

Cost Effective Local Road Safety Planning and Implementation



Introduction

According to the Bureau of Transportation Statistics, local roads (i.e. county and small rural community roads) comprise approximately 6,099,428 miles of the United States highway network as of 2009.¹ Figures from the National Highway Traffic Safety Administration for 2008 indicate that there were 18,762 fatal crashes on rural roads, comprising 55 percent of such crashes on United States roadways for that year.² The corresponding fatality rate per 100 million vehicle miles traveled on rural roads was 2.11, compared to 0.81 for urban roads. While these figures have been dropping in recent years, they indicate that much work remains to be done in improving the safety of U.S. roads, and local roads in particular.

Working to improve the safety on local roads can be a challenge for officials, particularly those faced with limited staff and financial resources. The extensive depth and breadth of information pertaining to safety analysis and treatments can be daunting to these officials, particularly when they are tasked with a variety of other daily duties. These officials may know a safety problem exists at a given highway location (ex. a high number of crashes occurring at a particular site), but the time to identify and assess the available solutions to address that problem is not necessarily available. Furthermore, conveying both the problem and potential solutions to non-engineers (elected officials, the general public), can also be a challenge. Finally, identifying and obtaining funding for potential safety improvements can be difficult. Consequently, there is a need for a general guide which local officials can utilize to identify and quantify existing safety issues, identify potential solutions to those issues, and identifying potential state and local partnerships to fund them.

The American Traffic Safety Services Association (ATSSA) and the National Association of County Engineers (NACE) have partnered to develop such a guide for local officials that will serve as an easy-to-read resource and reference on roadway infrastructure safety. This publication, *Cost Effective Local Road Safety Planning and Implementation*, is the result of that partnership. The focus of this work has been on local roads (i.e. county and smaller rural community roads), but the approaches and solutions presented are often just as transferable to urban areas. Of course, engineering judgment should be used in all cases when employing the material presented in this document.

The information provided in this document is not only for reference, it is also intended to aid in implementation. By identifying where issues exist and implementing low cost safety solutions, a jurisdiction can contribute to the overall improvement of safety of the roadway network from the local level. It is hoped that the approaches and countermeasures presented in this document are sufficiently low cost so that they can be considered by local jurisdictions regardless of the level of funding that may be available.

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- ² National Highway Traffic Safety Administration. "Rural/Urban Comparison". United States Department of Transportation, Washington, D.C., 2009. Available at: <http://www-nrd.nhtsa.dot.gov/Pubs/811164.pdf>



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Part 1: Analyzing and Planning



Locally owned roads comprise over 3 million miles, or 76 percent of the highway network in the United States.¹ The fatality rate from crashes along these roads is disproportionately higher than it is on their urban counterparts. Consequently, there is a need to dramatically improve safety along these roadways by all available means. Toward Zero Deaths (TZD), an effort to develop a national approach to eliminating highway fatalities, is seeking to address fatal crashes from a variety of perspectives, including engineering. This document provides an overview of approaches and countermeasures that can be employed to identify and make low cost safety improvements to local roads toward achieving this national goal.

Before safety can be improved along a roadway, the problem(s) itself must first be identified and understood. For a local entity faced with limited budgets and staffing, knowing where to begin when addressing safety can be daunting. In light of this, Part 1 of this document has been developed to provide information and approaches on how to examine and address highway safety from a number of different perspectives. The sections provide an overview of how a crash study can be conducted, as well as what crash data is and how it can be used in making safety investments. An alternative discussion of making a safety investment without the use of crash data using a risk-based approach is also provided. In line with the analysis of crash data, the Highway Safety Manual (HSM) is discussed, providing the reader with an alternative tool for evaluating various aspects of safety.

In addition to the reactive approach to safety, proactive approaches are also discussed, namely Road Safety Audits (RSA). RSAs are formal safety performance examination of an existing or planned roadway segment or intersection by an independent audit team that qualitatively estimates and reports on potential road safety issues and identifies opportunities for safety improvements. They seek to identify potential or existing issues before they result in crashes and have shown useful in defending tort liability.

Finally, county wide safety plans and rural road safety programs are outlined. County wide safety plans identify high-priority safety projects, both proactively and reactively. This allows a county to identify and document safety concerns they wish to emphasize and address, select appropriate countermeasures to address them, and prioritize specific projects, locations or elements that will be addressed. In completing a county wide safety plan, a county will not only better understand what its safety issues are and how to address them, but also begin to position itself for pursuing funding opportunities to improve safety. Rural road safety programs establish where safety problems exist and identify appropriate, typically low cost countermeasures to address those problems. The approaches employed may range from simple, examining crash data and conducting field audits, to complex, examining crash data, conducting field evaluations, ranking locations by risk and conducting cost-benefit analysis of each identified project or countermeasure. [n](#)

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COST EFFECTIVE LOCAL ROAD SAFETY PLANNING AND IMPLEMENTATION

Conducting a Crash Study

Identifying Where Safety Issues Exist and Their Causes

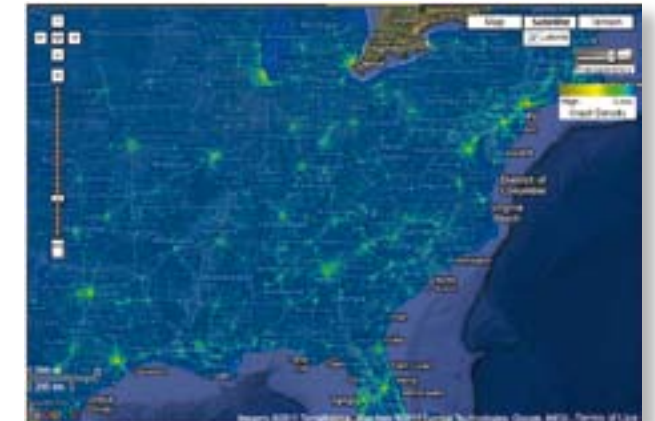
Local roads comprise a majority of the total highway mileage in the United States. Most of these roads carry lower traffic volumes and possess decades-old design features. As a result, these roads present a number of safety issues. A previous ATSSA/NACE publication, entitled *Low Cost Local Road Safety Solutions*, cited three basic causes for rural road safety issues, including 1) inadequate roadway geometry (e.g. width, grades, alignment, sight distance), 2) lack of passing opportunities due to either limited sight distance of heavy oncoming traffic, and 3) traffic conflicts due to turns at access points (e.g. intersections and driveways^{1, 2}). Widening, realigning or completing other extensive reconstruction activities on a roadway to address a safety issue is typically not financially feasible; as a result, it is necessary to identify low cost safety improvements to address issues.

In order to identify proper solutions to a safety issue, that issue must initially be identified and understood. To do so, crash studies are necessary. As noted by different reports crash studies are generally comprised of six steps: 1) identify sites with potential safety issues, 2) characterize crash experience, 3) characterize field conditions, 4) identify contributing factors and potential countermeasures, 5) assess countermeasures and select the most appropriate, and 6) implement the countermeasures and evaluate their effectiveness.^{3, 4} In addition, application of the Highway Safety Manual (HSM) to identify safety issues and estimate the potential crash reductions of different countermeasures should also be considered.

Identify Sites with Potential Safety Issues

The initial step in a crash study is to identify where a safety issue(s) may exist. A number of different approaches can be used in completing this step, both formal and informal. These include examining crash data (e.g. identifying accident clusters or high crash sites), traffic studies (spot speed studies, etc.), on-site observation, citizen and law enforcement input and surrogate measures (traffic conflicts at intersections, brake light observations, etc.).^{3, 4} Each of these approaches has its benefits and drawbacks which must be carefully considered by a practitioner when selecting them. In most states, crash data is readily available from transportation departments by request and therefore, the most commonly used approach to identifying a safety issue. Additionally, crash data is available from sources such as the Fatality Analysis Reporting System (FARS) easily accessed via the Center for Excellence in Rural Safety's (CERS) Safe Road Maps tool.^{5, 6}

Crashes are random events and consequently, can occur at any location along the roadway. However, geometric, traffic and other features may lend themselves toward more crashes happening in spot locations. As a result, identifying such "clusters" of crashes is the most simplistic approach to identifying a site-specific crash issue. Another applicable method is to identify the top nth number of locations with crash problems. Spot mapping, the mapping of crashes along a roadway (either by GIS or simpler methods like pin mapping) and identifying locations where clusters of crashes have occurred is another approach, although this approach may produce misleading conclusions. As traffic volumes can vary considerably from site to site, two locations with the same number of crashes may not reflect the true safety issue that is



Center for Excellence in Rural Safety heat maps display high crash areas using FARS data, and can be a useful tool in engaging the public and elected officials.

present when one site has twice the traffic volume as the other. Consequently, more sophisticated approaches to identifying and prioritizing safety issues should be considered.

