in crash rate and crash frequency that would be possible if specific improvement scenarios were implemented on specific road design categories (i.e., convert an existing divided highway to a freeway, convert a two-lane highway to a four-lane highway, improve an existing two-lane highway by making intersection improvements that would cut the frequency of intersection-related crashes in half, etc.).

EuroRAP is designed with the philosophy that safety improvement programs should move from blackspot treatment (i.e., improvement of identified high crash locations) to route management and eventually to network safety management. European countries have set ambitious safety improvement goals (e.g., 50 percent reduction of fatal and serious injury crashes by 2010). EuroRAP takes the view that the achievement of this goal requires “mass action” to improve safety along extended road sections and that the goal cannot be achieved solely by low-cost improvements at identified spot locations. This leads to the focus of EuroRAP on safety for extended roadway sections rather than for point locations.

While most countries participating in EuroRAP appear comfortable at present with risk rating based on Maps 1 through 4, at least one country has raised concerns that none of the EuroRAP measures or maps address which specific improvement types would be used to improve safety at particular sites and whether those improvements would be cost-effective. Specific concerns raised were as follows:

- total crash costs for road sections should be identified so that crashes of all severity levels can be included in benefit-cost analyses
- the cost of minor injury crashes and property-damage-only crashes should be included, even though it is recognized that their contribution to safety management decisions will be small compared to fatal and serious injury crashes
- the cost per crash should vary by road type because the average number of fatalities and injuries per crash varies by road type
- while Map 4 comes the closest to representing the potential benefits from an improvement, neither Map 4 nor any of the other maps does so realistically. An alternative approach would be for each road section should have a target design that represents future highway agency plans for that road section and that the most appropriate measure to be mapped is the potential number of crashes saved per km in three years if the section’s crash rate were reduced from its current level to the average crash rate for roads similar to the target design. This measure has been referred to as the “safety potential” for a roadway segment.

These concerns represent a view that the EuroRAP risk maps, by themselves, may not be useful in decision making about roadway improvements unless a more traditional engineering economic analysis is also incorporated. Such an extension seems natural because the risk maps by themselves were never envisioned as sufficient to set safety improvement priorities. EuroRAP has formed a benefit-cost working group to look at these concerns.
Star Ratings Based On Road Protection Score

The second of the two EuroRAP protocols is the use of star ratings for road sections based on the EuroRAP Road Protection Score (RPS). The use of RPS to derive star ratings is discussed in this section.

The objective of using star ratings based on RPS is to:

- identify important differences in road design or management which are likely to lead to different probabilities of fatal or serious crashes
- provide ratings based on inventories that can be made either directly during inspection drives, or subsequently from the video of the drive, at reasonable cost

The RPS concept was developed to address the road design and management factors that relate to four specific crash types which were identified as the highest priority for safety improvement:

- head-on crashes
- single-vehicle run-off-road crashes
- intersection crashes
- crashes involving vulnerable road users (pedestrians and bicyclists)

The specific criteria that will be used by EuroRAP to rate the design features for these specific crash types have not yet been finalized, but a preliminary set of criteria have been developed. The specific items that contribute to the current RPS ratings are shown below.

<table>
<thead>
<tr>
<th>Crash type</th>
<th>Design elements considered</th>
<th>Specific issues that contribute to RPS ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head-on crashes</td>
<td>Median treatment</td>
<td>Presence of median</td>
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<td></td>
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<td>Median width</td>
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<td>Safety barrier</td>
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<td>Centerline rumble strips</td>
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<td>Single-vehicle run-off-road</td>
<td>Roadside treatments</td>
<td>Safety barrier</td>
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<td>crashes</td>
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<td>Width of clear zone</td>
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<td>Intersection crashes</td>
<td>Intersection treatments</td>
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<tr>
<td></td>
<td></td>
<td>Four-leg unsignalized intersections</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with and without left-turn lanes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Three-leg unsignalized intersections</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with and without left-turn lanes</td>
</tr>
</tbody>
</table>
No rating criteria have yet been developed or implemented for pedestrian and bicyclist crashes. The primary reason that no criteria have been developed for pedestrians and bicyclists is that it has been decided that such ratings cannot be based on pedestrian and bicycle facilities alone, but should also consider pedestrian and bicycle usage of the road section (i.e., pedestrian and bicycle volumes). This creates a potential difficulty since usage/volume data for pedestrians and bicycles are not typically available from highway agencies and cannot be determined accurately in a drive-through inventory.

RPS ratings on a 1 to 4 scale are determined separately for median features, roadside features on both the right and left sides of the roadway, and intersection features. The star ratings are assigned as follows: 0 to 1.5 rating = 1 star, 1.5 to 2.5 rating = 2 star, 2.5 to 3.5 rating = 3 star, 3.5 to 4.0 rating = 4 star.

The RPS criteria are such that the ratings are generally 3 and 4 stars for freeways, 2 or 3 stars for other divided highways, and 1 or 2 stars for two-lane highways. A two-lane highway can rise to a 3-star rating if it has a median treatment such as would be present on a Swedish 2+1 road.

Some of RPS rating criteria vary with speed limit. Thus, a given road section might be rated as 4 stars with a speed limit of 45 mph (70 km/h), but might be given only 3 stars with a speed limit of 60 mph (100 km/h). These speed-sensitive criteria are based primarily from reasoning about the affect of speed on the biomechanical forces on crash victims; there does not appear to be any research that demonstrates whether lowering speed limits actually reduces fatal and serious injury crashes. EuroRAP uses speed limit in their criteria, rather than actual speeds, because of a view that motorist travel at speeds above the posted limit is irresponsible and that the responsibility of highway agencies should be to provide a road that performs safely for travel at the speed limit. The widespread use of speed cameras (i.e., photo radar) has a potential to lower speeds effectively and keep motorists within the speed limit at particular locations.

During the EuroRAP pilot program, a drive through inspection was conducted for approximately 600 mi (1,000 km) of British roads and 1,200 mi (2,000 km) of roads in the Netherlands, Sweden, and Germany. The pilot measurements involved a human observer who recorded a preliminary assessment of the road followed up a review of a drive-through video tape. The pilot program used preliminary rating criteria that have now been refined to become the criteria discussed above (including the sensitivity to speed limit).

The current RPS rating criteria have been applied to develop ratings for selected roads in several European countries including 6,200 mi (10,000 km) of road in Sweden and 3,700 mi (6,000 km) of main freeways (autobahnen) and 1,200 mi (2,000 km) of national and state roads in Germany. Recent pilot tests have also been conducted in Finland and Switzerland.
2.2 Australian Road Assessment Program (AusRAP)

A pilot program for the Australian Road Assessment Program (AusRAP), modeled on EuroRAP, has been completed in Australia and AusRAP is now moving forward to implementation. This Australian effort has established the technical feasibility of risk mapping and has developed risk maps for the national highway system [a limited network of 12,000 mi (20,000 km) main rural roads that joins the state and territorial capitals].

The AusRAP risk maps include maps for each state and territory equivalent to EuroRAP Map 1 (referred to as the collective risk map) and equivalent to EuroRAP Map 2 (referred to as the individual risk map). The maps use five color-coded risk levels each including 20 percent of the road sections considered.

AusRAP is currently conducting road inspections to gather data for developing star rating maps of the national highway system. The road inspections are being conducted primarily with video data collected from additional cameras mounted on the vehicles used in traditional video-logging operations. AusRAP has developed RPS criteria that include both crash causation/crash likelihood and crash-severity-increasing factors.

2.3 International Road Assessment Program (iRAP)

The International Road Assessment Program (iRAP) was established in 2004 to provide international coordination for all road assessment program efforts. iRAP serves as an umbrella organization to coordinate AusRAP, EuroRAP, and usRAP.

Road assessment programs are expected to expand to additional countries in the future. Pilot tests for a Canadian Road Assessment Program (CanRAP) are under discussion. An iRAP project to improve safety in low- to medium-income developing countries is being planned; this project would be conducted on a fast-track schedule and would include pilot studies in Asia, Africa, and Latin America.

2.4 Related U.S. Efforts

The following discussion reviews ongoing U.S. efforts relevant to usRAP.
Risk Mapping

The increasing use of Geographic Information Systems (GIS) in the management and operation of highway systems has led several U.S. highway agencies to produce maps similar to those developed in road assessment programs. Two examples from New Hampshire and Oregon are presented below. Both the New Hampshire and Oregon maps shown here are publicly available on the web sites of the respective highway agencies.

New Hampshire

The New Hampshire Department of Transportation (NHDOT) has developed a crash rate map very similar in concept to a EuroRAP risk map. The NHDOT crash rate map, illustrated in Figure 5, clearly distinguishes areas with higher and lower crash rates, although no numerical definitions are given for the color codes shown on the map. Instead, the map uses three color-coded categories to identify the safety performance of particular roadway sections. These categories are defined on the basis of crash rates for specific roadway sections to the statewide average are:

- Low crash rate—crash rates do not warrant further investigation at this time (shown as green on the map)
- Moderate crash rate—crash rates are not extremely high, but may warrant further investigation over time (shown as yellow on the map)
- High crash rate—crash rates warrant further investigation at this time (shown as red on the map)

The statewide crash rate used as the basis for the map in Figure 5 is 2.8 crashes per million veh-mi of travel.

One issue encountered by NHDOT was that, in 1997, only 30 percent of all police-reported crashes were locatable. Work with local police agencies has increased the percentage of police-reported crashes that are locatable to 60 percent. Further efforts along these lines are planned.

Oregon

The Oregon Department of Transportation has used their TransGIS system to prepare maps showing crash counts like that shown in Figure 6.

Other Safety Analysis Initiatives

The maps prepared in road assessment programs are useful in strategic decision making concerning safety improvements to specific routes only if accompanied by other tools that help to diagnose crash problems and select appropriate improvements for specific locations. Current safety analysis initiatives to assist highway agencies in such decisions include:
• FHWA Safety Analyst Software Tools—Safety Analyst will provide software tools for use by highway agencies for safety management of specific highway sites. Safety Analyst is intended to replace outdated safety management software with state-of-the-art approaches and to automate parts of the safety management process that have previously been conducted by manual methods. MRI serves as the prime contractor for developing functional specifications for Safety Analyst and testing the software to assure that it meets those specifications. The software is being written by ITT Industries, Systems Division, in a separate FHWA contract. Safety Analyst is being developed in a pooled-fund study, with financial contributions from FHWA and 19 state highway agencies. The participating states are represented on a Technical Working Group (TWG) that guides Safety Analyst development.

The development of Safety Analyst began in 2001 and the final software tools are expected to be completed in 2007. Interim software tools for a portion of Safety Analyst are currently being beta-tested. More information about Safety Analyst can be found at www.SafetyAnalyst.org.

Six software tools will be provided within Safety Analyst to analyze the safety performance of specific sites, suggest appropriate countermeasures, quantify their expected benefits, and evaluate their effectiveness. These include tools for network screening to identify sites with potential for safety improvement; diagnosis and countermeasure selection to determine the nature of collision patterns at particular locations and select appropriate countermeasures to address those collision patterns; economic analysis and priority ranking to determine which countermeasures are cost-effective and which should receive the highest priority for implementation; and countermeasure evaluation to document the crash reduction effectiveness of implemented countermeasures.

• FHWA Interactive Highway Safety Design Model (IHSDM)—FHWA has undertaken a long-term effort to develop an Interactive Highway Safety Design Model (IHSDM) to assist highway designers to address safety considerations in the development of geometric designs for highway improvement projects. Currently, IHSDM has capabilities for analysis of improvement projects on rural two-lane highways, but future expansion to other highway types, including rural multilane highways is anticipated.

IHSDM is intended for review of projects for which plans are being developed in a computer-aided design (CAD) environment. CAD data can be imported into IHSDM for analysis. Highway design data can also be entered manually for analysis of projects for which CAD-based plans are not available. More details are available and the software can be downloaded at www.tfhrc.gov/safety/ihsdm/ihsdm.htm.
Figure 5. New Hampshire Crash Rate Map
Figure 6. Oregon Crash Frequency Map
The current version of IHSDM consists of five modules. These modules include a design policy review module to identify and flag aspects of designs that do not conform to established design policies; a design consistency module to identify and flag locations where there are substantial differences in expected speed between adjacent geometric elements; a crash prediction module that estimates the expected crash frequency, crash severity distribution, and crash type distribution for an existing or proposed highway section; an intersection diagnostic review module that identifies potential safety concerns in the existing or proposed design of an at-grade intersection and calls them to the designer’s attention; and a traffic analysis module that quantifies the traffic operational level of service of an existing or proposed highway section. A driver/vehicle performance module, combining driver performance and vehicle dynamics modeling is expected to be released at a later date.

- **TRB Highway Safety Manual**—In 1999, a group of Transportation Research Board (TRB) committees began an initiative to develop a Highway Safety Manual (HSM) that could be used to make estimates of traffic safety performance that are analogous to the estimates of traffic operational performance that can be made with the Highway Capacity Manual (HCM). The HSM initiative began with the recognition that the HCM did not include a capability to make safety estimates and that, given its current size, expansion of the HCM to address safety was not practical. In addition, there was a clearly recognized need for the capability to make quantitative safety estimates. In the development and design of highway improvement projects, quantitative estimates are currently made of nearly every important design consideration (traffic operations, user delay, vehicle operation costs, air quality, noise, wetlands impacts, construction cost, and others) except safety, which is typically dealt with on a qualitative basis. The HSM is intended to provide a quantitative basis for estimating the safety performance of an existing highway or street and for estimating the effects of proposed improvement projects.

The HSM initiative has continued to be led by TRB. Initially, a joint subcommittee was established, co-sponsored by seven TRB standing committees. In 2003, the joint subcommittee was reconstituted as the TRB Task Force on Development of the HSM, with the possibility of full committee status within 6 years. Discussions are underway to bring additional partners, including AASHTO, into the HSM effort. Further information about the HSM is available at www.highway safety manual.org.

The first edition of the HSM is scheduled for publication in 2008.
Section 3.
usRAP Pilot Studies

This section of the report presents an overview of the pilot studies conducted in Iowa and Michigan as part of the usRAP pilot program.