In addition to the crash rate method, there are several methods available in identifying sites with safety issues. These include the crash rate method, which is most commonly used, the crash frequency method, the crash density method, the frequency-rate method, quality control methods, crash severity methods, index methods, and the use of complimentary methods. A document from the Iowa Department of Transportation provides a thorough overview of each of these methods, including the approaches to calculation, and the reader is encouraged to reference this work.⁷

Characterize Crash Experience

The next step is to characterize the safety issues of the sites identified. This includes a review of the types of crashes that have occurred, a review of crash report forms, preparation and review of collision diagrams (primarily at intersections) and site visits. The review of this information will begin to provide an indication of the predominant crash types that may be occurring at a location, the contributing factors, and an initial indication of potential treatments that could be employed.

Characterize Field Conditions

If a field visit has not occurred during the previous step, one should now be carried out in order to better understand and record the geometrics, traffic levels and behaviors and other general features present at a site. Data should be recorded as notes, photographs/video, diagrams/drawings, measurements, as well as other means as appropriate. The site visit should be made at a time that coincides with the safety issues identified previously. Additional data should be obtained as needed, such as traffic counts and signal timings. This data may be available from databases (ex. signal timing plans) and may not need to be collected in the field. In other cases, specific information, such as turning movement volumes per hour at an intersection, are not typically recorded in existing agency databases; this information should be measured in the field at a time that corresponds to observed crash trends.



Identify Contributing Factors and Potential Countermeasures

At this point, the factors contributing to crashes should have been identified from crash records, but they should also be identified through observations made while in the field (ex. sight distance obstructions). A review of site plans, other engineering studies, best practices employed by other agencies, past research/studies for similar sites or crashes, and additional technical information may also be consulted. This will contribute to determining countermeasures that may be implemented to address safety issues. Appropriate countermeasures are available from different references, including ATSSA/NACE's *Low Cost Local Road Safety Solutions*,¹ the American Association of State Highway Transportation Officials (AASHTO) *Highway Safety Manual*,⁵ the Institute of Transportation Engineers *Traffic Engineering Handbook*,⁴ the National Cooperative Highway Research Program's (NCHRP) *Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan Transportation Research*,⁸ and NCHRP *Report 440: Accident Mitigation Guide for Congested Rural Two-Lane Highways*,³ among others.

Assess Countermeasures and Select the Most Appropriate

This step determines which potential countermeasure(s) holds the greatest promise in addressing a safety issue. This includes identifying all applicable countermeasures, including the do-nothing option, determining which countermeasures may be applicable in combination with others, identifying constraints and limitations to the countermeasures, and identifying what the potential effect of each countermeasure might be.¹ The data and process employed in evaluating and selecting applicable countermeasures should be documented for later reference if needed.

The evaluation of different countermeasures should be made in such a way as to determine which will provide the greatest return for the amount invested. The countermeasure which minimizes the number of future crashes at the lowest investment cost should be sought. This is not to say that higher cost countermeasures should be excluded. Rather, careful consideration of the amount of savings (to an agency, society, etc.) accrued over time should be considered versus the cost of implementing a countermeasure. Countermeasure evaluations may range from simplistic (comparing advantages versus disadvantages) to complex (cost-benefit analysis based on modeling expected crashes). This more complex approach would entail estimating the expected crash reduction (using an approach such as the Highway Safety Manual discussed elsewhere in this document), assigning a dollar value to the reduction in crashes, determining and valuing any secondary benefits (e.g. improved traffic flow), estimating the cost of the countermeasure, examining effectiveness by each location and ranking site priorities.¹ The result of this step is the selection of one or more countermeasures for implementation.

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Implement the Countermeasures and Evaluate Their Effectiveness

The final step is to implement and evaluate the selected countermeasure(s). Implementation consists of applying the countermeasure(s) in the field, and may range from simple (new pavement markings) to complex (roadway reconstruction), depending on the nature of the safety issue(s) being addressed. Evaluation entails the monitoring of the performance of the selected countermeasure(s) to ensure that they are meeting the primary objective of reducing or eliminating crashes.

The Federal Highway Administration laid out a six step procedure for evaluating the effectiveness of safety improvements, including 1) develop an evaluation plan, 2) collect and reduce data, 3) compare measures of effectiveness, 4) perform statistical tests, 5) perform economic analysis and 6) prepare documentation.⁹ In performing the statistical test of step 4, practitioners will likely employ a before-after study. Before-after studies can be grouped into three types: the simple (naïve) before-after study, the before-after study with control groups and the before-after study using the Empirical Bayes (EB) technique.¹⁰ The selection of the study type is usually governed by the availability of the data, such as crashes and traffic flow, and the amount of available data (or sample size), among other factors.

Of the three approaches to before-after studies, the EB technique has become the most commonly employed. This is the result of the ability of the EB method to provide better performance in addressing the issues typically posed by crash data (e.g., regression-to-mean (RTM), shortly before or after the time period of data). RTM is the potential for a high or low number of crashes to occur during any given year, but over time, for such crashes to hover around a mean annual figure. While the EB method may appear to be statistically daunting to many practitioners, the recent publication of the *Highway Safety Manual* has provided a step-by-step process to follow in completing an evaluation for many types of sites. The reader is encouraged to refer to this document, as well as others which outline different statistical approaches to evaluation.^{8,9,11,12,13,14}

In conclusion, in order to address a safety issue along a local road, a practitioner must first identify and understand the issue(s). This is accomplished through a crash study. This section has provided a general outline of the approach to completing such a study. Of course, the needs of each agency are unique, and a different approach may be applied to a crash study on a case by case basis. This information should serve as a starting point to guide the overall process employed by an agency in identifying crash issues and potential countermeasures to address them.ⁿ



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Crash Data and Its Use

Identifying Safety Issues With and Without Crash Data

Crash data allows an agency to identify where crashes occur, what the causes may have been, and to identify what countermeasures might be applicable in addressing them. Crash data can be in many formats including paper records, computerized databases or spreadsheets, Geographic Information Systems (GIS) files, or online sources such as the Fatality Analysis Reporting System (FARS) (accessible via the Center for Excellence in Rural Safety's Safe Road Maps tool).¹ The origin of this data is crash forms filled out by police officers and typically incorporates information on drivers and passengers, injuries, vehicles (type), the roadway, conditions (weather, lighting, road surface), contributing causes, location and a diagram or drawing (on the paper form).² Unreported crashes are not captured by these reports; however, the more serious crashes which need to be addressed by safety countermeasures are. With this information, a practitioner can identify the types of crashes that have occurred and what may have caused those crashes, leading to an initial identification of potential countermeasures. Another section of this document discusses how to conduct a crash study. This section provides an overview of the use of crash data to make a safety investment as well as approaches to making an investment without using crash data.

Safety Investment Using Crash Data

An example of the use of crash data in making safety investment decisions is provided by Freeborn County, Minn.⁴ The County employed the Minnesota Crash Mapping Analysis Tool (MnCMAT) and its corresponding crash data set to conduct an analysis of five years of crash data. This analysis identified different crash trends (ex. urban vs. rural, county vs. state –maintained routes, etc.) and allowed for comparison of the identified trends to the critical emphasis areas identified in the Minnesota statewide and Freeborn County safety plans. This, together with participant feedback/prioritization through a county road safety workshop, helped to narrow down the focus of the safety strategies that would be pursued.

Following these steps, a more detailed analysis of data for crashes that occurred on county-maintained roads was made. This involved breaking each highway down into segments of specific length (this can be done based on a number of different factors, including changes in geometry, intersections, pavement width/type, etc.) in order for site-specific prioritizations to be made. The prioritization process assigned a risk level to each segment based on five factors, including:

- Average Daily Traffic (ADT) range – segments within a specified range that experienced the highest number of road departure crashes were assigned one star
- Road departure density – segments with a road departure density higher than the average were assigned one star
- Road departure rate - segments with a road departure rate higher than the average were assigned one star
- Critical radius curve density – segments with a higher than the average density of curves assigned one star
- Edge risk assessment – ratings assigned to categorize risk to vehicles leaving the travel lane on a specific segment. Roads lacking a shoulder, adequate clear zone or both received a star.⁴

Based on the cumulative total of stars a segment received, a general ranking of priority sites could be developed. To break



Potential countermeasure locations can be identified both with and without crash data available.

ties between segments, the edge risk and road departure density values assigned to each segment were individually taken into consideration.

Similar to the overall analysis of county-maintained road segments, prioritization of curves within segments and stop-controlled intersection sites was also made. These approaches were similar to those previously discussed, utilizing a star-based risk level system. The specific features assigned risks differed however. For curves, these included:

- Curve radius – curves with a radius between 500 and 1,500 feet (range containing the majority of crashes) assigned one star
- Traffic volumes – sites in the range of volumes overrepresented in curve-related crashes assigned one star
- Intersection in curve – curves with an intersection present assigned one star
- Visual trap – curves with a crest vertical curve at the start of the horizontal curve and a continuing minor roadway assigned one star
- Crash experience – if a severe crash occurred within the study period, a curve was assigned one star⁴

For stop-controlled intersections, risk features included:

- Geometry of intersection – intersections with a skewed approach of greater than 15 degrees were assigned one star
- Geometry of roadway – intersections located on or near a horizontal curve were assigned one star
- Commercial development – intersections with commercial development in one or more quadrants were assigned one star
- Distance to previous stop sign – intersections with minor leg approaches that did not have a stop sign within five miles were assigned one star
- ADT ratio – intersections with an ADT ratio (major/minor) between 0.4 and 0.8 were assigned one star
- Railroad crossing on minor approach – intersections with a railroad crossing on one of the minor legs were assigned one star
- Crash history – intersections experiencing a crash within the study period were assigned one star⁴

With the high risk locations identified and prioritized, low cost solutions for issues specific to the county's safety plan emphasis areas were identified. These treatments are discussed in a number of different references, which the reader is encouraged to consult.^{5,6,7,8} The emphasis in Freeborn County on the need



for low cost solutions stemmed from the fact that the county experienced a very low density of severe crashes annually across the entire system. Consequently, the widespread application of low cost solutions offered a more effective approach to addressing high-priority emphasis areas.

The infrastructure-based strategies identified based on the prioritization process for segments, included:

- Two foot shoulder paving with a safety edge and rumble strip
- Rumble strips
- Rumble stripes
- Six inch wet reflective epoxy in rumble strip grooves
- Six inch latex markings⁴

A decision tree was employed to select between the available treatments for each site based on different factors (traffic, land use, etc.).⁴ Based on the selected treatment, an estimated cost for application on the particular segment could then be made.

Low cost treatments identified for curve locations included:

- Two foot shoulder paving with a safety edge and rumble strip
- Chevron installation⁴

The curves identified during the prioritization process were set to receive each of these treatments.

Low cost treatments identified for stop-controlled intersections included:

- Installation of street lights
- Upgraded signs and pavement markings⁴

Additional, higher cost treatments were also identified, including roundabouts, construction of directional medians and the installation of mainline dynamic warning signs. Similar to the selection of segment treatments, a decision tree was employed to choose the most appropriate treatments for each site. Based on these rankings/prioritizations, the selected improvements could then be pursued. Collectively, the approach employed by Freeborn County illustrates a data-driven process for identifying, prioritizing and selecting safety investments.

Safety Investment Without Crash Data

Crash data is not the only reference point available to practitioners for identifying and addressing a safety issue. A local jurisdiction may lack crash data for a number of different reasons, but primarily, data may not be available because crashes have not yet occurred. As a result, an agency will lack the crash data necessary to perform a crash data-driven identification of locations requiring safety investments. In such cases, proactively identifying and addressing the issue can potentially prevent future crashes.

An approach to identifying and selecting a location for a safety investment without crash data is outlined by the Federal Highway Administration:⁹

- Identify roadway segments, intersections, curves, etc., with a higher number of crashes than average in the jurisdiction. First, you will need to draw on segments that have crashes, using such resources as FARS or the Safe Road Map Tool. Alternatively, reported problems/locations from maintenance staff, law enforcement or citizens can also identify potential problem areas, as can statewide trends.

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- Examine the crash reports from the previously identified sites and determine the contributing circumstances and attributes of each crash.
- Identify common attributes between these crashes.
- Identify other roadway segments, intersections, curves, etc., with similar features but for which no crash data is available or crashes have occurred. Since these locations are similar to those which have experienced crashes, it is reasonable that they hold the potential for future crashes.
- Conduct a field review to assess each identified location and determine potential improvement needs, including a risk assessment.
- Select and implement low cost safety improvements at sites based on needs.

This approach takes a more narrowed focus on applying low cost improvements. A systematic approach could also be employed by an agency. In this case, a countermeasure could be applied to all necessary locations along a jurisdiction's roads (ex. install chevrons on all curves lacking delineation) to address a potential safety issue, regardless of whether crashes have occurred historically.

Another approach that can be employed is surrogate measures. This type of approach employs roadway and traffic characteristics to identify sites with a crash risk and prioritize their treatment. Different aspects of roadway segments, curves and intersections can be examined to determine whether they pose a risk for crashes. An example of this approach has been employed by counties in Minnesota and mirrors that presented in the previous text in terms of the assignment of rankings to different criteria.¹⁰ These criteria can include pavement width, edge (shoulder) presence, clear zone conditions, driveway/access density (ex. per mile), conflicting movements (observed through an on-site count), presence of visual traps, critical curve radius, signing adequacy and traffic, among others. Based on the specific criteria of interest to an agency, different features are assigned different ratings. For example, a segment with an adequate clear zone would be assigned a rating of 1, an average clear zone a rating of 2, and a poor clear zone a rating of 3. The cumulative total of rating points (stars were used in Minnesota) for a category (ex. segments), allows a general ranking of priority sites to be developed. An agency may need to establish a means to break ties between sites with the same score/rating (ex. driveway density for segments). Once sites have been prioritized, a review of specific safety issues or deficiencies can be made to identify countermeasures. For example, a horizontal curve with a visual trap present may receive chevrons and centerline rumble strips as countermeasures to provide driver guidance and address cross centerline crashes.

The reader should also note that other approaches, such as usRAP's Safer Roads Investment Plan, are investigating the development of safety improvement plans in the U.S. based on road attributes, without the need for site-specific crash data.¹¹ These should be monitored and considered as they become available. In addition, other strategies may also be employed to identify potential locations for safety improvement, including Road Safety Audits (discussed in another section of this document), traffic studies (spot speed studies, etc.), on-site observations and citizen and law enforcement input.^{6, 12}



COST EFFECTIVE LOCAL ROAD SAFETY PLANNING AND IMPLEMENTATION

Applying the Highway Safety Manual to Local Road Safety

The Highway Safety Manual (HSM) is a new tool for transportation professionals. It is to safety what the Highway Capacity Manual is to capacity and operations. It allows users to quantitatively assess roadway safety. The HSM allows for an estimate of substantive safety, whereas previous utilized documents like the American Association of State Highway and Transportation Officials' (AASHTO) *A Policy on Geometric Design of Highways and Streets* (the "Green Book") only provides a user with an understanding of nominal safety.¹ Nominal safety looks only at whether or not design standards or warrants have been met and essentially provides answers to yes and no questions: yes, the design standards have been met, or no, the design standards have not been met.



Figure 1: Highway Safety Manual

70 percent of fatal crashes occurring on horizontal curves occurred on secondary roadways.² Therefore, one can conclude that the majority of the roads are not managed by a state department of transportation.² Consequently, improving safety at the local level is essential to supporting the overall U.S. Department of Transportation "Safety Strategic Goal" to "Enhance public health and safety by working toward the elimination of transportation-related deaths and injuries."³ Using the Highway Safety Manual will also allow limited funding to be used at sites that can benefit most from a reduction in the frequency of crashes.

It is imperative for practitioners to understand how the HSM can and cannot be utilized. "The HSM focuses on the reduction of crashes and crash severity where it is believed that the roadway/environment is a contributing factor, either explaining or through interactions with the vehicle or the driver, or both."⁴ The HSM does not address educational, policy and legislative or enforcement activities that may enhance safety. Similarly, the HSM only introduces the reader to human factors (Chapter 2). It directs those wishing to learn more to *NCHRP Report 600: Human Factors Guidelines for Road Systems*.^{4,5}

The Highway Safety Manual can be used when one is interested in the safety of a new design or to compare design alternatives. Figure 2 shows an example of three design alternatives which are being considered for an existing roadway. Being able