3.1 Objective

The objective of the pilot studies was to develop and test potential usRAP concepts by application to roads in two states, Iowa and Michigan. Initial usRAP concepts to be tested have been derived from EuroRAP and from the discussions of the usRAP technical advisory panel. It is expected that the initial usRAP concepts will evolve significantly as a result of these pilot studies and subsequent pilot studies.

3.2 usRAP Protocols to be Tested

Based on EuroRAP concepts, the usRAP pilot studies have tested two potential protocols for safety assessment and mapping of roadway systems. These are:

- *risk mapping* to document the risk of death and serious injury crashes and show where risk is high and low
- *star ratings* based on inspection of roads to examine how well they protect users from crashes and from deaths and serious injuries when crashes occur

The third EuroRAP protocol, performance tracking, will be tested in planned future work.

Road assessment programs have used both risk mapping and star ratings to present a complete picture of the safety of a given road section, including the level of safety that the road has achieved and the extent to which it is equipped to protect the road user. Countries participating in EuroRAP differ in their level of interest in and reliance on the two protocols; all participants are potentially using both protocols, but some appear to assign a higher priority to risk mapping, as based on documented system performance, while others prefer star ratings which are directly sensitive to specific roadway design features.

usRAP will potentially use four risk measures based on observed crash history. Each measure is computed for the road sections of appropriate length for each type of road that makes up the road network under consideration. Each measure is classified into five categories, and displayed on maps using color coding for the five categories. The four maps and their corresponding risk measures are:

- Map 1—fatal and serious injury crashes per mile of road
- Map 2—fatal and serious injury crashes per hundred million vehicle-miles of travel
- Map 3—ratio of fatal and serious injury crash rate per hundred million vehicle-miles of travel to the average crash rate for similar roads
- Map 4—potential number of fatal and serious injury crashes saved per mile in a specified time period if crash rate per hundred million vehicle-miles were reduced to the average crash rate for similar roads

All four maps can be prepared from a database that contains just four pieces of information about each road section:

- number of fatal and serious injury crashes that occurred on the road section in a specified time period
- road design type
- section length
- traffic volume (ADT)

Map 1 is considered useful because it presents the actual observed number of crashes per unit-length (crash density).

Map 2 is considered the basic risk map because fatal and serious injury crashes per hundred million vehicle-miles of travel are proportional to the risk of a fatal or serious injury to an individual motorist traveling through the section in question.

Maps 3 and 4 are useful because they compare the crash experience for particular road segments to their group average. Map 4, in particular, is intended as indicative of the safety benefit that could be achieved if a road section were improved.

Additional map types, not considered in EuroRAP, are being considered for use in usRAP because they are appropriate for North American conditions or because they address specific concerns of participating highway agencies. These include intersection risk maps and maps that express risk in terms of the economic losses due to crashes.

The second of the two potential usRAP protocols tested in the pilot program is the use of star ratings for road sections based on the EuroRAP concept of a Road Protection Score (RPS). The objectives of using star ratings based on RPS are to:

- identify important differences in road design or management which are likely to lead to different probabilities of fatal or serious crashes
- provide ratings based on inventories that can be made either directly during inspection drives, or subsequently from the video of the drive, at reasonable cost
The RPS concept was developed to address the road design and management factors that relate to four specific crash types which were identified as the highest priority for safety improvement:

- head-on crashes
- single-vehicle run-off-road crashes
- intersection crashes
- crashes involving vulnerable road users (pedestrians and bicyclists)

RPS scores based on features potentially affecting crashes involving pedestrians and bicyclists have not yet been implemented in either EuroRAP or usRAP because an appropriate scoring method requires data on volumes of pedestrians and bicycles using particular facility segments, and such data are not generally available.

Appendix A presents the preliminary RPS scoring criteria for usRAP on which the Iowa and Michigan pilot studies have been based. These RPS scoring criteria have been adapted from EuroRAP to better address U.S. conditions.

### 3.3 Pilot Study Activities

The following activities have been conducted as part of the pilot studies:

- The research team met with the participating highway agencies to identify existing data files, and data elements within those files, that were available for testing of usRAP concepts and to discuss the quality of those data.
- Using the available data, and in consultation with the participating highway agencies, the research team developed procedures for preparing risk maps. The following issues were considered:
  - how should the highway system be divided into analysis sections considering road design types, traffic volumes, logical termini, desirable minimum section lengths, and desirable minimum average crash frequencies?
  - what data quality controls should be used with crash locations?
  - what crash severity levels should be addressed in risk maps?
  - what safety-related measures are most appropriate as the basis for specific maps?
  - how should those measures be divided into levels that are appropriate for color coding of highway sections on the maps?
- The research team prepared risk maps for the highway systems of interest selected in each state. The risk maps included maps similar to EuroRAP Maps 1 through 4, and other maps identified by the research team and the participating
highway agencies as potentially relevant. The feasibility and need for both roadway section maps and for intersection maps were considered.

- The research team reviewed the data elements used to develop the EuroRAP Road Protection Score (RPS) and adapted the RPS scoring criteria to better address U.S. roads.

- In consultation with the participating highway agencies, the research team selected a portion of each state for testing the RPS concept. The geographic areas selected for testing the RPS concept includes a sufficient mileage of highways and variety of road types to fully test the concept, but was not so large as to exceed the available data collection resources.

- The research team collected the data elements of interest for RPS scoring from existing data files and from a videolog review. The research team tried various combinations of data collection approaches to help assess the best combination of low data collection cost and high data quality. A videolog was already available in one state for review in the office to obtain the data needed for RPS scoring; in the other state, video recordings were made in the field specifically for this project and were then reviewed in the office in a similar manner.

- The research team applied the collected data in determining RPS star ratings for highways within the selected geographical areas. For comparison and evaluation of potential concepts, two approaches were used in developing star ratings and preparing maps to illustrate those ratings. First, star ratings were prepared using the existing EuroRAP rating criteria. Second, the research team formulated modifications to the EuroRAP rating criteria that appear more appropriate to U.S. roads and applied those modified criteria.

- The research team prepared overlay maps in a suitable form that combine the information shown on the risk maps and in the star ratings and made an assessment of whether such overlay maps provide insights into safety improvement needs that are not evident in either the risk maps or star ratings alone.

### 3.4 Results of the Iowa Pilot Study

The Iowa pilot study was conducted in cooperation with the Iowa Department of Transportation. This section presents the results of the Iowa pilot study. The section first discusses general issues concerning the roadway network included in the pilot study, the manner in which that road network was divided into road segments for analysis, and the data that were assembled for analysis. The results of risk mapping and star-rating protocols are then presented. Finally, the comparison of the risk and star rating maps is discussed.

A decision was reached in consultation with the Iowa Department of Transportation to focus the pilot study on rural state highways in Iowa. Consideration was also given to risk mapping for urban intersections in one city.
Roads Selected for Inclusion in Mapping

Iowa has over 100,000 miles of publicly owned and operated roads. Only state-owned (primary) roads were selected for the Iowa pilot study. These roads include Interstate, US, and state numbered routes.

State highways were included in the study scope except for:

- Conventional highways within cities with populations of 2,000 or more
- Freeways within metropolitan area boundaries for metropolitan areas with populations of 50,000 or more

For the sake of continuity, freeway sections within smaller cities that were not part of larger metropolitan areas were included in the pilot study. Final “rural” designation was based on visual inspection. As a result, the rural/urban designation on a few sections was changed to provide continuity.

Road Classification

Roads were classified into four road design types: freeway, divided highway, undivided multilane and two-lane roads. Road type definition was based on access control, median type, and number of lanes. Unique access control-median type number of lanes combinations were assigned to one of the road-type categories. In some cases, particularly where this combination was atypical, sections were visually inspected using GIS and aerial imagery. The appropriate category was then assigned based on this assessment.

Scope of Analysis and Mapping

Risk maps were developed for the entire state (all roads shown in Figure 7). Road Protection Scores (RPS) were developed for the southeast quadrant of the state only (shaded in Figure 7).

Segmentation

Iowa DOT sufficiency sections were used as the initial segmentation for analysis and display purposes. These sections comprise road segments of relative homogeneity that combine shorter segments from Iowa’s Geographic Information Management Systems (GIMS) file. Sections represent only mainline sections of roadway (no ramps). As sufficiency sections are not perfectly homogeneous, the Iowa DOT designates one segment within the section as “typical,” and its characteristics are used to represent the entire section. For the current project, however, weighted averages of ADT and speed limit were computed for each sufficiency section.
As some sufficiency sections are quite short, the project team joined together adjacent sections with similar characteristics into “analysis sections.” Rules were developed to allow aggregation of sections:

- with same county, route number, and road type
- of speed limits within 5 mph
- with ADTs within 20 percent, or within 2,000 veh/day
- with similar ADT, same road type, and speed limits less than or equal to 50 mph in towns with population under 2,000
- with speed limits less than or equal to 50 mph just outside a town with similar sections within the town
- with very short sections with speed limits greater than or equal to 55 mph, with same road type and similar ADT
- of extremely short length

Short roadway sections classified as rural that were bounded by urban roadways at both ends were deleted rather than aggregated.

Even with the aggregation of road sections described above, the roadway sections used in the Iowa pilot study are shorter and experience fewer expected fatal and major injury crashes than the road sections used by EuroRAP. The EuroRAP sections averaged approximately 12 mi in length, while those for the Iowa pilot study averaged only 5 mi in length. However, if the EuroRAP criterion that road sections should average 20 fatal and major injury crashes in three years were applied in Iowa, an average road section length of 55 mi would be needed. Such long sections would reduce the usefulness of the maps in defining risk in a way that would help in identifying potential future safety improvement projects. Therefore, a decision was reached to retain the shorter section length in the Iowa pilot study.
Crash Type, Selection, and Assignment

For most maps prepared in the Iowa pilot study, only fatal and serious injury crashes were analyzed. However, economic loss (crash cost) maps were compiled using crashes of all severity levels.

Crashes were located, their coordinates were derived, and they were assigned to specific roadway segments using best available GIS cartography.

Study Period and Data Summary

Three and five years of data (2001-2003, 2000-2004) were selected for analysis and presentation. EuroRAP uses three years of data, but the traffic volumes and crash densities on Iowa rural highways are much lower than for typical European rural highways. It should be noted that the Iowa crash report form was substantially changed in 2001, so that the crash data for 2000 may be different in some respects from the data for 2001 to 2004. In addition, preliminary 2004 crash data were utilized. Table 1 presents crash totals for rural state highways for each year of the study period.

Table 1. Crash Data for Iowa Pilot Study by Severity Level

<table>
<thead>
<tr>
<th>Year</th>
<th>Fatal Crashes</th>
<th>Major Injury Crashes</th>
<th>Total Fatal, Major Injury Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>151</td>
<td>588</td>
<td>739</td>
</tr>
<tr>
<td>2001</td>
<td>139</td>
<td>372</td>
<td>511</td>
</tr>
<tr>
<td>2002</td>
<td>146</td>
<td>405</td>
<td>553</td>
</tr>
<tr>
<td>2003</td>
<td>131</td>
<td>382</td>
<td>513</td>
</tr>
<tr>
<td>2004</td>
<td>121</td>
<td>404</td>
<td>525</td>
</tr>
<tr>
<td>2000-2004</td>
<td>690</td>
<td>2151</td>
<td>2841</td>
</tr>
</tbody>
</table>

Risk Maps

Following is a summary of the data used for risk mapping in the Iowa pilot study:

- Statewide totals for rural state highways
  - 1,580 segments (3,100 sufficiency sections; 27,900 GIMS)
  - 7,800 road miles
  - 13 billion annual veh-mi of travel (VMT)
  - 2,841 fatal and serious injury crashes
- Statewide averages for analysis sections on rural state highways
  - Average length = 4.92 mi
  - AADT = 4,600 veh/day
Table 2. Summary Risk Mapping Data for Iowa Pilot Study

<table>
<thead>
<tr>
<th>Road Type</th>
<th>Sections</th>
<th>Average Length (mi)</th>
<th>Average AADT</th>
<th>Fatal &amp; Major Injury Crashes</th>
<th>Total Frequency</th>
<th>Annual Frequency</th>
<th>Annual Density</th>
<th>Annual Rate (HMVM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstate/Freeway</td>
<td>119</td>
<td>3.683</td>
<td>860</td>
<td>5.4</td>
<td>541.3</td>
<td>0.91</td>
<td>0.13</td>
<td>2.00</td>
</tr>
<tr>
<td>Multi-lane Divided</td>
<td>152</td>
<td>4.201</td>
<td>547</td>
<td>1.7</td>
<td>479.1</td>
<td>0.63</td>
<td>0.18</td>
<td>5.61</td>
</tr>
<tr>
<td>Multi-lane Undivided</td>
<td>71</td>
<td>4.15</td>
<td>63</td>
<td>0.9</td>
<td>4218</td>
<td>0.10</td>
<td>0.11</td>
<td>7.20</td>
</tr>
<tr>
<td>Two-lane</td>
<td>1,239</td>
<td>19.557</td>
<td>6307</td>
<td>5.5</td>
<td>1785.8</td>
<td>0.29</td>
<td>0.08</td>
<td>8.21</td>
</tr>
<tr>
<td>Total</td>
<td>1,581</td>
<td>27,856</td>
<td>7,777</td>
<td>4.9</td>
<td>4,564</td>
<td>0.36</td>
<td>0.12</td>
<td>4.39</td>
</tr>
</tbody>
</table>

Selection of Risk Categories for Use on Risk Maps

For presentation purposes, five categories for most risk maps were used to be consistent with EuroRAP. A sequence of color codes was used to define categories on each map in ascending order of risk:

- dark green (lowest risk)
- light green
- yellow
- red
- black (highest risk)

Risk maps were initially prepared using the same risk category boundaries used in EuroRAP. On some of these maps, most or all of the road sections were shown in the lowest risk category, because crash densities, crash rates, and/or traffic volumes are generally lower on roads in Iowa than on roads in Europe. Such uniformly colored maps would not be useful in managing roadway safety or communicating risk. Maps were then developed using risk categories based on quintiles of the data (i.e., 20 percent of roadway length in each risk category); this approach has also been used in AusRAP. Finally, a decision was made to adjust the risk categories so that each category in increasing order of risk contained a progressively smaller portion of the roadway system and so that the highest risk category on each map includes 5 percent of roadway length. The selected risk categories and their associated colors are as follows:

- dark green (lowest risk) 40 percent of roadway length
- light green 25 percent of roadway length
- yellow 20 percent of roadway length
- red 10 percent of roadway length
- black (highest risk) 5 percent of roadway length
This approach should serve to focus attention on the roadway sections with the greatest potential for safety improvement. The highest risk category (shown in black on the various maps) should assist in meeting the new Federal mandate that states identify 5 percent of locations with the most severe safety needs (see Section 4.2 of this report). The roads in the highest risk category vary among the various types of maps, indicating that there are multiple considerations in deciding which road sections have the most severe safety needs.