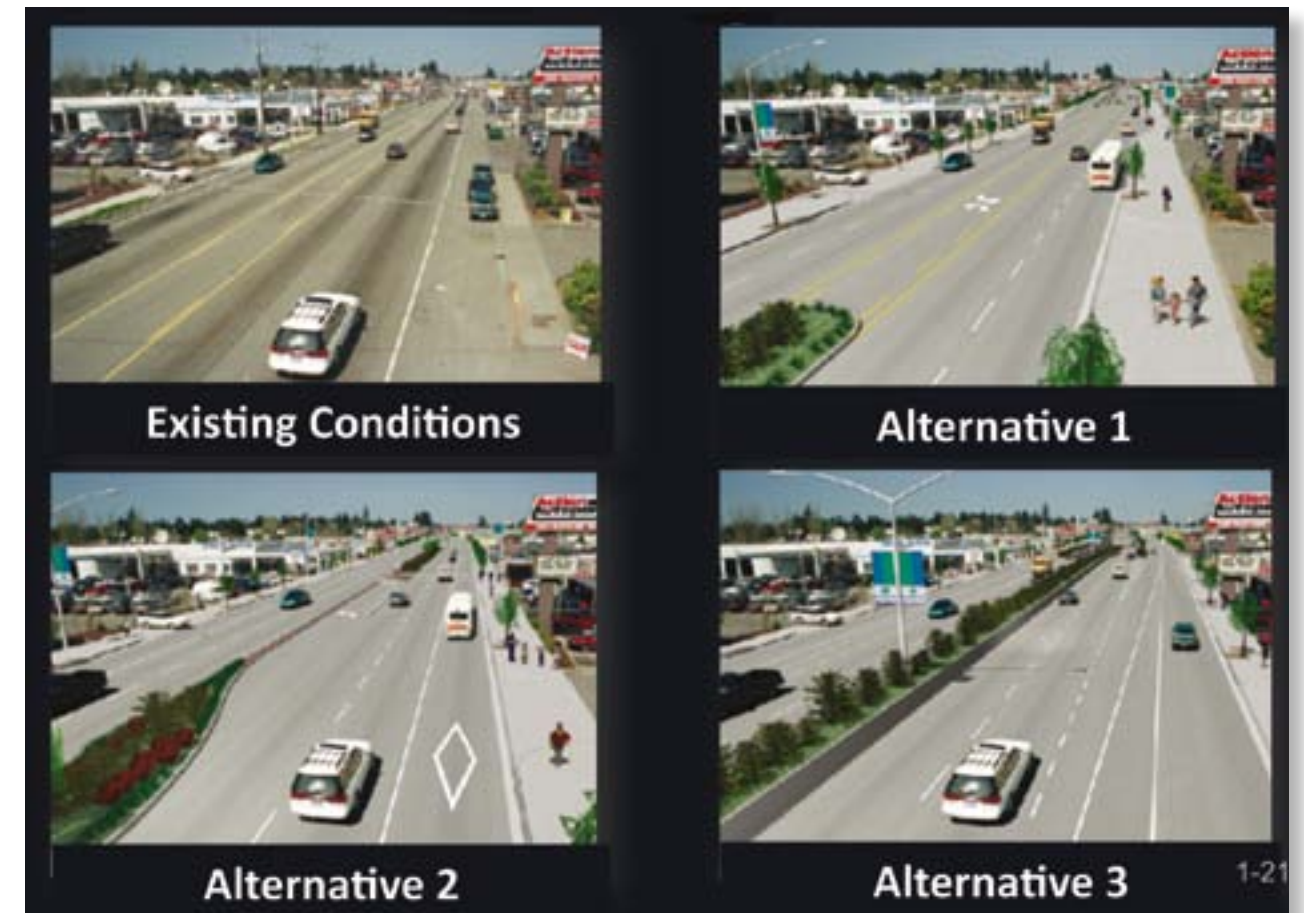


Figure 2: Comparing the Safety of Design Alternatives (National Academy of Sciences).



to quantify the safety of the three alternatives allows the designer to compare how safety changes for each design similar to how operational, environmental and right-of-way trade-offs are considered. The Federal Highway Administration provides an overview of a similar application of the HSM from a case study in Missoula, Mont.⁶ The Highway Safety Manual may also be used to quantify the safety benefits from implementing an individual or a combination of treatments, like the application of centerline rumblestrips and/or the widening of shoulders.

There are four parts to the HSM (Figure 3):

- Part A – Introduction, Human Factors, and Fundamentals
- Part B – Roadway Safety Management Process
- Part C – Predictive Method
- Part D – Crash Modification Factors

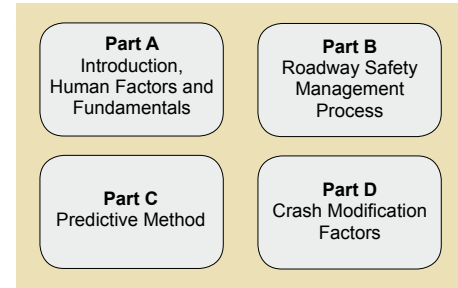


Figure 3: Highway Safety Manual Components.

Part A introduces the methods used within the HSM. Of particular importance is Chapter 3 where many of the definitions for terms used throughout the HSM are presented, including those for crash frequency and severity, regression-to-the-mean (RTM), safety performance functions (SPFs) and crash modification factors (CMFs). Part B provides details of the roadway safety management process. Part C presents the predictive method. Here, an 18 step process describes how to calculate expected average crash frequency which can be applied to the three types of facility types: rural two-lane, two-way roads; rural multilane highways; and urban and suburban arterial highways. Note that rural multilane highways with access control are currently not addressed in the HSM. Part D presents the comprehensive listing of crash modification factors found within the HSM.

Regression-to-the-mean (RTM) is discussed throughout the HSM, but what is regression-to-the-mean? RTM is a product of the randomness associated with crash occurrence (for reference, a graphic representation is presented in Figure 3-4 (p.3-11 in the HSM).⁴ For example, there may be no observed crashes at an intersection one year, whereas in the following year there was double the number of crashes. This does not necessarily indicate that the safety of the intersection is of concern. Rather, the crash history of the intersection over a span of years needs to be considered. The process of considering the average crash history over a period of time helps to smooth out the individual observations.

Safety performance functions (SPFs) are also discussed throughout the HSM. Part C, as highlighted previously, discusses the predictive method which makes use of SPFs. They are formally defined as “equations that estimate expected average crash frequency as a function of a traffic volume and roadway characteristics (e.g. number of lanes, median type, intersection control, number of approach legs).”⁴ They can be used to predict the safety of a treatment (like a conversion from a two-way stop

controlled intersection to a roundabout) that has been implemented for a short period of time or at limited locations, or to predict the future safety of a treatment. Furthermore, they can help by smoothing out the variability of the crash data which in turn address issues like regression-to-the-mean. A calibration factor (C) is used to adjust an SPF to local conditions.

The HSM also discusses crash modification factors (CMFs) frequently. Part D, as highlighted previously, discusses them in-depth. However, a nice overview of CMFs is presented in Chapter 3. CMFs represent “the relative change in crash frequency due to a change in one specific condition”.⁴

CMF = 1.00: No change
 CMF < 1.00: Expected Average Crash Frequency is Reduced
 CMF > 1.00: Expected Average Crash Frequency is Increased

If the facility has the same conditions as the base case, then the CMF is 1.00. If the CMF is less than 1.00, then the treatment is expected to reduce the crash frequency. In contrast, when the CMF is greater than 1.00, then the treatment is expected to increase the crash frequency. For example, a CMF = 0.95 reduces the expected crash frequency by 5 percent. CMFs can be applied individually to SPFs or in different combinations. However, the application of multiple CMFs to SPFs must be done with engineering judgment.

There are many opportunities for training and support for any agency interested in applying the Highway Safety Manual. The Highway Safety Manual website (<http://www.highwaysafetymanual.org>), managed by AASHTO, is a good resource for an individual or agency to consult when learning about the HSM. At this site, a practitioner can find pre-recorded webinars developed by the Federal Highway Administration under the “Training” heading. Another useful feature on the website is the “User Discussion Forum.” Here, you will find questions posed by other users and associated responses. One of the subheadings, “HSM Applications and Success Stories” provides an example of an HSM application.

Many potential users may want to better understand the implications of the HSM from a legal perspective. For a good discussion on the “Tort Liability and the HSM,” start at 36:25 in the “Introductory Webinar hosted by AASHTO, FHWA, and TRB” listed under the “HSM Training Webinar Series.”⁷ As a synopsis, the following clearly defines what the HSM is *not*:¹

The HSM does *not* set requirements or mandates.
 The HSM is *not* a best practice document for design or operations.
 The HSM contains *no* warrants or standards and does not supersede other publications that do.
 The HSM does *not* establish a legal standard of care *nor* does it create a duty to the public.

There are several software tools which were designed to support the Highway Safety Manual.^{4,8} SafetyAnalyst was designed to complement Part B of the HSM. The Interactive Highway Safety Design Model was designed to support Part C of the HSM. The Crash Modification Factor Clearinghouse supports Part D of the HSM. Information on these tools can also be found on the Highway Safety Manual website under “Related Tools,” and the reader is encouraged to learn more about these safety resources.⁷ n

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COST EFFECTIVE LOCAL ROAD SAFETY PLANNING AND IMPLEMENTATION

Project and Corridor Road Safety Audits

A Proactive Approach to Road Safety That Identifies Opportunities for Low Cost Improvements

Road Safety Audits (RSAs) are formal safety performance evaluation of an existing or planned roadway segment or intersection by an independent audit team.¹ RSAs are a proactive approach to safety that qualitatively estimate and report on potential road safety issues and identify opportunities for safety improvements for all road users.² They seek to identify potential or existing issues before they result in crashes and have been shown useful in defending tort liability. Although employed successfully worldwide for many years, they have only seen recent use in the United States.¹ An RSA can be performed at any time and for any roadway, including existing roadways/intersections as well as during the planning, preliminary design, detailed design, traffic control planning, construction and pre-opening of construction and reconstruction projects. Additionally, an RSA can be conducted for a specific design project (i.e. new construction or reconstruction) or a corridor. Note that design project and corridor safety audits are each subsets of road safety audits.