Examples of maps for the Iowa pilot study are presented below. Maps have been developed using three and five years of data; all of the examples presented below use five years of data.

Because shorter section lengths were used in the Iowa pilot study than would be suggested by EuroRAP criteria (see discussion of segmentation above), some road sections in the Iowa pilot study experienced only a few fatal and major injury crashes in five years but were classified in a high risk category. It did not appear appropriate to classify sections with limited crash experience as high risk, since they generally had short lengths or very low traffic volumes, so a criterion was adopted that no road section would be considered for classification in the two highest risk categories (red and black on the various maps) unless it experienced more than two fatal or major injury crashes in five years; such low-crash-count segments with higher risk measures generally appear in the medium risk (yellow) category on the maps presented. The segmentation issues for low-crash-count sections will be considered in future research.

Road Section Crash Density Maps (Map Type 1)

The first type of risk map developed was the annual crash density map (Map 1). Figure 8 presents a crash density map for Iowa using categories with risk category boundaries using the criteria discussed above. The lowest risk category (dark green) on this map includes 40 percent of the total length of the Iowa state highway system; the highest risk category includes 5 percent of the total length. Because Map 1 is based on crashes per mile, some higher volume roads, including freeways, appear in the higher risk categories; on subsequent maps taking traffic volumes into account, freeways generally appear in the lower risk categories.

To facilitate comparison with national data, average Iowa crash densities were compared to national statistics as presented in the latest edition of Highway Statistics, and alternative risk categories based on national estimates were developed. The data from Highway Statistics show that the average fatal crash density on rural roads in Iowa are only about 46 percent of the national average fatal crash density for rural roads. This may be due in part good roadway and roadside design and in part due to lower than average traffic volumes in Iowa. The available data suggest that the Iowa risk category boundaries could be multiplied by 2.17 (= 1.00/0.46) to estimate a set of national risk categories. Unfortunately, no comparable data for major injury crashes are available to develop.
Figure 8. Example of Map 1 for Iowa Using State-Specific Risk Categories
national risk categories based on both fatal and major injury crashes. A sample Iowa map using “national” categories is shown in Figure 9. The “national” categories used to prepare this alternative map are preliminary in nature. A broader analysis is needed to determine the most suitable “national” categories for application in usRAP.

Road Section Crash Rate Maps (Map 2)

Risk maps based on crash rate were also developed for Iowa roads. While five years of crash data were used, a single AADT value (2003) was used to compute exposure. Figure 10 presents a typical crash rate map for Iowa roads.

Ratio of Crash Rate Relative to Similar Road Types (Map 3)

Figure 11 presents a map based on the ratio of fatal- and major-injury crash rate for each road section to the average rate based on similar roads (Map 3).

Potential Crash Savings (Map 4)

Map 4 indicates the potential for reducing fatal- and major-injury crashes if road sections with above-average crash rates could be brought to the average crash rate for roads of similar type. Figure 12 presents a typical map of this type for rural state highways in Iowa. EuroRAP presents these maps in terms of three years of savings; the map shown in Figure 12 is based on five years of crash savings, which was more appropriate for the lower crash densities found in Iowa.

Crash Loss Maps (Maps 5 and 6)

Two additional map types were created specifically for the Iowa pilot study to document the total economic losses from crashes. Figure 13 presents Map 5, which is based on annual total crash loss per mile. To compute total crash loss costs, crashes of all severity levels were used, not just fatal and injury crashes. Iowa DOT economic values for fatal and injury crashes were used along with estimates of property damage for each crash made by the investigating officer. Figure 14 presents Map 6, which is based on average crash loss per vehicle-mile traveled.

Intersection Risk Maps

Two risk maps for urban intersections were created for the Iowa pilot study. Map 7 (Figure 15) presents intersection crash rate per hundred million entering vehicles. An example of Map 8, based on average number of intersection crashes per year, is presented in Figure 16.
Figure 9. Example of Map 1 for Iowa Using Estimated National Risk Categories
Figure 10. Example of Map 2 for Iowa Using State-Specific Risk Categories
Figure 11. Example of Map 3 for Iowa Using EuroRAP Risk Categories
Figure 12. Example of Map 4 for Iowa Using State-Specific Risk Categories
Figure 13. Example of Map 5 for Iowa Using State-Specific Risk Categories
Figure 14. Example of Map 6 for Iowa Using State-Specific Risk Categories
Figure 15. Example of Map 7 for Urban and Suburban Intersections in Cedar Rapids, Iowa
Figure 16. Example of Map 8 for Urban and Suburban Intersections in Cedar Rapids, Iowa
Star Ratings Based on RPS Criteria

The RPS criteria applied in the Iowa pilot study were based on the RPS criteria from EuroRAP criteria, but have been adapted in significant ways to be better applicable to U.S. conditions. Each road is assigned a rating from four stars (highest rating) to one star (lowest rating) based on the criteria presented in Appendix A.

Data Collection for RPS

Data elements to support development of road protection scores (star ratings) for the Iowa pilot study were collected from primary and secondary sources. Secondary sources of data included existing Iowa DOT databases. These items included median type, median width, shoulder type, shoulder width, lane width, and speed limit. Attributes not available in the existing databases were derived from review of the Iowa DOT 2003 videolog by trained observers. The attributes obtained from the videolog review included (1) intersection count and type, turning lanes, control, ramp type and driveway type, (2) passing zones, (3) presence of guardrail, drop-offs, and safety (clear) zone width, and (4) estimates of foreslope and backslope. Figure 17 presents the RPS inspection form developed for the Iowa pilot study.

RPS Data Collection Issues

Given schedule constraints, data collection from the videolog began prior to final determination of RPS methodology for usRAP. Data were collected for 1-mi segments (by sufficiency section) in the rural, unincorporated areas and for analysis sections as a whole in small towns. In total, data from the videolog were obtained for more than 2,200 segments. Roadside slope estimates were collected in three ranges based on expected requirements of the usRAP RPS method, flat (1:5 or flatter), gentle (1:4), or steep (1:3 or steeper). No estimation was made of lateral distance to ditches. Consequently, only foreslope was used in determining the RPS scores for the Iowa pilot study. The data reduction from video logs was considered successful, but the potential inaccuracy in slope estimation was the greatest concern.

Clear zone widths were easier to determine and were more reliably estimated with the video data reduction process. All other data elements were straightforward to observe from the videolog. For linear features (e.g., presence of guardrail), a maximum resolution of 0.1 mi was reported. For example, if guardrail was present for approximately 2,500 ft of roadway length on the videolog, 0.5 mi of the 1-mi section were classified as “with guardrail.” For point features such as poles and trees, 0.1 mi of the section, at a minimum, were classified with the clear zone distance to these features. For example, a lone tree 10 ft from the pavement edge in an otherwise clear 1-mi section of road would cause the section to be classified as 0.9 mi with clear zone greater than 30 ft (10 m) and 0.1 mi with a clear zone of 3 to 13 ft (1 to 3.99 m). Data for 0.1-mi subsections of 1-mi
### Figure 17. RPS Inspection Form

<table>
<thead>
<tr>
<th>Section</th>
<th>50-4-30-0014</th>
<th>50-4-40-0014</th>
<th>50-4-70-0014</th>
<th>50-4-80-0014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direction</td>
<td>1 of 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Inspection Elements

<table>
<thead>
<tr>
<th>Description</th>
<th>Number along Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beg MI</td>
<td>0.2</td>
</tr>
<tr>
<td>End MI</td>
<td>0.2</td>
</tr>
<tr>
<td>Length</td>
<td>0.2</td>
</tr>
<tr>
<td>Speed</td>
<td>50</td>
</tr>
</tbody>
</table>

#### Intersections

| Number along Section | 1 | 1 | 10 | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 1 |

#### Median Treatment

| Number along Section | 1 | 1 | 10 | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 1 |

#### Clear Zone

| Number along Section | 1 | 1 | 10 | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 1 |

#### Slope

| Number along Section | 1 | 1 | 10 | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 1 |

#### Other

| Number along Section | 1 | 1 | 10 | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 1 |

* Railroad Crossing
segments were weighted and averaged (in both directions of travel) for the 1-mi segments.

Risk scores were assigned to all pertinent data elements. Scores were weighted, averaged, and consolidated to compute overall risk scores for the analysis sections.

For southeast Iowa as a whole, data were collected from videologs at the average rate of 11 mi/hr for each direction of travel; thus, for both directions of travel combined, data collection from video was conducted at the rate of 5.5 mi/hr. Following is a data summary for the RPS mapping effort for roads in southeast Iowa:

- **Total for state highways in southeast Iowa**
  - 400 segments
  - 1,918 mi of road
  - 4.4 billion VMT

- **Average for state highways in southeast Iowa**
  - Average length = 4.8 mi
  - Average AADT = 6,283 veh/day

<table>
<thead>
<tr>
<th>Road Type</th>
<th>Sections</th>
<th>Road Miles</th>
<th>Directional Miles</th>
<th>Average Length (mi)</th>
<th>Average AADT</th>
<th>Annual VMT (Billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstate/Freeway</td>
<td>33</td>
<td>260</td>
<td>521</td>
<td>7.9</td>
<td>23,868</td>
<td>2.3</td>
</tr>
<tr>
<td>Multi-lane Divided</td>
<td>56</td>
<td>210</td>
<td>420</td>
<td>3.8</td>
<td>8,715</td>
<td>0.7</td>
</tr>
<tr>
<td>Multi-lane Undivided</td>
<td>19</td>
<td>15</td>
<td>30</td>
<td>0.8</td>
<td>4,964</td>
<td>0.0</td>
</tr>
<tr>
<td>Two-lane</td>
<td>292</td>
<td>1,432</td>
<td>2,864</td>
<td>4.9</td>
<td>2,741</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>400</strong></td>
<td><strong>1,918</strong></td>
<td><strong>3,835</strong></td>
<td><strong>4.8</strong></td>
<td><strong>6,283</strong></td>
<td><strong>4.4</strong></td>
</tr>
</tbody>
</table>

**Star Rating Maps Based on RPS Criteria**

Figure 18 presents a star-rating map for roads in southeast Iowa using the EuroRAP rating methodology (converted to US customary units). Figure 19 presents a comparable star-rating map developed using the preliminary RPS criteria developed for usRAP.

**Comparison of Risk Maps and Star Rating Maps**

The risk maps and star rating maps developed in the Iowa pilot study were developed separately. Each type of map provides a different perspective on highway system safety. Risk maps address the safety performance of individual roadway sections on the highway system, while star rating maps represent the presence of features of the highway system that potentially influence safety, but may or may not be reflected in the safety performance of individual roadway segments.
Figure 18. Star Rating Map for Southeast Iowa Using EuroRAP RPS Criteria
Figure 19. Star Rating Map for Southeast Iowa Using EuroRAP RPS Criteria
Consideration of both types of maps together may provide more insight into highway safety conditions than either type of map by itself. Nine comparison maps were prepared with the Iowa pilot study data, combining information from selected risk maps and corresponding star rating maps. Since the star rating maps cover only southeast Iowa, these combined maps necessarily address only southeast Iowa as well. The nine maps represent combinations of three risk measures and three approaches to combining the risk and star rating maps.

The risk measures addressed in the comparison maps are:

- fatal and serious injury crashes per mile of road (i.e., the risk measure for Map 1)
- fatal and serious injury crashes per hundred million vehicle-miles of travel (i.e., the risk measure for Map 2)
- ratio of fatal and serious injury crash rate per hundred million vehicle-miles of travel to the average crash rate for similar roads (i.e., the risk measure for Map 3)

In preparing the comparison maps, the color-coded ratings from the maps for each of the risk measures have been combined with the color-coded ratings from the star rating maps. Since the RPS score is the only measure used in preparing star rating maps, the star rating data used in all of the comparison maps is the same, while the risk data varies between maps. Three different approaches have been used in combining ratings from risk maps and star rating maps to create the comparison maps. For any given roadway section, the risk and star rating were combined in the following manner to determine the color in which each roadway section is shown on the comparison maps:

- **Alternative 1**: Use the higher of the risk and star ratings for each roadway section (i.e., a section rated green on a risk map and black on a star rating map, or vice versa, would appear as green on the combined map)
- **Alternative 2**: Use the lower of the risk and star ratings for any given roadway section (i.e., a section rated green on a risk map and black on a star rating map, or vice-versa, would appear as black on the combined map)
- **Alternative 3**: Determine a combined rating, considering both the risk and star ratings, as shown in Table 3

Alternative 3 for developing maps required the use of additional colors. The numbers 1 through 8 shown in Table 3 represent eight colors that are used in preparing combined maps in this way. The colors range from green to black, as in the other maps prepared in the pilot study, but additional “in-between” shades are needed to provide eight distinct
colors. For example, each of the cells labeled 5 in Table 3 is represented by a pink color on the comparison maps of this type.

Table 3. Alternative 3 for Combining Risk and Star Rating Categories

<table>
<thead>
<tr>
<th>Star rating</th>
<th>Dark green</th>
<th>Light green</th>
<th>Yellow</th>
<th>Red</th>
<th>Black</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 stars</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3 stars</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>2 stars</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>1 star</td>
<td>4</td>
<td></td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

**NOTE:** The cells of this table show a combined rating number. Higher combined rating numbers represent higher risk levels and/or fewer stars. Cells containing the same combined rating number are shown in the same color in maps for Alternative 3.

The comparison maps that were developed in the Iowa pilot study were reviewed by the research team and the Iowa DOT. This review found that the use of separate risk maps and star rating maps appeared to be a more useful than using combined maps like those described above for Alternatives 1 through 3. Therefore, the use of combined maps was not pursued further.

### 3.5 Results of the Michigan Pilot Study

The Michigan pilot study was conducted in cooperation with the Michigan Department of Transportation, the Genesee County Road Commission, and the Livingston County Road Commission. This section presents the results of the Michigan pilot study. The section first discusses general issues concerning the roadway network included in the pilot study, the manner in which that roadway network was divided into road segments for analysis, and the data that were assembled for analysis. The results of risk mapping and star-rating protocols are then presented.

As in the previous pilot study, the Michigan pilot study focused on rural state highways in Michigan. In addition, the Michigan pilot study involved two local highway agencies and considered the rural county primary road systems in Genesee and Livingston Counties. Figure 20 shows the location of Genesee and Livingston Counties in relationship to the State of Michigan as a whole.

**Roads Selected for Inclusion in Mapping**

Michigan has over 120,000 miles of publicly owned and operated roads. To limit the scope for presentation purposes, only state-owned (trunkline) roads were selected for the Michigan pilot study (see Figure 21). These roads include Interstate, US, and Michigan numbered routes.
To be consistent with EuroRAP, the scope of the pilot study was focused on rural roads. Rural roads were defined as roadway segments classified as rural in the Michigan DOT sufficiency section data. These are generally locations outside incorporated city boundaries with a population of 5,000 or more and outside defined metropolitan areas, which also corresponds to the rural national functional class (NFS) designations. To provide better continuity to the road networks in Genesee and Livingston Counties, a few trunkline segments classified as urban were added to these rural roads.

**Road Classification**

Roads included in this pilot study were classified into four types: freeway, divided highway, undivided multilane and two-lane roads. Road type definition was based on the traffic operation (road type), rural/urban development type, and national functional class assigned to each trunkline sufficiency section by the Michigan DOT.
Figure 21. State Trunkline Roads
Scope of Analysis and Mapping

Risk maps were developed for the entire state. Road Protection Scores (RPS) were developed for the state maintained roadways in Genesee and Livingston Counties. Risk and star rating maps were also developed for the rural county primary roadways in Genesee and Livingston Counties.

Segmentation

Michigan DOT sufficiency sections were used as the initial segmentation for analysis and display purposes. These sections are relatively homogeneous with respect to pavement characteristics (type, age, and condition), traffic volume, national functional classification, and national truck network status. Sections represent both mainline and ramp sections of roadway and each direction of travel for divided roadways. As sufficiency sections are not perfectly homogeneous, the Michigan DOT designates predominant characteristics to represent the entire section.

As some sufficiency sections are quite short, the project team joined together adjacent sections with similar characteristics into “analysis sections.” Rules were developed to allow aggregation of sections:

- with same county, route number, and road type
- with speed limits within 5 mph
- with ADTs within 20 percent, or within 2,000 veh/day
- with similar ADT, same road type, and speed limits less than or equal to 50 mph in towns with population under 2,000
- with speed limits less than or equal to 50 mph just outside a town with similar sections within the town
- with very short sections with speed limits greater than or equal to 55 mph, with same road type and similar ADT
- of extremely short length

Crash Type, Selection, and Assignment

For all maps prepared in the Michigan pilot study, only fatal and incapacitating injury crashes were analyzed. Incapacitating injury crashes in Michigan were defined in a manner analogous to major injury crashes in Iowa.

In Michigan, crashes are located with respect to the Statewide All Roads layer of the Michigan Geographic Framework. Crash locations were defined, and geocoded, based on
a mileage along a unique road segment (physical road number). Once a crash was geocoded, the corresponding geographic coordinates (longitude, latitude) were derived.

**Study Period and Data Summary**

Based on the results of the Iowa pilot study and guidance by the Michigan DOT, five years of data (2000-2004) were selected for analysis and presentation. EuroRAP uses three years of data, but the traffic volumes and crash densities on Michigan rural highways are substantially lower than for typical European rural highways. Table 4 presents crash totals for rural state highways for each year of the study period.

<table>
<thead>
<tr>
<th>Year</th>
<th>Fatal crashes</th>
<th>Major injury crashes</th>
<th>Total fatal and major injury crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>207</td>
<td>1,130</td>
<td>1,337</td>
</tr>
<tr>
<td>2001</td>
<td>196</td>
<td>971</td>
<td>1,167</td>
</tr>
<tr>
<td>2002</td>
<td>200</td>
<td>1,017</td>
<td>1,217</td>
</tr>
<tr>
<td>2003</td>
<td>212</td>
<td>990</td>
<td>1,202</td>
</tr>
<tr>
<td>2004</td>
<td>207</td>
<td>1,040</td>
<td>1,247</td>
</tr>
<tr>
<td>Total</td>
<td>1,022</td>
<td>5,148</td>
<td>6,170</td>
</tr>
</tbody>
</table>

**Risk Maps**

Following is a summary of the data used for risk mapping in the Michigan pilot study:

- Statewide totals for rural state highways
  - 1,357 segments
  - 7,134 road miles
  - 19.3 billion annual veh-mi of travel (VMT)
  - 6,170 fatal and major injury crashes

- Statewide averages for analysis sections on rural state highways
  - Average length = 5.3 mi
  - AADT = 7,400 veh/day
  - Fatal and major injury crashes = 0.91 crashes/section/year
  - Fatal and major injury crash density = 0.29 crashes/mi/year
  - Average crash rate = 6.40/100MVMT

Table 5 presents summary information by road type.
Table 5. Summary of Rural State Trunkline Risk Mapping Data for Michigan

<table>
<thead>
<tr>
<th>Road type</th>
<th>Sections</th>
<th>Road miles</th>
<th>Average length (mi)</th>
<th>AADT</th>
<th>Annual VMT (billion)</th>
<th>Fatal &amp; major injury crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total frequency  Annual frequency  Annual density  Annual rate (HMVM)</td>
</tr>
<tr>
<td>Freeway</td>
<td>160</td>
<td>1,001</td>
<td>6.3</td>
<td>23,922</td>
<td>8.7</td>
<td>1,354.6        1.69        0.27       3.10</td>
</tr>
<tr>
<td>Multilane Divided</td>
<td>33</td>
<td>85</td>
<td>2.6</td>
<td>13,937</td>
<td>0.4</td>
<td>116.0          0.70       0.27       5.38</td>
</tr>
<tr>
<td>Multilane Undivided</td>
<td>38</td>
<td>78</td>
<td>2.1</td>
<td>11,259</td>
<td>0.3</td>
<td>147.8          0.78       0.38       9.17</td>
</tr>
<tr>
<td>Two-lane Roads</td>
<td>1,126</td>
<td>5,970</td>
<td>5.3</td>
<td>4,492</td>
<td>9.8</td>
<td>4,551.6        0.81       0.15       9.30</td>
</tr>
<tr>
<td>Total</td>
<td>1,357</td>
<td>7,134</td>
<td>5.3</td>
<td>7,405</td>
<td>19.3</td>
<td>6,170.0        0.91       0.29       6.40</td>
</tr>
</tbody>
</table>

Selection of Risk Categories for Use on Risk Maps

The statewide risk maps for the Michigan pilot study use the same risk categories developed in the same manner as the risk categories in the Iowa pilot study. The risk categories and their associated colors are as follows:

- dark green (lowest risk) 40 percent of roadway length
- light green 25 percent of roadway length
- yellow 20 percent of roadway length
- red 10 percent of roadway length
- black (highest risk) 5 percent of roadway length

The highest risk category (shown in black on the various maps) should assist in meeting the new Federal mandate that states identify 5 percent of locations with the most severe safety needs (see Section 4.2 of this report).

Examples of all statewide maps for the Michigan pilot study are presented in below. All maps for the Michigan pilot study have been developed using five years of data.

As in the Iowa pilot study, road sections with two or fewer fatal and major injury crashes in five years were not included in the two highest risk categories. It did not appear appropriate to classify sections with limited crash experience as high risk, since they generally had short lengths or very low traffic volumes, so a criterion was adopted that no road section would be considered for classification in the two highest risk categories (red and black on the various maps) unless it experienced more than two fatal or major injury crashes in five years; such low-crash-count segments with higher risk measures generally appear in the medium risk (yellow) category on the maps presented. The segmentation issues for low-crash-count sections will be considered in future research.
Road Section Crash Density Maps (Map Type 1)

The first type of risk map developed was the annual crash density map (Map 1). Figure 22 is a typical crash density map using rural state trunkline highways in Michigan.

Road Section Crash Rate Maps (Map Type 2)

Risk maps based on the fatal- and major-injury crash rate were also developed for Michigan roads. While five years of crash data were used, a single AADT value (2003) was used to compute exposure. Figure 23 presents a typical crash rate map for Michigan roads.

Ratio of Crash Rate Relative to Similar Road Types (Map 3)

Figure 24 presents a map based on the ratio of fatal- and major-injury crash rate for each road section to the average rate of similar roads (Map 3).

Potential Crash Savings (Map 4)

Map 4 indicates the potential for reducing fatal- and major-injury crashes if road sections with above-average crash rates could be brought to the average crash rate for roads of similar type. Figure 25 presents a typical map of this type for rural state highways in Michigan.

County Maps

The Michigan pilot study included preparation risk maps for both state and local roads in two local jurisdictions, Genesee and Livingston Counties. Figures 26 through 29 present examples of Maps 1 through 4, respectively, for Genesee County. Figures 30 through 33 present examples of Maps 1 through 4, respectively, for Livingston County. The maps for rural roads in Genesee and Livingston Counties use the same risk categories as were used for the analogous statewide maps presented in Figures 22 through 25. This approach was necessary so that road sections on state trunkline highways in Genesee and Livingston counties would appear in the same color on both the statewide and the county maps. Therefore, it should be recognized that the risk categories on the county maps do not represent specific percentages of roadway length within that specific county, but rather are appropriate for statewide risk levels.
Figure 22. Example of Map 1 for Michigan Using State-Specific Risk Categories
Figure 23. Example of Map 2 for Michigan Using State-Specific Risk Categories
Figure 24. Example of Map 3 for Michigan Using State-Specific Risk Categories
Figure 25. Example of Map 4 for Michigan Using State-Specific Risk Categories
Figure 26. Example of Map 1 for Genesee County Using State-Specific Risk Categories
Figure 27. Example of Map 2 for Genesee County Using State-Specific Risk Categories
Figure 28. Example of Map 3 for Genesee County Using State-Specific Risk Categories
Figure 29. Example of Map 4 for Genesee County Using State-Specific Risk Categories
Figure 30. Example of Map 1 for Livingston County Using State-Specific Risk Categories
Figure 31. Example of Map 2 for Livingston County Using State-Specific Risk Categories
Figure 32. Example of Map 3 for Livingston County Using State-Specific Risk Categories
Figure 33. Example of Map 4 for Livingston County Using State-Specific Risk Categories
Star Ratings Based on RPS Criteria

The RPS criteria applied in the Michigan pilot study were based on the RPS criteria used in EuroRAP, but have been adapted in significant ways to be better applicable to U.S. conditions. Each road is assigned a rating from four stars (highest rating) to one star (lowest rating) based on the criteria presented in Appendix A.

Data Collection for RPS

Data elements to support development of road protection scores (star ratings) for the Michigan pilot study were collected from primary and secondary sources. Secondary sources of data included attributes provided by the Michigan DOT and Genesee and Livingston Counties. These items included shoulder type, shoulder width, lane width, and speed limit (in some cases). Attributes not included in these databases were derived from review of the videolog by trained observers. The attributes obtained from the videolog review included (1) intersection count and type, turning lanes, control, ramp type and driveway type, (2) presence of guardrail, drop-offs, and safety (clear) zone width, and (4) estimates of foreslope.

RPS Data Collection Issues

Given the absence of professional-grade videolog, which would include DMI measurements, data could not be collected for 1-mi segments, as was done in the Iowa pilot and suggested by EuroRAP. Data were collected for the sufficiency sections defined in the risk analysis. As the research team collected videolog in the field, the time at which the section termini, as well as other known features, were crossed was recorded. Other required information also recorded was the DVD number, DVD title value, and direction of travel. In total, data from videolog were obtained for more than 100 rural paved primary segments in Genesee and Livingston Counties. This does not include the state maintained highways presented in Section 3 of this report. Roadside slope estimates were collected in four ranges based on the requirements of the usRAP RPS method developed for the Iowa pilot study, flat (1:6 or flatter), gentle (1:4), steep (1:3), and very steep (1:2). No estimation was made of lateral distance to ditches. Consequently, only foreslope was used in determining the RPS scores for run-off-road crashes in the Michigan pilot study.

Clear zone widths were collected in conjunction with roadside slope and were easier to determine and more reliably estimated with the video data reduction process. All other data elements were straightforward to observe from the videolog. However, the absence of distance information on the videolog made estimation of the length of linear features challenging. For linear features (e.g., presence of guardrail), a percentage of the total section length was reported. For example, if guardrail was present for approximately half of roadway segment length on the videolog, 50 percent of the section was classified as “with guardrail.” The same technique was employed to classify of the segment into the pre-defined usRAP clear zone distance, roadside slope categories. The category best
representing the segment as a whole was recorded. If the clear zone distance or slope varied along the segment, multiple categories were assigned, and the estimated proportion of the section in each category recorded.

Risk scores were assigned to all pertinent data elements acquired via database or videolog extraction. Scores were weighted, averaged, and consolidated to compute overall risk scores for the analysis sections.