RSA Process

An RSA is completed by a three to five person interdisciplinary team that reviews design features during field visits to determine where safety issues may exist. The data collected in the field is recorded via checklists of items to examine/look for (see South Dakota for an example checklist),³ field notes, video/photo, and other means as necessary. The audit team members may possess skills in a number of different areas, including highway safety,

traffic engineering, geometric design, human factors, planning, pedestrians/bicyclists, accident reconstruction, enforcement and maintenance. While all of these skill sets may not be necessary given a specific project, the first four skills listed should be considered core needs for an RSA. The eight step process in completing an RSA is as follows:⁴

1. Identify existing project, road or corridor to audit.
2. Select interdisciplinary audit team.
3. Conduct pre-audit meeting to review information and drawings.
4. Conduct field reviews under various conditions using checklists and collecting video/photos.
5. Conduct audit analysis and prepare report of findings.
6. Present findings to project agency or design team.
7. Prepare formal response, indicating which recommendations will be implemented and which will not, along with why they will not be implemented.
8. Incorporate findings.

A number of documents provide specific details for various steps of the process, checklists of field elements to examine, etc. which the reader should consult.^{3, 5, 6, 7, 8}

Design Project RSA Example

The identification of potential safety issues during or after construction activities have occurred may limit the applicable solutions available to address a safety issue and result in additional cost to correct. Consequently, a project RSA should occur at an earlier point of a project during design. A case study from Clark County, Wash., is presented here to outline such an approach.⁸



Visual indications, such as skid marks, can identify potential safety issues during a field audit.



WTI

In Clark County, an RSA was conducted during the design phase (80 percent completed) of a project that involved roadway realignment and intersection improvements on a two-lane rural road. The project was initially identified because of safety concerns stemming from high-severity run off the road crashes. An audit team comprised of Clark County and private consultant staff with different backgrounds (County and consulting engineers, law enforcement, and planners) and no association with the project was assembled to complete the RSA.

Planned improvements at the time of the RSA included a roadway realignment, introduction of a new signalized intersection, improvements to stop-controlled intersections, including introduction of a free right turn lane on an approach at one intersection, and intersection realignment. The RSA team reviewed the most recent design plans for the project, crash and traffic data, as well as made site visits in conducting their audit. During the design plan review and in-field audit, they identified a number of safety concerns associated with the project. New conflict points would be established following reconstruction, increasing the potential for rear end, turning and merging crashes. The free right turn lanes that were incorporated into the design added to driver workload and presented a safety concern to the team. Limited clear zones had been designed into the project, and proposed signage and pavement markings were deemed inadequate.

Following their audit, the team analyzed their data and observations and prepared their report of findings. As part of the report, a number of recommended changes and improvements to the design/project were made, incorporating both low cost solutions and more extensive changes. These interim improvements included the removal of vegetation to improve intersection sight triangles, the addition of new pavement markings and the introduction of a left turn lane at one intersection where adequate pavement width was already present. In the project design, the team recommended the inclusion of turning lanes, providing delineation in merging areas and reviewing the safety of allowing right turns on red to address conflicts. Turning radii revisions and yield control were also recommended, along with examinations of proposed guardrail locations to confirm that they would not restrict sight distance. It was also recommended that clear zone issues be addressed by removing fixed objects proposed to remain in the zone and the provision of barriers at locations with steeper slopes if these could not be flattened. Finally, pavement marking and signage improvements were also recommended.

The audit team presented their report of findings and recommended changes to county staff. In the case of this project, the originally proposed design features were the result of the public input process. The feedback received during this process resulted in a design that was beyond the original intent of the project, which was to address run off the road crashes. During the RSA, it became evident that the new design actually compromised safety by adding conflict points along the roadway. As a result of the audit and the presentation of results and recommendations, the county re-examined the major elements of the project and scaled back the design.

Corridor RSA Example

To illustrate the application of an RSA to a corridor a case study from Day County, S.D., is presented.³ This RSA was done in a proactive manner rather than as part of any construction or reconstruction effort. It was initiated by the Day County Highway Department in 2009 along County Route 1 as the result of recent crash history raising concerns. Vehicle

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speed (posted speed limit of 55 mph) and limited sight distance concerns (both horizontal and vertical) prompted an RSA of a two mile segment of the route approximately four miles south of Waubay, S.D.

The team assembled for this RSA consisted of a highway superintendent, a local director of emergency management, a civil engineer and three Local Technical Assistance Program (LTAP) staff. The team reviewed available crash, traffic and roadway design information prior to a field visit. Crash data indicated that the corridor had experienced three crashes between 2004 and 2009, as well as a fatal crash with six fatalities (the date of this crash was not specified). Traffic data showed an Average Daily Traffic of 400+, while design information indicated a roadway width of 22 feet (two 11-foot lanes), variable shoulder widths and composition (paved, gravel and earth) and the presence of vertical and horizontal curves.

The audit team reviewed checklists of items during a field visit to identify safety deficiencies and issues. Some existing infrastructure, such as the roadway surface, pavement markings and signs, appeared to be in very good condition along the entire route. However, a number of other safety issues were identified. There was a need for additional delineators and object markers to indicate the presence of curves, roadside obstructions and drop offs along the length of the corridor. Additionally, locations on reverse curves needed chevrons added to aid in curve definition. Several locations also lacked warning signs and advisory speed plaques. Finally, slope flattening and culvert extension improvements were identified for several intersecting driveways. Aside from slope flattening and culvert extension, these deficiencies represented low cost improvements which could improve safety along the entire length of the corridor.

Several site-specific issues were also identified during the RSA. This included one severe angle intersection in which the low cost solution of installing advanced warning signs was recommended. A culvert extension and side slope flattening were recommended for a site with a 40 inch culvert pipe beneath a narrow shoulder and steep side slope, along with the low cost treatment of delineators.

Following the site visit, the auditors conducted analysis and review of the observed and collected field observation data, identified the recommended improvements discussed earlier, and developed a report of findings. Along with the low cost solutions identified, the team recommended upgrading the roadway to current design standards in the future to address existing sight distance issues. The report was presented to Day County officials, in accordance with the RSA process. A formal response to the recommendations was developed, resulting in the Day County Commission requesting funding assistance from the FHWA High Risk Rural Road Safety Fund, through the South Dakota Department of Transportation, to make the recommended construction improvements on the route.³

In summary, the conduct of RSAs is a straightforward process that can proactively identify safety issues during the project design phase, during construction/reconstruction, after a project has been completed or along an existing roadway. Often, low cost solutions exist to address these issues. The improvements identified often represent elements that would be forgotten had an RSA not been made, such as signage and pavement markings, removal of obstructions from the clear zone, etc. Field visits made to a project site can yield further opportunities to improve safety, as an RSA team in the field may make observations which may not have necessarily been identified, such as the absence of adequate delineation or barrier protection. n



COST EFFECTIVE LOCAL ROAD SAFETY PLANNING AND IMPLEMENTATION

County-Wide Systemic Safety Plans

Identifying High-Priority Safety Projects Countywide Both Proactively and Reactively

As part of SAFETEA-LU, state Departments of Transportation (DOTs) have been tasked with generating Strategic Highway Safety Plans (SHSPs).¹ These plans (sometimes referred to as Comprehensive Highway Safety Plans) provide a framework for each state in reducing fatal and serious injury crashes on all public roads. They have been developed in consultation with a number of stakeholders, including local entities such as county officials. Given that a significant portion of the nation's public roadway system falls under the jurisdiction of local governments, their role in improving safety through SHSPs is considerable. However, translating the goals and objectives of these plans into actionable strategies at the county, and local, level is a significant challenge. In addressing this challenge, county wide safety plans are a useful tool for practitioners to employ. Such plans identify high-priority safety projects of low, medium and high cost, both proactively and reactively.² In this sense, county wide safety plans differ from local road safety plans in that they examine the system as a whole and encompass a wide variety of projects, compared to looking for site-specific issues that can be addressed with low cost countermeasures.

Addressing and improving safety along county roads may appear to be a significant challenge, especially for local agencies that are faced with limited funding or personnel. However, in developing county wide safety plans, some states such as Minnesota offer funding grants. This funding is targeted specifically for plan development in order to help implement the strategies articulated in the SHSP as well as establish other local priorities. What this funding does is provide a local agency an opportunity to identify its own set of high priority safety projects and position them to compete for additional safety funds in the future. The reader is encouraged to investigate such funding opportunities with their state DOT when developing a county plan.

While each county will have its own high priority focuses and corresponding safety strategies, in some cases, the SHSP produced by a state may identify specific crash issues on a county or regional basis, providing local officials with initial guidance on where a county wide safety plan should focus its efforts. Regardless, a systematic approach should be taken in developing a county safety plan. While the approach outlined here may differ in details from case to case, in general it represents the core steps necessary to produce a county wide safety plan.

The development of a county wide safety plan is a multi-step process and relies on input during various stages from local stakeholders with experience in the four E's of safety: Engineering, Enforcement, Education and Emergency Response. This input develops focus areas, identifies strategies and solutions and aids in selecting projects for implementation.

Generally, the process in establishing a county wide safety plan consists of the steps outlined in Figure 1 and was employed by Olmsted County, Minn.^{2,3} Depending on the specific needs of a county additional steps may be required, such as the conduct of a public hearing or review period.