For the rural paved primary highways in Genesee and Livingston Counties, video data were recorded in the field at a rate of 55 mi per day (including both directions of travel) by a two-person crew. Data were reduced from videologs at the average rate of 25 mi/hr for each direction of travel; thus, for both directions of travel combined, data collection from video was conducted at the rate of 12.5 mi/hr. The data used for RPS mapping of state roads in Genesee and Livingston Counties is summarized as:

- **Total for the rural trunkline roads in Genesee and Livingston Counties**
  - 24 segments
  - 100 mi of road
  - 0.6 billion VMT
- **Average for the rural trunkline roads in Genesee and Livingston Counties**
  - Average length = 4.2 mi
  - Average AADT = 15,887 veh/day

The data used for RPS mapping effort for rural paved primary roads in Genesee and Livingston Counties:

- **Total for rural paved primary roadways in Genesee and Livingston Counties**
  - 106 segments
  - 355 mi of road
  - 453 million VMT
- **Average for rural paved primary roadways in Genesee and Livingston Counties**
  - Average length = 3.4 mi
  - Average AADT = 3,487 veh/day

**Star Rating Maps Based on RPS Criteria**

Figures 34 and 35 present examples of star-rating maps for both the state maintained and rural primary roads in Genesee County using the EuroRAP rating methodology (converted to US customary units and a comparable star-rating map developed using the preliminary RPS criteria developed for uSRAP, respectively. Figures 36 and 37 present comparable maps for Livingston County.

Most of the roads shown on the star rating maps are two-lane roads which, in accordance with the RPS scoring criteria, are always assigned ratings of one or two stars. The Genesee County maps show as under construction several rural freeway segments which would have received ratings of three or four stars if they could have been scored.
Figure 34. Example of Star Rating Map for Genesee County Using EuroRAP RPS Criteria
Figure 35. Example of Star Rating Map for Genesee County Using Preliminary usRAP RPS Criteria
Figure 36. Example of Star Rating Map for Livingston County Using EuroRAP RPS Criteria
Figure 37. Example of Star Rating Map for Livingston County Using Preliminary usRAP RPS Criteria
Section 4.
Key Issues for usRAP Implementation

This section of the report presents key issues for usRAP implementation based on the results of the Iowa and Michigan pilot studies and looking forward for future activities. The discussion addresses risk maps, star rating maps, and public release of usRAP information. Recommendations for usRAP implementation are presented in Section 6.

4.1 Risk Maps

The pilot studies conducted to date have shown risk maps to be a useful tool for safety management of highway systems. In both the Iowa and Michigan pilot studies, the participating highway agencies have reported that the usRAP maps provide a valuable perspective on the safety performance of the highway system. It has been demonstrated that risk mapping is feasible and, indeed, relatively straightforward, for agencies whose crashes are located with latitude and longitude coordinates or tied to roadway segments that are themselves mapped in a Geographic Information System (GIS) environment. Greater challenges will be faced in risk mapping for agencies that do not have an established GIS framework for their roadway system.

The pilot studies performed for usRAP have established that the existing databases available to both the Iowa and Michigan DOTs, and to two local agencies in Michigan, are sufficient to prepare risk maps for road sections on rural state highways using all four safety measures considered by EuroRAP (referred to as Maps 1 through 4), as well as several new map types developed for usRAP. No new data, not already available to the these agencies were needed to prepare the risk maps, although efforts were needed to create longer analysis sections by combining the existing relatively short sections in state and local roadway inventory data bases.

There are a number of key issues that will need to be addressed for broader application of risk maps in usRAP. These issues are discussed below.

Road Types

It was found that rural state highways in Iowa and the rural state highways and county roads in Iowa and Michigan could be readily classified into four road types using information from available databases. These road types are: freeway; multilane divided highways; multilane undivided highways; and two-lane highways. The data elements available in roadway characteristics records that were used to make this determination included number of lanes, median type, access control, and rural/urban identifier or urban area code. If such data are not readily available for an agency considering participation in usRAP, these data elements might need to be determined from videolog review, aerial photograph review, or field visits.
Risk Measures and Types of Maps

The risk maps prepared in the pilot studies using the four key safety measures adopted by EuroRAP addressed the risk of fatal and serious injury crashes only. Reduction of these higher severity crashes is, and should be, the greatest concern in highway safety programs, so maps based on fatal and serious injury crashes can help in targeting highway safety improvements. However, the usRAP pilot studies also investigated the use of data for crashes of data for all severity levels in maps of economic losses due to crashes.

Several examples of risk maps prepared in the usRAP pilot studies have been presented earlier in this report including:

- Map 1 – crash density (see Figures 8, 9, 22, 26, and 30)
- Map 2 – crash rate (see Figures 10, 23, 27, and 31)
- Map 3 – crash rate ratio (see Figures 11, 24, 28, and 32)
- Map 4 – potential crash savings (see Figures 12, 25, 29, and 33)
- Map 5 – crash loss per mile (see Figure 13)
- Map 6 – crash loss per veh-mi of travel (see Figure 14)
- Map 7 – intersection crashes per hundred million entering vehicles (see Figure 15)
- Map 8 – intersection crashes per year (see Figure 16)

It is evident that the variety of maps developed in usRAP is needed because none of the maps, by itself, provides a complete view of the safety performance of the road system without consideration of the others. For example, a freeway section that serves high volumes of traffic may have a high crash density (crashes per mile) on Map 1, but Map 2 may confirm that the freeway has a very low overall crash rate (crashes per hundred million vehicle-miles of travel). A low-volume two-lane highway may have a high crash rate on Map 2, but Map 1 may confirm that the highway section has such a low crash frequency that there are no cost-effective improvements that would reduce that frequency. However, consideration of Maps 1 through 4, which were derived from EuroRAP maps, as well as additional map types developed specifically for usRAP, can help to identify highway sections that do provide opportunities for cost-effective improvements.

The maps prepared in the pilot study highlight the roads where crashes are most likely and least likely to occur. An important feature of both EuroRAP and this pilot study for usRAP is that Maps 1 and 2 show the overall crash density and crash rate in categories that apply across the highway system as a whole, regardless of the type of road on which the crashes occurred. This systemwide view is important to understanding the safety performance of the highway system. For example, many motorists do not appreciate that freeways, while they have the highest traffic speeds of any roadway type, are also the safest roads on which to travel. Map 2 illustrates this clearly.

Map 1, based on crash density per unit length of highway, is valuable because it shows the roads where the most crashes occur. In many cases, the roads shown as having the most crashes on Map 1 are simply the highest volume roads and may not have any
identifiable safety issues. However, the roads with the most crashes, even if they merely result from high volumes, often present good opportunities for projects that will reduce crashes in a highly cost-effective manner.

Map 2, based on crash rate per hundred million veh-mi of travel, represents the risk of a crash for individual motorists traveling through a particular roadway section. Of all the maps prepared in the pilot study, Map 2 provides the information most likely to be useful to individual motorists. The information provided by Map 2 could be used by motorists to select the lowest risk route from their origin to their destination for a specific trip and could also be useful in encouraging motorists to modify their behavior on roads where the risk of a serious crash is the greatest.

Map 3, based on the ratio of the crash rate per hundred million veh-mi of travel for a particular roadway to the average crash rate for similar roads, provides a useful tool to identify whether the crash rates for individual road sections are higher than might be expected for similar roads. Map 3 is directly useful in deciding which roadways might be candidates for detailed engineering studies to investigate crash patterns and circumstances.

Map 4, based on the potential number of crashes reduced per mile in a specified time period if the crash rate per hundred million veh-mi were reduced to the average crash rate for similar roads. Map 4 provides an important enhancement to Map 3 in that it not only identifies locations with crash rates that are higher than expected for similar roads, but also indicates the magnitude of the opportunity to reduce crashes.

usRAP has investigated additional maps types that appear to have value in understanding the safety performance of the highway system and looking for opportunities to improve safety. In particular, Maps 5 and 6 developed for the Iowa pilot study illustrate economic losses due to crashes. These maps were based on the economic losses for crashes of all severity levels, rather than just on fatal and serious injury crashes, as was the case for the other risk maps. The economic loss maps are of potential interest to highway agencies in identifying targets for future safety improvements, and may also be valuable to insurance carriers in identifying the likely overall pattern of insurance losses.

To date, EuroRAP’s risk mapping has focused exclusively on rural roadways. In the Iowa pilot study, usRAP has begun to consider how risk mapping concepts might be applied to urban and suburban locations. Intersections appear to present the greatest opportunity for safety improvement on urban and suburban roads. Maps 7 and 8 have used two risk measures and two different map formats to illustrate how risk maps for urban and suburban areas can be developed.

Risk mapping both for EuroRAP and for the Iowa pilot study focused on rural primary roads. In the Michigan pilot study, risk maps were prepared not only for state primary roads, but also for local jurisdictions, specifically including the rural county primary road systems of two counties. While state primary routes are likely to remain a focus of usRAP activity, the inclusion of both rural and urban roads and roads under local jurisdiction is desirable.
Interpretation of Risk Maps

The preceding discussion has discussed the need for multiple map types in fully understanding the safety performance of a road system and identifying opportunities for safety improvement. The need for multiple map types indicates that the interpretation of the maps is complex. A key to understanding the nature of safety on the highway system is to recognize that, while every crash occurs on some road segment, this does not imply that the design or operational characteristics of that segment are necessarily the cause of those crashes. Driver and vehicle factors contribute to the causation of many more crashes than road factors. It is also important to recognize that road types differ inherently in their safety performance. For example, because of their design features, freeways have substantially lower crash rates than other highway types, even though they operate at higher speeds. Thus, the classification of a road segment in a particular category on a particular map does not imply that the road is inherently safe or unsafe. A road segment may appear in red or black on Map 1 simply because that road has a high traffic volume with many vehicle-vehicle interactions that provide an opportunity for crashes to occur. A road segment may appear in red or black on Map 2 because it is traveled by a high proportion of impaired drivers or by a high proportion of vehicles with high rates of severe crashes, such as motorcycles. The maps prepared in the pilot study are useful, even though the crashes that occur on a given road may not be related to the design features of that road, because any concentration of crashes provides an opportunity for highway agencies and their safety partners to identify appropriate engineering, enforcement, and education strategies to reduce those crashes. A road section with a sufficient number of crashes can provide an appropriate location for implementing crash reduction strategies, even if the frequency of crashes on that road section is not unusually high given the characteristics of the road and the traffic that travels on it.

Section Lengths and Boundaries

Road sections used in risk mapping should be as long as possible to obtain reliable results. The road sections used in EuroRAP typically averaged 12 mi (20 km) in length. EuroRAP’s intention was that each road section should experience at least 20 fatal or serious injury crashes in 3 years. To obtain this desired length, EuroRAP risk maps, at times, combine road segments of contrasting road type into a single analysis section.

The usRAP pilot studies attempted to maintain a consistent road type within each analysis section. As a result, a shorter average section length of 5 mi (8 km) was obtained. To avoid shorter sections, all candidate analysis segments under 2 mi in length were reviewed; adjacent segments with the same road type but with different traffic volumes or speed limits were combined.

A major challenge in preparing the maps was the selection of analysis sections that are sufficiently long so that the data used to prepare the map provide a valid estimate of
the true risk of crashes on each section. In general, the lower the traffic volume on a roadway, the longer each analysis section should be to provide reliable overall safety performance measures. Analysis sections for the usRAP studies were made as long as feasible. However, it was also necessary to ensure that each analysis section was as homogeneous as possible with respect to road type, traffic volume, and speed. In addition, to make the maps useful in highway system management, each analysis section was required to be a continuous roadway with the same route number and within the same county. In some cases, these considerations made the lengths of some analysis sections shorter than desired.

It does not appear to be feasible to have a formal guideline for the minimum length of roadway segments for usRAP. Rather, the best guideline for usRAP appears to be that each analysis section should be as long as possible consistent with maintaining the internal homogeneity of the section.

Assignment of Crashes to Roadway Segments

The maps for this pilot study were developed using a GIS in which crashes were matched to roadway segments based on their spatial locations. There were several key challenges that had to be overcome, primarily related to determining which roadway crashes should be assigned to intersections where roadway sections meet or cross and at section boundaries where adjacent analysis sections along the same roadway join. For the maps based on three years of data in the Iowa pilot study, which were prepared before the maps with longer study periods, a relatively complex approach was used for allocating crashes at or near intersections based on the relative ADTs of the intersecting roads. A simpler approach, based on spatial proximity, that was easier to implement and appeared to produce satisfactory results, was used for the five-year maps. In future efforts for usRAP, the method for assigning/allocating crashes near intersections may be influenced by available data and prior agency decisions. The manner in which crashes at or near intersections are assigned/allocated to specific roadway sections should be determined based on three primary factors: (1) the definition of intersection crashes used by the highway agency; (2) the topographical integrity of the GIS-based roadway network to which the crashes are assigned; and (3) the availability or lack of a comprehensive intersection database applicable to all years of the analysis period.

Risk Category Definitions

For Maps 1 through 4, risk categories or risk levels were color-coded with either four or five levels, with green representing the lowest risk and black representing the highest risk. There is no single obvious rationale for how the risk categories should be assigned; ultimately such categories should be assigned in whatever manner makes the maps most useful. Initially, the same categories used in EuroRAP maps were assigned for comparative purposes. Other categorization schemes including the use of risk categories based on quintiles of the roadway system (i.e., 20 percent of roadway length in each risk
category); this approach has also been used in AusRAP. Finally, a decision was made to adjust the risk categories so that each category in increasing order of risk contained a progressively smaller portion of the roadway system and so that the highest risk category on each map includes 5 percent of roadway length. The selected risk categories and their associated colors are as follows:

- dark green (lowest risk) 40 percent of roadway length
- light green 25 percent of roadway length
- yellow 20 percent of roadway length
- red 10 percent of roadway length
- black (highest risk) 5 percent of roadway length

This approach should serve to focus attention on the roadway sections with the greatest potential for safety improvement. The highest risk category (shown in black on the various maps) should assist in meeting the new SAFETEA-LU mandate that states identify 5 percent of locations with the most severe safety needs (see Section 4.2 of this report). The roads in the highest risk category vary among the various types of maps, indicating that there are multiple considerations in deciding which road sections have the most severe safety needs.

The usRAP pilot program has used the original EuroRAP color palette described above. EuroRAP adopted a revised color palette during 2005 as follows:

<table>
<thead>
<tr>
<th>Risk category</th>
<th>Original color</th>
<th>New color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Dark green</td>
<td>Green</td>
</tr>
<tr>
<td>Low-Medium</td>
<td>Light green</td>
<td>Yellow</td>
</tr>
<tr>
<td>Medium</td>
<td>Yellow</td>
<td>Orange</td>
</tr>
<tr>
<td>Medium-High</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>High</td>
<td>Black</td>
<td>Black</td>
</tr>
</tbody>
</table>

The reasons for the change in color palette were to create a more logical progression from lighter to darker colors with increasing risk and the reduce the extent of roads colored in green on the maps to avoid the suggestion that much of the highway system was not in need of safety improvements. A decision will need to be made by usRAP as to whether to adopt the revised EuroRAP color palette in future pilot studies.

A potential goal of usRAP is to compare safety performance levels across the United States. This may require a common set of risk categories suitable for application to roadway section data from all states. The Iowa pilot study included an effort to define risk categories based on national data. This was difficult because, while nationwide data on fatal crashes are universally available from NHTSA’s FARS system, there is no comparable source of nationwide data on serious injury crashes. Therefore, the national categories used in the Iowa pilot study should be considered as tentative. A dilemma to be resolved is that maps based on national risk categories will best illustrate the relative risks to the motoring public of traveling through multiple states, while maps based on categories established individually for each state are most appropriate to meet the
requirements of SAFETEA-LU Section 1401. Further investigation of appropriate risk categories for nationwide application is needed.

**Duration of Analysis Period**

EuroRAP has generally used analysis periods of three years in duration to prepare risk maps. The usRAP Iowa pilot study began by preparing maps based on three years of data. However, due to low crash densities, maps based on five years of data were also prepared and maps based on ten years of data were investigated. Based on the Iowa experience, all maps prepared in the Michigan pilot study used five years of crash data.

A key issue with Maps 2, 3, and 4 is that on some low-volume highways the random occurrence of one or two fatal or major injury crashes can be sufficient to make the highway section appear on the map to have a high crash risk (i.e., to be colored as red or black on one or more of the maps) even where another such crash might not occur for many years. Two very similar low-volume road sections can appear in different colors on the maps just because one happened to experience one or two fatal or serious injury crashes during the study period, and the other did not. The likelihood of such misleading results can be reduced by making the analysis sections longer (which, as suggested above, may not be feasible) or by adding additional years to the period for which crash data are obtained. As noted above, the maps prepared in the pilot studies have used both three- and five-year study periods. Periods as long as ten years have been tried, but even periods as long as five years have definite disadvantages. With longer time periods, there is increased likelihood that some roadway sections may have undergone reconstruction (i.e., two-lane to four-lane conversion, or the addition of a median), increased development, increased traffic volume, or other significant changes that can affect safety. Longer study periods also increase the likelihood that other changes may have taken place during the study period, including changes in the crash report form or data, crash location and referencing processes, cartographic accuracy of the road network to which crashes are referenced or jurisdictional control of roadways (state vs. local). Addressing each such variation adds complexity to the analysis methods and/or necessitates the adoption of additional assumptions. The appropriate minimum and maximum number of years in the study period needs further investigation, but at present, a three- to five-year period appears appropriate.

Some alternative approaches to dealing with low crash densities and highly variable crash counts may need to be considered. First, it may be possible to use a hybrid approach to map development, with longer analysis periods (perhaps even as long as ten years used) for segments with extremely low expected crash counts. Second, to stabilize the crash counts and reduce the likelihood that the classification of some analysis sections results primarily from randomness in crash counts, consideration should be given to use of a Bayesian approach to estimated the expected long-term average safety performance for each analysis section. For example, the Empirical Bayes (EB) approach provides a method to combine observed crash counts, like those used to prepare Map 1, and expected crash counts, like those that serve as the implied basis for Maps 3 and 4. In the BE approach, the expected crash counts would be obtained from a Safety Performance
Function (SPF) that represents the relationship between crash frequency and traffic volume for particular road types. SPFs are normally developed with negative binomial regression analysis. An advantage of this approach is that it would eliminate the need for the assumption that crashes vary linearly with traffic volume, inherent in the computation of the average crash rates that are used to prepare Maps 3 and 4. In other words, the EB approach would provide a more reliable statistical approach to working with small crash counts and would provide more accurate estimates of expected crash frequencies for specific road types in developing Map 3. A potential disadvantage of the EB approach is that the risk category for a given roadway section would no longer be based exclusively on the actual crash experience of that roadway section.

As an interim solution to this issue, a decision was made in the Iowa and Michigan pilot studies to require that a roadway section experience more than two fatal and major injury crashes in five years before it could be placed in the medium-high (red) or high (black) risk categories. Roadway sections with low crash counts we so short or had traffic volumes so low as to have a high risk measure for any of the maps were placed in the medium (yellow) risk category.

4.2 Potential Use of usRAP Maps in Addressing the Requirements of SAFETEA-LU Section 1401

The Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was signed into law in August 2005. A provision in Section 1401 of SAFETEA-LU requires that states, as a condition for obtaining Federal funds from the Highway Safety Improvement Program (HSIP), must submit an annual report to the U.S. Secretary of Transportation describing at least 5 percent of locations with the most severe safety needs, and an assessment of remedies, costs, and other impediments to solving the problems at each location. The Secretary is required to make these reports available on the U.S. Department of Transportation web site and through other means. In addition to this report, states are also required to submit a report, according to the schedule and content established by the Secretary, describing progress on safety improvement projects, their effectiveness, and their contribution to reducing roadway-related fatalities, injuries, and crashes as well as railroad-highway crossing crashes. No procedures or criteria have yet been developed for meeting the Section 1401 requirements.

The risk maps prepared for usRAP may provide an effective tool to assist highway agencies in meeting the requirements of SAFETEA-LU Section 1401 and for this reason, the highest risk category in the pilot studies maps has been chosen to include 5 percent of roadway system length. The potential of a role for usRAP in helping to establish the criteria for highway agencies to follow in meeting the Section 1401 requirements and the potential use by highway agencies of maps prepared for usRAP, to identify the specific sites to be documented should be explored.

The usRAP risk maps may also provide an effective tool to assist highway agencies in identifying roadway sections eligible for improvement as part of the SAFETEA-LU high-risk rural roads program. This program includes roadways that are functionally
classified as rural major or minor collectors or rural local roads with a fatal and incapacitating injury crash rate above the statewide average for those functional classes of roadway or likely to experience an increase in traffic volume that leads to a crash rate in excess of the average statewide rate. A variation of usRAP Map 3 could serve as an appropriate tool to identify road sections eligible for improvement funding as part of the high-risk rural roads program. While the usRAP maps prepared to date address primarily state primary highways, the SAFETEA-LU Section 1401 requirements address all public roads. Adaptation of usRAP mapping to address all public roads will be considered in future pilot studies.

4.3 Star Rating Maps

The pilot studies conducted to date have investigated the application to U.S. conditions of the EuroRAP Road Protection Score (RPS) concept as the basis for star rating maps. This investigation has found a need for significant adaptations of the RPS concept for application in North America and a set of preliminary usRAP RPS criteria have been developed. The RPS concept has been tested in three geographical areas through the collection of data from existing highway agency data bases and from videologs of the roadway. Star rating maps have been developed for the three jurisdictions. Comparison or “overlay” maps have been developed to compare the risk maps and star rating maps and the correlation between risk levels and star ratings of specific roadways has been evaluated.

Adapting RPS Criteria to North American Conditions

A thorough review of the EuroRAP RPS scoring criteria was undertaken. First, each element of the EuroRAP scoring criteria was reviewed and compared to the results of relevant U.S. research and safety models. Second, to the extent feasible, the RPS scoring criteria were modified for greater consistency with U.S. conditions. The resulting preliminary usRAP RPS criteria are presented in Appendix A of this report.

The key issues identified in the review of the applicability of the EuroRAP RPS criteria to U.S. conditions are:

- The EuroRAP RPS criteria appear to be oriented toward crash-severity-reducing features rather than toward crash-causation features. This makes the RPS ratings insensitive to some key road safety countermeasures, such as increasing lane and shoulder widths, because these features are more related to reducing crash frequencies than crash severities.
- The EuroRAP RPS criteria show no additional benefit for widening the medians of divided highways beyond 30 ft. Recent U.S. research has found benefits of widening medians up to 70 ft in width and has found safety benefits from installation of median barriers in medians up to 70 ft in width.
- The EuroRAP RPS scores for roadside features differ from those implied by U.S. models, such as the Roadside Safety Analysis Program (RSAP)
The EuroRAP RPS scores for intersection types and turn lanes differ from the relative safety differences of those features implied by U.S. research results.

- The EuroRAP RPS scores for driveways don't differ between driveway types.
- The EuroRAP RPS scores for driveways don't differ between driveway types.
- No U.S. data are available to verify variations of RPS scores with speed.
- EuroRAP RPS weights by collision type differ from U.S. data.

Based on the review of these issues the following adaptations have been made or considered in developing preliminary usRAP RPS criteria:

- Scores for lane and shoulder widths have been added to the criteria for run-off-road crashes.
- Three new median width categories have been added:
  - 30 to 50 ft
  - 50 to 70 ft
  - 70 ft and over
- Scores for roadside features have been revised based on RSAP results.
- Scores for intersection types have been revised based on safety prediction models.
- Driveway scores have been revised to distinguish between major and minor driveways.
- No changes have been made to the proportional effects of speed on RPS score, but this remains a concern.
- Weights for collision types have been revised based on local data, separately for each state involved in usRAP pilot studies.

These adaptations to the RPS criteria, which are more fully explained in Appendix A, were based on available research results and safety models. More extensive research is needed if RPS is to be fully adapted to U.S. conditions.

**Application of RPS Criteria to Develop Star Rating Maps**

A portion of the roadway system considered in each pilot study was identified and used in a trial application of the preliminary usRAP RPS criteria. This included approximately 1,900 mi of road in Southeast Iowa; approximately 220 mi of road in Genesee County, Michigan; and approximately 220 mi of road in Livingston County, Michigan. RPS scoring was accomplished with a combination of data from existing files provided by the participating highway agencies and data obtained from review of videologs. The Iowa pilot study used existing videologs available from the Iowa Department of Transportation. For the Michigan pilot study, state and county roads in Genesee and Livingston Counties were videotaped by the research team. The videolog approach was essential to the completion of the pilot study, because the cost of field...
reviews for approximately 2,340 mi of road would have been well beyond the available resources.

The two pilot studies used similar, but not identical approaches to reducing data from the videologs, because the types of data available and not available from existing data bases differed among the participating highway agencies. The research team was generally satisfied with the quality of data obtained from the videolog review, with the exception of data on roadside slopes. The research team has concerns about whether roadside slopes can be accurately estimated by a visual process.

Star rating maps developed for the usRAP pilot studies were developed for each of the three jurisdictions using both the EuroRAP and preliminary usRAP criteria. Samples of these maps have been presented in Section 3 of this report.

**Comparison of Risk Levels and Star Ratings**

Risk levels and star ratings have been compared in two ways as part of the Iowa pilot study. First, comparison or “overlay” maps combining risk levels and star rating criteria were developed as part of the Iowa pilot study. The comparison maps were reviewed, but did not appear to provide any insights that could not be obtained from review of the separate risk and star rating maps. Several methods for developing comparison maps were tried. No recommendation has yet been made as to whether one of these methods appears to have advantages over the others.

Second, a formal statistical comparison of the risk levels and star ratings was conducted for the rural state highway system in Iowa. Figure 38 shows a bar chart of the average star rating for roads in each of the five risk levels from one version of Map 2, based on crash rate per hundred million veh-mi. The figure show that the average star rating varies only a little between star rating categories.

Figure 39 shows a log-linear regression relationship between fatal and serious injury crash rate per 100 million veh-mi and star rating. The regression model shows that crash rate decreases as star rating increases, which is a desirable indicator. However, the regression relationship, while statistically significant, has an $R^2$ value of only 0.0297, meaning that the star rating explains less than 3 percent of the variation in crash rate. This result indicates that the relationship between risk levels and star ratings is weak.

The data shown in Figures 38 and 39 are based on star ratings developed with the preliminary usRAP criteria. However, the same analysis was repeated with star ratings based on the EuroRAP RPS criteria and a similar low correlation was found. In addition, negative binomial models for crash rate were developed using three independent variables: traffic volume (ADT); section length; and star rating. Traffic volume and section length had strong relationships to crash frequency, but again the relationship of star rating to crash frequency was weak.
Figure 38. Average Star Ratings for Specific Risk Levels for Star Routes in Southeast Iowa
Figure 39. Regression Relationship Between Crash Rate and RPS Score for State Routes in Southeast Iowa
In one sense, the star rating for a roadway should not necessarily be expected to explain a large percentage of the variation in crash rates because there are many factors that affect crash rates that are not considered in the star ratings. The EuroRAP approach to star ratings considers primarily crash-severity-increasing factors, and crash causation/crash likelihood factors have been incorporated in the usRAP RPS criteria only in preliminary form. For example, crash rates are strongly affected by factors that are not considered in the usRAP star ratings, such as traffic volume and roadway horizontal alignment, and factors that are only considered in preliminary ways, such as lane width and shoulder width. Thus, the low correlation between crash rates and star ratings is in one sense expected, because of the absence of crash causation/crash likelihood factors, but in another sense calls into question the utility of the current approach to star ratings in comparison to the utility of risk maps.

4.4 Role of Risk Maps vs. Star Rating Maps

The usRAP pilot study results indicate that risk maps have a potentially valuable role in contributing to the safety management of the highway system and increasing public understanding of safety levels on the roadway system and public support for further safety investment. A number of issues still need to be resolved to formalize and standardize the preparation of risk maps for usRAP, but the potential for this approach to gain broad acceptance appears substantial.

By contrast, the results to date do not indicate great utility for star ratings based on RPS criteria, at least as currently constituted. The concept of star ratings is potentially attractive as a means to rate the safety of a roadway system without need for crash data or to explain the observed differences in risk levels. However, the lack of correlation between risk levels and star ratings does not bode well for broad acceptance of RPS in its current form by the safety community. The primary concerns about RPS can be characterized as follows:

- If risk maps are available, why is RPS needed?
- If risk maps are not available, is RPS a good substitute given its lack of correlation with risk levels?