The county safety plan process begins with a crash analysis. This analysis may consist of information provided from the state DOT and include identification of statewide trends and areas of concern, such as run off the road crashes, or more localized trends for a specific county or region. A county/local entity might also be interested in addressing localized concerns in addition to those outlined by the state. In such cases, it could perform its own crash analysis using data from the state DOT, local police or other sources (such as the Center for Excellence in Rural Safety's Safe Road Maps tool which maps FARS data).⁴ The analysis of this data should examine total crashes, crash types and their locations to narrow the focus of the county's plan.

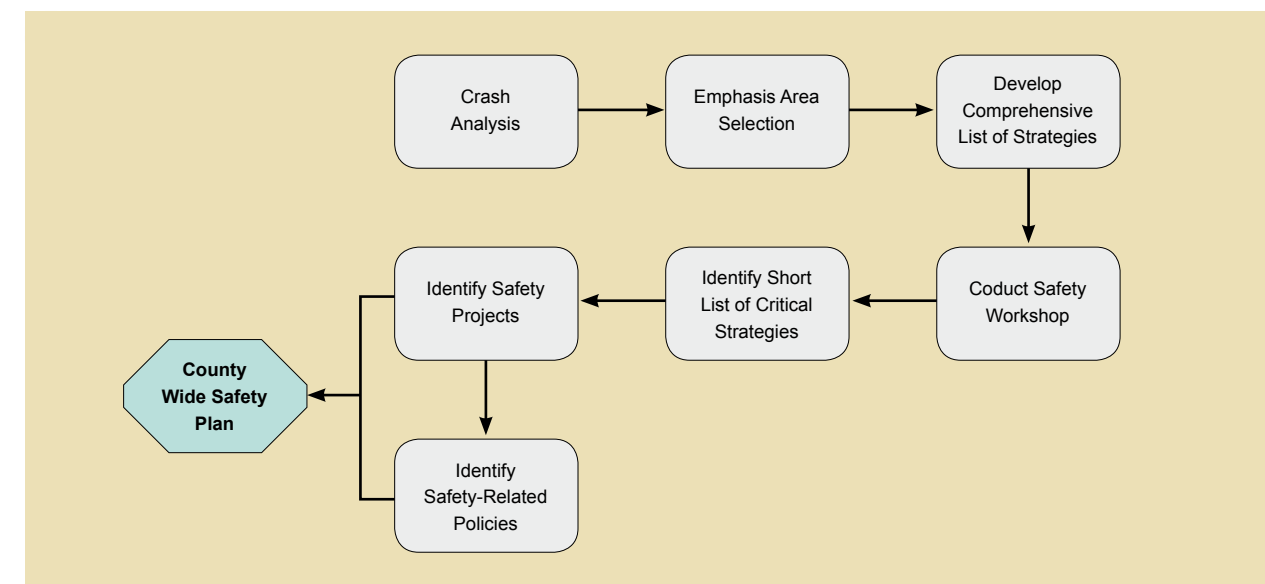


Figure 1: County Wide Safety Plan Development.



Based on the crash data analysis, a county can select emphasis areas. Typically, emphasis areas focus on addressing specific types of crashes, trends, vehicle types and so forth. Examples of emphasis areas include road departure, impaired driving, intersections, seat belt use, heavy vehicles and young drivers. An overview of different emphasis areas is provided by the American Association of State Highway and Transportation Officials' (AASHTO) *AASHTO Strategic Highway Safety Plan*.⁵

Once emphasis areas have been established, specific strategies to address them can be identified. A useful reference in identifying such strategies is the National Cooperative Highway Research Program's (NCHRP) *Report 500* series, which outlines strategies and countermeasures for addressing crash issues for specific emphasis areas.⁶ These guides contain a number of low cost solutions to different safety problems that a county may have identified. This process is typically conducted by county/local staff.

Following the identification of the different strategies to address the emphasis areas, a safety workshop is conducted. This is a point where stakeholders representing the "four E's" meet with county officials to discuss the development of the plan completed to date. The purpose of the meeting is to share the results of the data-driven analysis and overall process conducted to identify existing crash problems and emphasis areas, as well as present and discuss the list of safety strategies identified up to that point. This meeting also provides an opportunity to narrow down the list of available strategies to a "short list," which is the next step in the process of developing a county safety plan. This narrowing of strategies may be accomplished by prioritization, a ranking process, a vote of stakeholder representatives or other strategy.

Next, specific safety projects are identified. These projects/locations will typically have been identified during the course of crash analysis, although a follow up analysis may be conducted at this point to further identify specific locations. In prioritizing specific projects to pursue, a county may consider a number of factors, including cost, (i.e. where can low cost solutions be widely implemented), crash frequency/severity (i.e. problem locations), emphasis (i.e. driver education/awareness) and so forth. Many counties choose to focus on low cost strategies that can be widely applied throughout the area and achieve the greatest impact in reducing crashes. For example, a county may choose to improve roadway edges and delineate curves along all roadways. Along with the identification of specific projects, estimated costs associated with each strategy/site may also be developed during this step. Such estimates provide an agency with a good idea of the funding necessary for implementation, which is a helpful data point to have for county budgeting or in deciding whether

Highway Safety Improvement Program (HSIP) funds, High Risk Rural Road Program (HRRR) funds or other funding sources will be pursued.

Aside from identifying safety projects, safety-related policies are also identified at this point. Such policies establish the initial dimensions (ex. length, width and depth or rumble strips) or on-going needs (ex. improved pavement marking dimensions and maintenance/rehabilitation) that may be associated with a strategy. This information provides a form of implementation guidance that can be employed county-wide to ensure uniformity and consistency.

Following these steps, the information generated through the entire process is compiled into the county wide safety plan. This document presents the results of the crash analysis, identifying specific problems faced by the county, outlines the emphasis areas selected, identifies the different strategies for addressing the emphasis areas, reviews the results of the safety workshop and selection of specific strategies, presents the specific safety projects that should be pursued as a result of the plan, and discusses any applicable impacts to policy that may result from the selected strategies or projects. The documentation should also include a discussion of implementation and avenues for funding safety improvements. Examples of county safety plan documents can be found through an online search.^{3, 7, 8}

One final discussion point is warranted: there may be some concern on the part of a county that the development of a county wide safety plan may present exposure to tort liability. The National Association of County Engineers (NACE) has addressed this point as part of a webinar entitled "Saving Lives in Your County (A systematic process for developing a road safety program)."⁹ The materials provided point out that a 2003 Supreme Court ruling involving Pierce County, Wash., determined that "Data collected and compiled by public agencies for the purpose of applying for Federal Safety funds were protected from being used against the agency."⁹ The material goes on further to indicate that this protection is limited to agencies using the actual data to prepare requests for safety funding.

In summary, county wide safety plans identify high-priority safety projects, both proactively and reactively. This allows a county to identify and document safety concerns they wish to emphasize and address, select appropriate countermeasures to address them and prioritize specific projects, locations or elements that will be addressed. In completing a county wide safety plan, a county will not only better understand what its safety issues are and how to address them, but also begin to position itself for pursuing funding opportunities to improve safety. n

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COST EFFECTIVE LOCAL ROAD SAFETY PLANNING AND IMPLEMENTATION

Rural Road Safety Programs

How to Identify The Most Effective Low Cost Safety Countermeasure for Your Rural Road

While comprising over three million miles of the network, local roads typically lack many of the safety and design features and experience higher rates of crashes than other roadways. Consequently, there is a need to identify high-risk rural road segments and determine what safety countermeasures or strategies are most appropriate to improve safety.¹ The approach to accomplishing this is through a rural road safety program. Such a program establishes where safety problems exist and identifies appropriate, typically low cost countermeasures to address those problems. This approach differs from the county wide safety plan in that it seeks out specific sites that have safety issues which can be addressed through low cost measures, as opposed to identifying high-priority projects of varying cost which may be applied on a systematic basis.

There are various approaches that may be taken by an agency in pursuing a rural road safety program. The exact approach employed is likely to depend on the specific characteristics and needs of an area and agency. It may range from simple, such as examining crash data and conducting field audits, to complex, examining crash data, conducting field evaluations, ranking locations by risk and conducting cost-benefit analysis of each identified project or countermeasure. Both a simple approach and complex approach will be presented here, note that the ultimate approach employed by a specific agency may follow one of these

approaches, use various aspects of each or be developed entirely from scratch, depending on specific needs.

Examples of simple rural road safety programs are provided by Douglas County, Ga.,² and Clark County, Wash.³ In Douglas County, a four step approach was taken in addressing rural road safety:

1. Identify high-crash locations using available crash data.
2. Identify low cost safety solutions, such as enhanced signage and pavement markings, shoulder improvements, vegetation and tree removal, rumble strips, guard rails, etc. These approaches can be identified through a number of available resources, including National Cooperative Highway Research Program (NCHRP) *Report 500*,⁴ the American Traffic Safety Services Association/National Association of County Engineers (ATSSA/NACE) *Low Cost Local Road Safety Solutions*⁵ and other documents.^{6, 7}
3. Determine potential benefits of solutions to establish implementation priorities. This is accomplished through the use of Crash Reduction Factors (CRFs) that aid in establishing the expected reduction in crashes that could potentially result from the use of a particular countermeasure. Based on the expected reductions, countermeasures or projects can be ranked accordingly.
4. Implement solutions to address safety problems with low cost safety solutions, based on ranking/priority and available funding.