The concerns about the utility of RPS in its current form is especially great given the substantial cost of collecting the data needed to apply the RPS criteria.

Based on the information assembled in this pilot study, it appears that one of two courses of action should be undertaken with respect to RPS criteria and star ratings:

- Drop or deemphasize the use of RPS in usRAP and focus on the development and application of risk maps.
- Undertake a major research program to further develop RPS for application to U.S. conditions with a sound theoretical and empirical basis. In other words, to
gain acceptance, RPS must be both consistent with our theoretical understanding of safety principles and well-grounded in research with actual crash data or with safety models that are themselves derived from actual crash data.

These options are not necessarily mutually exclusive. The first option could be pursued in parallel with research to implement the second option. However, the application of current RPS criteria in the U.S. without further research is not recommended.

Where risk mapping is not feasible, because of unavailable, incomplete, or poorly located crash data, as might be the case in many developing countries, RPS scoring and star ratings maps may provide the only available approach to assessing highway safety improvement needs. Improved RPS criteria that consider both crash likelihood and crash-severity-increasing factors would be desirable.

4.5 Public Release of usRAP Risk Maps and Related Information

usRAP risk maps have the potential to assist highway agencies in managing the safety of their highway systems and increasing public understanding of safety levels on the roadway system and public support for further safety investment. The goal of improving safety management of the highway system can potentially be achieved through a partnership between usRAP and various highway agencies. The goal of increasing public understanding and support for highway safety investment inherently requires some release of usRAP maps and related information to the public although only some of the maps prepared for internal use may be appropriate for public use. In general, the presentation of crash rates per hundred million veh-mi on Map 2 is thought to provide the most appropriate map for public release.

Another purpose of EuroRAP in providing risk maps and related information to the public is to influence motorist route choice to emphasize use of routes with the lowest risk and to influence motorist’s driving behavior on roads with higher risk. Preliminary discussions with usRAP participants have indicated less interest in this goal than in promoting public support for highway safety investments. The goal of influencing motorist route choice from a safety standpoint may also be accomplished, at least in part, by public education not dependent on the release of maps, such as by calling attention the role of freeways as the safest part of the roadway system.

The usRAP approach to public release of risk maps will need to be developed in close consultation with the participating highway agencies. Two major highway agency concerns must be addressed. First, any use of usRAP risk maps must be arranged so as not to increase the tort liability exposure of highway agencies, which is a major concern of state and local agencies in the U.S. This concern may, in part, be lessened by the new requirement in SAFETEA-LU Section 1401 that highway agencies identify at least 5 percent of their roadway system with the most severe safety needs. Given this requirement, some highway agencies may see usRAP as an effective program for developing and releasing such information in a consistent, thoughtful, and well-documented way. Second, any use of usRAP risk maps must avoid creating negative
media coverage for highway agencies. Rather, usRAP and highway agencies should work together to create positive media coverage, emphasizing success in improving safety on the highway system.

The Iowa and Michigan pilot studies are helping to address issues related to public release of selected usRAP maps. Public information strategies for the usRAP pilot studies will be developed in consultation with the top management of both the Iowa and Michigan Departments of Transportation and should present the Iowa and Michigan results in a national perspective. There is a need for additional pilot studies so that these issues can be addressed comprehensively with a broad range of highway agencies. usRAP risk maps and related information has the potential to begin a new and unprecedented level of state and national dialogue on highway safety needs, but the methods for accomplishing this objective must be developed in close consultation with the participating highway agencies.
Section 5.
Recommendations for usRAP Implementation

The recommendations for further usRAP implementation developed in this pilot program are as follows:

1. The Iowa and Michigan pilot studies have indicated that a road assessment program can provide develop and present valuable information for use by highway agencies. These pilot studies indicate that the usRAP concept, based on EuroRAP and AusRAP, is technically feasible and can be implemented with data available to U.S. highway agencies.

2. The communications aspects of road assessment programs need to be tested before a decision is made for broad implementation of usRAP. A communications strategy for providing usRAP results in a form that is potentially useful to the motoring public should be developed. usRAP should work cooperatively with participating highway agencies on public release of risk maps and related information and on using the risk maps to help guide safety improvement priorities.

3. Further work should be performed with Iowa and Michigan to develop and test a performance tracking protocol for usRAP. Performance tracking will involve obtaining at least one additional year of data, revising the Iowa and Michigan maps to incorporate that additional year of data, and tracking the changes in risk categories for particular roadway segments. The objective of performance tracking is to identify and document roadway segments on which highway agency action has improved roadway safety and reduced risk levels and to identify and document, as candidates for future highway agency action, roadway segments on which the risk level has remained high or increased.

4. Pilot studies should be performed in additional states both to further test the usRAP concepts and to involve more highway agencies in working with usRAP.

5. The usRAP protocol for risk mapping to illustrate sites that constitute the 5 percent of sites with greatest safety needs based on a set of risk measures has been accepted by the usRAP technical advisory panel. The protocol employs a relative assessment of roadway segments that fall in risk categories that represent, in increasing order of risk, 40, 25, 20, 10, and 5 percent of the road system. The relative risk categories are very appropriate for applying the usRAP concept within individual states and could assist states in meeting the new SAFETEA-LU mandate for states to identify 5 percent of sites with the most severe safety needs.

6. A variation of usRAP Map 3 could be used by highway agencies to identify roadways eligible for improvement as part of the SAFETEA-LU high-risk rural roads program. This program includes roadways that are functionally classified as rural major or minor collectors or rural local roads with a fatal and incapacitating injury crash rate above the statewide average for those functional
classes of roadway or likely to experience an increase in traffic volume that leads to a crash rate in excess of the average statewide rate.

7. Further development is needed for a set of national risk categories that could be employed that could be used in usRAP to compare risks across the United States. The development of national risk categories is challenging because, while there is consistent nationwide data on fatal crashes, there is no consistent nationwide data on serious injury crashes.

8. The pilot studies in additional states should focus on risk mapping of rural primary road systems. Further consideration should be given to how usRAP should address risk mapping for rural secondary and local roads, urban roads, and urban intersections.

9. Rural roadway segments in the United States generally have lower traffic volumes than similar roads in more densely populated European countries and U.S. roads Therefore experience lower crash densities. Minimum segment lengths that would be expected to experience an average of 20 fatal and serious injury crashes in 3 years would be too long to be of practical use in many U.S. jurisdictions. Further research is needed to consider the best combination of minimum segment length, minimum study period duration, and minimum number of fatal and serious injury crashes per segment for use in usRAP. Interim criteria have been established so that roadway segments that have experienced only one or two crashes as not classified as red or black on risk maps. These interim criteria should be reviewed, and revised as appropriate, in future usRAP pilot studies.

10. Investigation is needed into how best to apply usRAP risk mapping concepts to states whose roadway and crash data are not already in Geographic Information System (GIS) format.

11. usRAP risk maps have been prepared using the original EuroRAP color palette, in which increasing risk categories are represented by dark green, light green, yellow, red, and black on maps. EuroRAP has adopted a revised color palette in which increasing risk categories on maps are represented by green, yellow, orange, red, and black.

12. The star rating or Road Protection Score (RPS) concept needs further development before it can be successfully implemented in the U.S. AusRAP has extensively adapted the EuroRAP RPS concept for implementation in Australia. A substantial research effort would be needed for adapt the RPS concept for implementation in the United States. The preliminary RPS criteria presented in Appendix A of this report should be regarded as interim guidelines in need for further research and development. Highway agencies in the U.S. appear reluctant to implement the RPS concept, especially since the concept is not fully developed, when risk maps based on actual crash data can be prepared. The RPS concept might be considered for application by highway agencies whose crash and roadway data cannot be effectively linked or in developing countries where crash and roadway data are not available. Until further research on RPS criteria
can be conducted, it is recommended that future USRAP pilot studies focus on mapping of risk levels.

13. The key issues in research to further develop the star rating or RPS concept should include:
   - Developing a better tie between the RPS methodology and the results of North American safety research
   - Including RPS criteria based on crash likelihood reduction as well as crash severity reduction
   - Developing practical methods for including vulnerable road users, such as pedestrians and bicyclists, in the RPS methodology
   - Demonstrating a relationship between the results of the RPS methodology and actual crash data

14. The USRAP technical advisory panel should continue to play a key role in monitoring additional pilot studies that are conducted. A representative from each new state that agrees to participate in a USRAP pilot study should be invited to serve on the technical advisory panel.

15. USRAP should continue to work cooperatively with EuroRAP and AusRAP on development of the RAP concept through the iRAP umbrella organization. Cooperative efforts should include application of ideas from other RAP programs in North America and adaptation of RAP concepts for application in developing countries.
Section 6. 
Next Steps

The logical next step for usRAP is the conduct of a second-stage pilot program in which we continue to work with Iowa and Michigan and initiate new pilot study efforts in other states. Bringing more states into the program should create a strong base for eventual full implementation of usRAP.

The activities that are potentially planned for usRAP in 2006 are:

- Development of usRAP brochure
- Technical paper or article on usRAP
- Presentations at technical meetings or conferences
- Publication of the usRAP pilot program report
- Investigation of the most appropriate and effective information that should be made available to the motoring public
- Planning for ongoing partnership with Iowa and Michigan
- Additional pilot studies to bring more states into usRAP

These potential activities will be finalized in consultation with AAAFTS and the usRAP technical advisory panel.
Appendix A—Preliminary RPS Scoring Criteria for usRAP

RPS scoring criteria for use in the usRAP Iowa and Michigan pilot studies have been developed from comparable EuroRAP criteria with adaptations for U.S. conditions based on available research results and safety prediction models. The scoring criteria are presented in Tables A-1 through A-4. These criteria are very preliminary. Development of RPS criteria that are consistent with U.S. safety research and with safety performance data for U.S. roads will be a major research task.

The structure of the scoring criteria is similar to EuroRAP. Relative risk scores are determined for the most common types of crashes on rural highways:

- Head-on crashes
- Run-off-road crashes
- Intersection crashes

EuroRAP is also considering extending RPS scoring to include facilities for vulnerable road users (e.g., pedestrians and bicyclists), but has not yet done so because of a lack of data on the volumes of vulnerable road users on specific road sections. Volume data for vulnerable road users are also unavailable for rural highways in Michigan. Furthermore, data for rural state highways in Michigan show that vulnerable road users are involved in only about 1 percent of fatal and serious injury crashes. Thus, the limitation of RPS scoring to head-on, run-off-road, and intersection crashes appears reasonable at present.

Scoring for each of the crash type categories is explained below, followed by recommended weights for combining the three categories. Finally, computational procedures for RPS scoring and the determination of star ratings are presented. The computational procedures follow those used in EuroRAP, except in instances identified below where more appropriate procedures for U.S. application were developed. Where the computational procedures used in EuroRAP were not explicitly stated in the available documentation, appropriate procedures have been devised.

**Scoring for Head-on Crashes**

Scoring criteria for head-on crashes have been adapted from EuroRAP. The relative risk scores shown in Table A-1 have been modified from the EuroRAP RPS criteria by replacing the median width category of 30 ft (10 m) or more with three categories:

- 30 to 49.9 ft
- 50 to 69.9 ft
- 70 ft or more
### Table 6. Preliminary Relative Risk Scores and Star Rating Criteria for Head-On Crashes

#### Relative Risk Scores

<table>
<thead>
<tr>
<th>Median treatment</th>
<th>85th percentile or posted speed (mph)</th>
<th>Relative Risk Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70</td>
<td>65</td>
</tr>
<tr>
<td>Median width 70 ft or more</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Median width 50 to 69.9 ft</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Median barrier</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Median width 30 to 49.9 ft</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Median width 12 to 29.9 ft</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Median width 3 to 11.9 ft</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>Undivided with centerline rumble strips</td>
<td>27</td>
<td>20</td>
</tr>
<tr>
<td>Undivided with marked centerline only</td>
<td>38</td>
<td>28</td>
</tr>
</tbody>
</table>

#### Star Rating Criteria

<table>
<thead>
<tr>
<th>Number of Stars</th>
<th>Head-on Risk Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0 - 2</td>
</tr>
<tr>
<td>3</td>
<td>2.01 - 5</td>
</tr>
<tr>
<td>2</td>
<td>5.01 - 10</td>
</tr>
<tr>
<td>1</td>
<td>over 10</td>
</tr>
</tbody>
</table>
These additional categories have been added because the AASHTO Roadside Design Guide (2002) indicates that a median barrier may be used in the 30 to 49.9 ft range, and recent research in California (Nystrom, et al., 1997) has found that the use of median barrier is warranted for median widths up to 50 ft. Recent research in North Carolina (Lynch, 1998) has found that cable barrier may be warranted in median up to 70 ft in width. For consistency with EuroRAP, the relative risk score of 1.0 has been retained for median widths in the 30 to 49.9 ft range. Relative risk scores of 0.8 and 0.6 scores for median widths in the range from 50 to 69.9 ft and 70 ft or more, respectively, were chose based on safety prediction models for median width from recent Pennsylvania research (Donnell et al., 2002). The relative risk score for median barrier was set equal to the relative risk score for a 0 to 69.9 ft median, based on the California research results. All other relative risk scores for head-on crashes in Table A-1 were taken directly from EuroRAP, with a conversion of the speed categories from metric to U.S. customary units.

The star rating criteria for head-on crashes shown in Table D-1 have been adapted to correspond appropriately to the relative risk scores for head-on crashes.

**Scoring for Run-Off-Road Crashes**

Scoring criteria for run-off-road crashes shown in Table A-2 are a proposed replacement for the EuroRAP scoring criteria that are better suited to U.S. conditions. The relative risk scores for specific combinations of clear zone width, roadside slope, direction of slope, presence of guardrail, and speed were developed using the Roadside Safety Analysis Program (RSAP) (AASHTO, 2002). While the RSAP program has limitations, the resulting relative risk scores based on RSAP’s crash severity cost estimates represent the best available estimates for U.S. conditions.