Rural road safety plans identify low cost treatments to address safety. Photo by William Shorb.



As this approach illustrates, a rural safety program can be as simple as identifying existing safety problems on the network and countermeasures to address them, evaluating the potential benefits these countermeasures may provide, and pursuing implementation as funding and needs warrant.

An example of a more complex rural road safety program is provided by Wyoming, whose approach was developed to help counties identify high-risk roads and develop a strategy to obtain funding to reduce crashes on these segments.^{1, 8, 9} The approach developed consisted of five steps, including:

1. Crash data analysis, which examined various aspects of crashes over a ten year period in most cases, three years for total as well as fatal and injury crash rates, to establish high-risk locations for one mile segments.
2. Conduct a Level I field evaluation, which examined the geometric design of the roadway at each identified site. A score of 0 (most dangerous) to 10 (least dangerous) based on the answers to a series of questions was assigned to five categories, which included:
 - a) General (design features, visibility, pavement conditions, etc.)
 - b) Intersection and Rail Road Crossings
 - c) Signage and Pavement Markings
 - d) Fixed Objects and Clear Zones
 - e) Shoulder and Right of Way (ROW)
3. Ranking of high-risk locations, which combined the rankings of crash data (largest to smallest number of crashes) and the Level I field evaluation rankings. This process employed a weighting approach this is discussed in detail in the project report.⁸
4. Conduct a Level II field evaluation, which identifies the causative factors for crashes on each road section and identifies potential countermeasures, including low cost ones, to address the problems.

- 5) Conduct cost-benefit analysis, which evaluates which countermeasures most effectively reduce crashes while requiring the lowest cost to implement. This step allows for selection of appropriate safety countermeasures that can achieve best economic effectiveness. The Wyoming approach employed a cost-benefit analysis, with Crash Reduction Factors provided by the Federal Highway Administration's *Desktop Reference for Crash Reduction Factors*¹⁰ employed to estimate the potential crash reductions (benefits) of each available countermeasure.

The Wyoming approach incorporated more rigorous analysis in order to develop rankings and perform economic evaluation of projects and countermeasures prior to their implementation. However, aside from the greater emphasis on analysis, the overall approach matches the basic outline employed in the Georgia and Washington examples.

Rural road safety programs offer agencies an opportunity to identify where safety problems may exist on their system and what countermeasures are available to address them. Such a program is an effective way to identify safety problems that can be addressed through low cost solutions. As a result, improvements in highway safety can be achieved for a lower investment, while often maximizing the benefits being achieved. A rural road safety program can range from basic to complex, depending on the needs and capabilities of a particular agency. In establishing a rural roads safety program, a number of resources are available for practitioners to consult.^{4, 5, 6, 7, 11, 12} Regardless of the approach, a rural road program will typically incorporate information regarding crashes, countermeasures to address them and implementation. [n](#)

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Part 2: Applying Safety Solutions

Once an agency has identified what its safety issues are, it needs to identify what countermeasures are available to address them. A number of countermeasures have been developed over time to address safety issues, with varying costs and effectiveness. The amount of information available to practitioners regarding the different countermeasures can be overwhelming and a challenge to sort through. Additionally, many countermeasures are not practical at the local level because of cost considerations. As a result, there is a need for a concise summary of low cost countermeasures that are available for consideration at the local level to aid practitioners in identifying what is out there and how it can help to address the issues they face.

Fortunately, previous work by ATSSA/NACE recognized these needs, resulting in the development of the publication entitled *Low Cost Local Road Safety Solution*.¹ That document summarized a number of different low cost countermeasures, and the current document covers more of these that may be of interest or applicable to the issues faced by practitioners. Many of these countermeasures have seen increased use in recent years and all are low cost, making them particularly applicable to issues at the local level.

The countermeasures discussed in the following sections include horizontal curve chevrons, selection of sign sheeting, uses of signage to improve safety, improved pavement markings, rumble strips and stripes, lane separators with flexible channelizer posts, high friction treatments, unsignalized intersection lighting, w-beam guardrail, and the Safety Edge_{SM}. Finally, technologies on the horizon are highlighted. These items are still relatively new, but hold promise in addressing safety issues along local roads, including dynamic curve warning systems, intersection warning systems and cable guardrail. Each section provides a description of what the countermeasure is, what it does, its costs, its effectiveness in past applications, and other general information. [n](#)

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Improved Chevrons for Horizontal Curves: Enhanced Curve Delineation for Drivers

Horizontal curves present a significant challenge to safety, particularly on local roads. This is underscored by recent statistics from the Federal Highway Administration (FHWA), which indicate that 27 percent of fatal crashes occur at horizontal curves, with over 80 percent of these crashes involving roadway departure.¹ As these figures illustrate, horizontal curves represent locations where significant improvements in safety can be made, often at low cost.

One of the National Cooperative Highway Research Program's Report 500 focus areas is on the reduction of crashes at horizontal curves through low cost strategies such as improved curve delineation.² An FHWA report entitled *Low Cost Treatments for Horizontal Curve Safety* also presented a number of different treatments that can be applied singularly or in combination to address crashes, including the use of improved signage chevrons.³ Such devices delineate a curve, both as a driver approaches it, as well as while they traverse it. The pattern and size of such signs ensures that several are in view of the driver at all times when passing through a curve. Chevrons may be presented to drivers in one or both directions of travel through a curve depending on needs. This may entail the use of single chevrons on a pole for a single direction of travel or through the use of a chevron that allows two chevrons to be positions for both directions of travel on one pole. The signage employs retroreflective sheeting material to ensure continued visibility during inclement and nighttime conditions. The signs are installed on the outside of a curve and positioned at a right angle to a driver's line of sight (using post designs that minimize damage and injury if struck). A bracket may also be employed to align the chevrons to the line of sight to drivers.

Evaluation results have shown chevrons have a positive impact on safety at horizontal curve locations. Studies from Texas found that chevrons reduced vehicle speeds,⁴ while studies in Georgia and Virginia found that wheel path variations also were reduced.^{5, 6} Chevrons were found to reduce lane departure crashes in Washington during dark conditions by over 20 percent on rural two-lane roads.⁷ NCHRP Report 559 noted that chevrons were effective in reducing crashes at curves where standard curve signage had not been.⁸ Finally, Mendocino County, Calif., found that improving the signing of curves reduced crashes by 42.1 percent over a six year period, producing a cost-benefit ratio of 229.0.⁹

In choosing which curves to address, different approaches may be taken. This could include examining crash history, Average



Chevrons improve curve delineation and provide warning of an alignment change. Photo by William Shorb.

Daily Traffic, the radius of a curve, and/or the presence of visual traps at different sites. These items could be considered singularly or in combination. Once identified, *Low Cost Treatments for Horizontal Curve Safety* provides discussion of the basic design and detailed figures on the spacing/layout of chevrons, which vary based on curve radius and design speed.³ Information from Freeborn County, Minn., indicated that the cost of signage, including installation, was \$118, with an additional cost of \$39 if a dual chevron bracket was used.¹⁰ Other 2009 figures from Washington indicated a cost of \$100 per sign, not including installation cost.⁷ Cost will likely vary depending on factors such as location, the number of signs required, the dimensions and materials (i.e. reflective sheeting) required, installation hardware/costs and inflation. The cost figures cited indicate that the installation of chevrons at horizontal curves represents an opportunity to achieve safety improvements for a minimal cumulative investment, both at the site level and regionally.

Overall, the use of chevrons for horizontal curve delineation has shown to be an effective low cost treatment in improving safety. When considering the use of improved chevrons, a practitioner should consult local references and guides (ex. the *Manual on Uniform Traffic Control Devices*, state Department of Transportation signing manuals, etc.) regarding specific use, design and installation/placement guidance and criteria for their locale. n

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Choosing the Most Effective Sign Sheeting to Ensure Visibility at All Times

One quarter of travel occurs at night yet there are three times more crashes at night producing half of the fatalities occurring on the nation's roads each year; therefore, the visibility of a traffic sign during the night time hours is critical to saving lives.¹ One of the most straightforward and low cost treatments that can be used to address the different crashes that contribute to these statistics is the effective use of signing. The consideration and selection of reflective sheeting to increase the visibility at night should be based on the MUTCD requirements and life cycle cost. Effective signage that incorporates retroreflective sheeting to enhance visibility during all times of day can greatly improve safety. From a product and economic perspective, there is not one uniform signage solution for all agencies. Therefore, guidance on the selection of effective, retroreflective sign sheeting is necessary.