The effects on safety of lane width and shoulder width are not directly accounted for in the EuroRAP RPS criteria. These factors have been added to the preliminary usRAP criteria because there is strong evidence that lane width and shoulder width directly affect the frequency with which vehicles encroach on the roadside beyond the edge of the shoulder. The adjustment factors for lane and shoulder width are those used in the FHWA Interactive Highway Safety Design Model (IHSDM) (Harwood et al., 2000). These adjustments were developed for rural two-lane highways, but are applied here for all roadway types because no factors appropriate to other specific road types are available. The IHSDM adjustments were developed for application to single-vehicle run-off-road, multiple-vehicle same-direction sideswipe, and multiple-vehicle opposite-direction collisions; however, data for rural roads indicate that run-off-road collisions are the predominant collision type in these categories.

The star rating criteria for run-off-road crashes shown in Table A-2 have been adapted to correspond appropriately to the relative risk scores for run-off-road crashes.
## Table 7. Relative Risk Scores and Star Rating Criteria for Run-Off-Road Crashes

### Relative Risk Scores

<table>
<thead>
<tr>
<th>Clear Zone Width</th>
<th>Roadside Slope</th>
<th>Dirn of Slope</th>
<th>85th percentile speed or posted speed (mph)</th>
<th>Relative Risk Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>70</td>
<td>65</td>
</tr>
<tr>
<td>FILL SECTIONS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 ft or more</td>
<td>1:6</td>
<td>Down</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>30 ft or more</td>
<td>1:4</td>
<td>Down</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>30 ft or more</td>
<td>1:3</td>
<td>Down</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>30 ft or more</td>
<td>1:2</td>
<td>Down</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td>12 to 29.9 ft</td>
<td>1:6</td>
<td>Down</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>12 to 29.9 ft</td>
<td>1:4</td>
<td>Down</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>12 to 29.9 ft</td>
<td>1:3</td>
<td>Down</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>12 to 29.9 ft</td>
<td>1:2</td>
<td>Down</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td>3 to 11.9 ft</td>
<td>1:6</td>
<td>Down</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>3 to 11.9 ft</td>
<td>1:4</td>
<td>Down</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>3 to 11.9 ft</td>
<td>1:3</td>
<td>Down</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>3 to 11.9 ft</td>
<td>1:2</td>
<td>Down</td>
<td>27</td>
<td>24</td>
</tr>
<tr>
<td>0 to 2.9 ft</td>
<td>1:6</td>
<td>Down</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>0 to 2.9 ft</td>
<td>1:4</td>
<td>Down</td>
<td>19</td>
<td>17</td>
</tr>
<tr>
<td>0 to 2.9 ft</td>
<td>1:3</td>
<td>Down</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td>0 to 2.9 ft</td>
<td>1:2</td>
<td>Down</td>
<td>29</td>
<td>26</td>
</tr>
<tr>
<td>SECTIONS WITH GUARDRAIL</td>
<td>N/A</td>
<td>N/A</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>CUT SECTIONS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 ft or more</td>
<td>1:6</td>
<td>Up</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>30 ft or more</td>
<td>1:4</td>
<td>Up</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>30 ft or more</td>
<td>1:3</td>
<td>Up</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>30 ft or more</td>
<td>1:2</td>
<td>Up</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>12 to 29.9 ft</td>
<td>1:6</td>
<td>Up</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>12 to 29.9 ft</td>
<td>1:4</td>
<td>Up</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>12 to 29.9 ft</td>
<td>1:3</td>
<td>Up</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>12 to 29.9 ft</td>
<td>1:2</td>
<td>Up</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>3 to 11.9 ft</td>
<td>1:6</td>
<td>Up</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>3 to 11.9 ft</td>
<td>1:4</td>
<td>Up</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>3 to 11.9 ft</td>
<td>1:3</td>
<td>Up</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>3 to 11.9 ft</td>
<td>1:2</td>
<td>Up</td>
<td>11</td>
<td>10</td>
</tr>
</tbody>
</table>
Table 7. Relative Risk Scores and Star Rating Criteria for Run-Off-Road Crashes (Continued)

<table>
<thead>
<tr>
<th>Configuration</th>
<th>85th percentile speed or posted speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70</td>
</tr>
<tr>
<td>Clear Zone Width</td>
<td></td>
</tr>
<tr>
<td>Width</td>
<td></td>
</tr>
<tr>
<td>0 to 2.9 ft</td>
<td>1:6</td>
</tr>
<tr>
<td>0 to 2.9 ft</td>
<td>1:4</td>
</tr>
<tr>
<td>0 to 2.9 ft</td>
<td>1:3</td>
</tr>
<tr>
<td>0 to 2.9 ft</td>
<td>1:2</td>
</tr>
</tbody>
</table>

LANE AND SHOULDER WIDTH ADJUSTMENT FACTORS

<table>
<thead>
<tr>
<th>Lane Width</th>
<th>Adjustment Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 ft or more</td>
<td>1.00</td>
</tr>
<tr>
<td>11 ft</td>
<td>1.05</td>
</tr>
<tr>
<td>10 ft</td>
<td>1.30</td>
</tr>
<tr>
<td>9 ft or less</td>
<td>1.50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shoulder Width</th>
<th>Adjustment Factors for Specific Shoulder Types</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Paved</td>
</tr>
<tr>
<td>0 ft</td>
<td>1.00</td>
</tr>
<tr>
<td>2 ft</td>
<td>0.87</td>
</tr>
<tr>
<td>4 ft</td>
<td>0.77</td>
</tr>
<tr>
<td>6 ft</td>
<td>0.67</td>
</tr>
<tr>
<td>8 ft or more</td>
<td>0.58</td>
</tr>
</tbody>
</table>

Star Rating Criteria for Run-off-Road Crashes

<table>
<thead>
<tr>
<th>Number of Stars</th>
<th>Run-off-road Risk Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0 - 5</td>
</tr>
<tr>
<td>3</td>
<td>5.01 - 10</td>
</tr>
<tr>
<td>2</td>
<td>10.01 - 15</td>
</tr>
<tr>
<td>1</td>
<td>over 15</td>
</tr>
</tbody>
</table>
Scoring for Intersection Crashes

Scoring criteria for intersection crashes shown in Table A-3 are adapted from the corresponding EuroRAP RPS criteria using available U.S. crash prediction models and research results. The relative risk scores for merging maneuvers and roundabouts were adapted from the EuroRAP RPS criteria with a conversion of the corresponding speeds from metric to U.S. customary units.

Relative risk scores were estimated for four types of intersections using tentative safety performance functions (SPFs) for intersections developed for use in the FHWA Safety Analyst interim software tools (Harwood et al., 2004). The four types of intersections considered are:

- rural three-leg unsignalized intersections
- rural three-leg signalized intersections
- rural four-leg unsignalized intersections
- rural four-leg signalized intersections

The effect on safety of providing turn lanes at rural unsignalized intersections were based on accident modification factors (AMFs) for fatal-and-injury crashes developed for addition of left-turn lanes in recent FHWA research (Harwood et al., 2003). The effect of adding turn lanes at rural signalized intersections was estimated to be 50 percent of the effectiveness of adding turn lanes at unsignalized intersections, based on a judgment by the research team. The EuroRAP RPS criteria focused on right-turn lanes at intersections. U.S. research has found higher safety effectiveness from installation of left-turn lanes than from installation of right-turn lanes. Field data have been collected for both left- and right-turn lanes and, for the present, it is recommended that the relative risk scores for intersections with turn lanes be applied to any intersection with either left- or right-turn lanes on the road being evaluated.

There are no U.S. data concerning the relative safety performance of intersections on highways with differing speeds. Therefore, the intersection scores in Table A-3 vary among speed categories in proportion to the corresponding values for the EuroRAP RPS criteria. Further U.S. research on this issue would be desirable.

Relative risk scores for major and minor driveways have been added to the table. The EuroRAP RPS criteria recommended that driveways be counted and be given the weight equal to 30 percent of the weight for a three-leg intersection. The preliminary usRAP criteria include separate categories for two types of driveways:

- minor driveways—driveways that provide access to single- or double-family residences, or field entrances
- major driveways—all other types of driveways, including multi-family residences, and commercial, industrial, and institutional sites
Table 8. Relative Risk Scores and Star Rating Criteria for Intersection Crashes

<table>
<thead>
<tr>
<th>Relative Risk Scores</th>
<th>85th percentile speed or posted speed (mph)</th>
<th>Relative Risk Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction type</td>
<td>70</td>
<td>65</td>
</tr>
<tr>
<td>Minor driveway (unsignalized)</td>
<td>0.50</td>
<td>0.25</td>
</tr>
<tr>
<td>Major driveway (unsignalized)</td>
<td>2.00</td>
<td>1.75</td>
</tr>
<tr>
<td>Merging maneuver only; long acceleration lane</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Roundabout, low speed</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Roundabout, high speed</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Merging maneuver only; short acceleration lane</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Three-leg unsignalized intersection with turn lanes</td>
<td>2.00</td>
<td>1.75</td>
</tr>
<tr>
<td>Three-leg unsignalized intersection without turn lanes</td>
<td>4.25</td>
<td>3.75</td>
</tr>
<tr>
<td>Three-leg signalized intersection with turn lanes</td>
<td>8.25</td>
<td>6.75</td>
</tr>
<tr>
<td>Three-leg signalized intersection without turn lanes</td>
<td>10.75</td>
<td>8.75</td>
</tr>
<tr>
<td>Four-leg unsignalized intersection with turn lanes</td>
<td>6.75</td>
<td>5.25</td>
</tr>
<tr>
<td>Four-leg unsignalized intersection without turn lanes</td>
<td>10.25</td>
<td>8.00</td>
</tr>
<tr>
<td>Four-leg signalized intersection with turn lanes</td>
<td>17.75</td>
<td>14.50</td>
</tr>
<tr>
<td>Four-leg signalized intersection without turn lanes</td>
<td>21.50</td>
<td>17.50</td>
</tr>
</tbody>
</table>

Sum relative risk scores for all junctions within the highway section and divided by the length of the section in miles.

Star Rating Criteria

<table>
<thead>
<tr>
<th>Number of Stars</th>
<th>Total relative risk score per mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0 - 5</td>
</tr>
<tr>
<td>3</td>
<td>5.01 - 10</td>
</tr>
<tr>
<td>2</td>
<td>10.01 - 15</td>
</tr>
<tr>
<td>1</td>
<td>over 15</td>
</tr>
</tbody>
</table>
Major and minor driveways have been assigned scores equal to 50 percent and 10 percent of the score for a three-leg unsignalized intersection, respectively. The driveway categories apply only to unsignalized driveways. Signalized driveways are treated as signalized intersections for purposes of RPS scoring.

EuroRAP appears to use a weighted-average of the scores for all intersections within a given roadway section. This approach does not appear satisfactory because it is not sensitive to section length (i.e., five intersections within a 2-mi section should score better than the same five intersections location within a 1-mi section). A preliminary procedure has been developed for application in usRAP that involves summing the relative risk scores for all driveways, acceleration lanes, roundabouts, and intersections with a roadway section and then dividing by the length of the roadway section in miles.

The star rating criteria for intersection crashes shown in Table A-3 have been adapted to correspond appropriately to the relative risk scores for intersection crashes.

Weights for Combining Star Rating Categories

Table A-4 shows the weights used for combining star rating categories in the Michigan pilot study. These weights—head-on crashes (15 percent), run-off-road crashes (19 percent), and intersection crashes (66 percent)—are based on the relative frequency of these types of crashes on rural state highways in Michigan. These weights used in the Michigan pilot study are about the same as EuroRAP for head-on crashes, substantially lower for run-off-road crashes, and substantially higher for intersection crashes.

<table>
<thead>
<tr>
<th>Table 9. Category Weights for usRAP RPS Scoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPS category</td>
</tr>
<tr>
<td>-------------------------</td>
</tr>
<tr>
<td>Head-on crashes</td>
</tr>
<tr>
<td>Run-off-road crashes</td>
</tr>
<tr>
<td>Intersection crashes</td>
</tr>
</tbody>
</table>

**NOTE:** Weights based on crash frequencies for rural state highways in Michigan.

Computational Procedure for Determining Star Ratings

The star rating for a roadway section is determined as follows:

*Head-on Crashes*

1. Determine the median treatment and speed for a roadway section or for individual subsections of a roadway section.
2. Determine the risk score for the section based on median treatment and speed using Table A-1. If the median treatment or speed varies among subsections, determine a weighted-average risk score for the roadway section.

3. Based on the weighted relative risk score for the section as a whole, determine the star rating (1, 2, 3, or 4) using the criteria in Table A-1.

*Run-off-Road Crashes*

4. Determine the roadside configuration and speed for a roadway section or for individual subsections of a roadway section. Roadside configuration is based on clear zone width, roadside slope, direction of slope (down or up), and presence of guardrail.

5. Determine the relative risk score for the section based on roadside configuration and speed based on Table A-2. If the roadside configuration or speed varies among subsections, determine weighted-average risk score for the roadway section.

6. Adjust the risk score based on lane width and shoulder width using the factors in Table A-2.

7. Based on the adjusted relative risk score for the section as a whole, determine the star rating (1, 2, 3, or 4) using the criteria in Table A-2.

*Intersection Crashes*

8. Determine the junction type and speed for each driveway, acceleration lane, roundabout, and intersection on the roadway section.

9. Determine the relative risk score from Table A-3 for each junction on the section.

10. Sum the relative risk scores for all junctions and divide by the roadway section length in miles.

11. Based on the total relative risk score per mile, determine the star rating (1, 2, 3, or 4) using the criteria in Table A-3.

*Overall Star Rating*

12. Determine the overall star rating as a weighted average of the individual star ratings for head-on, run-off-road, and intersection crashes using the weights shown in Table A-4.

13. To get the overall star rating, round the weighted average star rating to the nearest integer.
Closure

The usRAP RPS rating criteria presented here are preliminary and will undoubtedly be modified as the pilot studies proceed. If usRAP goes forward to full implementation with RPS as a key element, a key first step may be a research project devoted specifically to formally calibrating RPS scoring criteria for U.S. conditions using U.S. crash data and/or predictive models more extensively than has been possible to date.

References


usRAP is a road safety program of the AAA Foundation for Traffic Safety and is affiliated with iRAP—the International Road Assessment Program, along with EuroRAP—the European Road Assessment Program and AusRAP—the Australian Road Assessment Program.