When choosing sign sheeting for an application, different factors must be taken into account. Most importantly, signage should incorporate retroreflectivity (reflecting light back to the source). Maintenance is another consideration, as sheeting will fade over time and require replacement. Cost is another consideration, as certain materials will have a higher cost but may be likely to last longer before fading compared to other alternatives.

In general, the *Manual on Uniform Traffic Control Devices* (MUTCD) has required signs to be illuminated or use retroreflective sheeting materials for years.² More recently, the MUTCD has adopted language requiring agencies to maintain retroreflectivity at or above specific levels. In selecting sheeting, many practitioners have referred to the American Society for Testing and Materials (ASTM) specification D4956, *Standard Specification for Retroreflective Sheeting for Traffic Control*, which describes the types of retroreflective sheeting materials that can be used on traffic signs.³ A summary of common sheeting types listed in this reference is presented in the accompanying table. The life cycle of each of these materials should be considered when deciding the type of sheeting to purchase. Type I sheeting has a life span of 7 years, while the other types listed have life spans ranging from 10 to 12 years. While ASTM provides information on the different materials types, it does not provide guidance on retroreflectivity needs (ex. viewing distances).

Based on this ASTM shortcoming, the Texas Transportation Institute (TTI) looked at how nighttime drivers used traffic signs and then recommended sheeting specifications based on those needs.⁴ The specifications developed by TTI provide a systematic way for agencies to select and specify retroreflective sign sheeting performance characteristics at night. This work developed

retroreflectivity requirements for specific sign applications (locations on the left, right or overhead of the roadway) based on different viewing geometries. By consulting this information, a practitioner can select or specify the type of sheeting that possesses that level of retroreflectivity for their application. This is done through a series of tables containing luminous intensity values for different vehicle and sign location scenarios and viewing distances. While space considerations preclude their presentation here, the reader is encouraged to refer to these tables while selecting their sheeting.⁴



The selection of sign sheeting plays an important role in ensuring all signage is visible at all times of day.

Minnesota developed a document that discussed best management practices in the purchase and maintenance of sign sheeting.⁵ This included the recommendation to purchase materials under a larger agency's purchase agreement for cost savings, the use of higher retroreflective sheeting on more critical signage and increasing sign size at locations with safety problems or limited visibility. The Federal Highway Administration developed a sign retroreflectivity handbook for small agencies that also discussed maintenance activities, inspection techniques and equations to estimate the replacement cost of regulatory, warning and guide signs in different locales.⁶ Replacement costs were based on a percentage of \$150, which depended on the number of signs being installed/replaced. The costs included materials and labor. An alternative estimation approach using centerline miles was also provided, using the same percentage approach described previously.

A number of different types of sheeting materials are available for the practitioner to choose from. Each incorporates different retroreflective characteristics that meet the needs of various signing applications. In selecting the most effective sheeting material for a sign, a practitioner should consider what the sign application is, its viewing position and distance, and the desired/necessary level of retroreflectivity. Based on this, different sheeting materials can be identified, with a selection made based on different factors including the lifespan of the material, its cost and future signing needs. By employing effective sheeting materials, signage will be more visible to drivers and provide them with additional guidance, improving safety. n

Type	Common Name	ASTM Description	Typical Construction
I	Engineering Grade	Medium Intensity	Enclosed Lens
II	Super Engineering Grade	Medium High Intensity	Enclosed Lens Glass Bead
III	High Intensity	High Intensity	Encapsulated Glass Bead
IV	High Intensity	High Intensity	Microprismatic
VIII	Super High Intensity	Super High Intensity	Microprismatic
IX	Very High Intensity	Very High Intensity	Microprismatic
XI	Super High Intensity	Super High Intensity	Microprismatic

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COST EFFECTIVE LOCAL ROAD SAFETY PLANNING AND IMPLEMENTATION

Using Signage to Make Local Roads Safer

Traffic signs visually communicate regulations, warnings, directions and locations to drivers.¹ In conveying this information in a uniform manner, a safer environment is created for drivers. Signage falls into three categories: regulatory (ex. stop, yield), warning (ex. intersections, curves) and information (ex. street names, directions).² When inadequate or deficient signage conditions exist, drivers may make inappropriate responses, negatively impacting safety and increasing agency liability.

The source of standards and warrants for the design and use of signs in the United States is the *Manual on Uniform Traffic Control Devices (MUTCD)*.³ The MUTCD establishes the shapes and colors of various signs to ensure uniformity and establish driver expectations. An effective traffic control device, such as a sign, should fulfill a need, command attention, convey a clear and simple meaning, command respect and give adequate time for a proper response.³ These concepts should all be kept in mind when planning, designing, placing and maintaining signs. Signs should be detectable and legible at a distance during both the day and at night and remain unobscured by foliage. The needs of all drivers should be considered when designing signs, particularly those with reduced vision, such as older drivers. When a sign is no longer warranted or needed for a particular location, it should be removed.

In using signs to improve local road safety, the most important consideration is whether a sign is needed. A good place to begin is to look at the crash history of your roads. As noted in other parts of this document, good crash records can be a tremendous tool to not only see "hot spots" where multiple crashes have occurred, but also where there are trends, such as crashes occurring at multiple rural T-intersections. Another place to look are areas where development is changing that may either cause increased traffic or more conflicts with pedestrians, cyclists and other drivers. The identification of sign needs or lack thereof may also come from maintenance/agency personnel, police or citizens based on observations of different changes in safety, operations, etc., at specific locations. Based on these observations, a consultation of the MUTCD should be made to determine if a sign is needed and what signing options are available. Note that the use of a sign should be carefully considered to avoid oversigning in a location, which can result in driver information overload and possibly degraded safety. This requires consideration of prioritization of information needs to ensure they are correctly processed by a driver.⁴

Frequent inspection and maintenance of existing signage is necessary to ensure it is still meeting its intended function. This includes determining if the sign is in good conditions and that an adequate level of retroreflectivity exists (as observed at night). Retroreflectivity needs are discussed in other sections of this document. While inspections are carried out by agency personnel, notification of sign issues by others, such as vandalism reported by police or citizens, can also be useful. Where deficiencies are confirmed to exist, repairs or upgrades should be made by trained maintenance or engineering personnel, who should also assure the signs are kept clean and their support structures in good condition.



The addition of signs along local roads can lead to safety improvements at a low cost.

The use of signage has been found to have a positive impact on safety. Figures from the Institute of Transportation Engineers (ITE) indicate that a number of different signs have produced crash reductions. These include curve warning arrows (20 percent), advance curve warning signs and speed plaques (20 percent), advisory speed signs (36 percent) and a special curve warning arrow sign with stated speed (75 percent).⁵ Further information from ITE indicated that traffic signs in general could be expected to reduce fatal crash rates (29 percent), injury crash rates (14 percent) and combined fatal and injury crash rates (14 percent), while producing a cost-benefit ratio of 7.3.⁵ Information from the Federal Highway Administration (FHWA) indicates that the installation of double stop signs reduced total crashes by 11 percent and right angle crashes by 55 percent, while advance warning signs reduced total crashes by 40 percent at rural locations.⁶

The use of signs to make local roads safer does not need to be a complicated process. Mendocino County, Calif., established a simple program that demonstrated that additional signs on local roads can improve safety.⁷ From 1992 through 1998, the county reduced crashes along its roads by 42.1 percent by simply adding and improving signage. The approach taken was basic, with a review of each road in the county made on a three year cycle to identify signing deficiencies. This included a combination of field reviews and a review of recent crashes that had occurred on each road. Over six years, a total of \$79,260 was spent on this effort; when crash reductions were accounted for, the program produced a cost-benefit ratio of 299.0.

When examining the use of signs to improve safety, a local agency should consider both roadway segments and intersections. Along segments, geometric features such as curves should be examined to determine whether adequate signage is present to provide drivers with advanced warning. The appropriateness of existing signs, such as the posted speed limit should also be reviewed with changes or removals made as needed. Intersections should also be reviewed for sign needs and existing adequacy. The FHWA indicates that signage should be used to provide drivers

with advanced notice of the presence of an intersection and applied where patterns of right angle, rear end or turning crashes exist.⁶ It should also be recognized that more or better signs are not an automatic panacea. In some cases, more extensive improvements (such as those highlighted in other parts of this document) may be needed to either prevent crashes or mitigate the impact if a driver does leave the roadway.

Signs are an important component of roadway safety, providing drivers with the guidance and information necessary to drive safely. The low cost of signs (both materials and installation) make them an ideal approach

to improving safety along local roads, particularly if past crash history indicates correctable problems exist. Figures have shown that the use of signs results in crash reductions and produces positive cost-benefit ratios. A simple approach can be employed to improve safety on local roads using signs. This can consist of a review of site conditions and crash data to identify locations or crash patterns where deficiencies exist or signs can address a safety issue. In using signs on local roads, a practitioner should take care to avoid overuse, which could potentially lead to drivers ignoring them and degrading safety. n

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More Visible Pavement Markings: Improved Vehicle Guidance

Roadway departure crashes represent a significant safety concern, particularly in rural locations. Statistics from 2009 indicate that 29 percent of fatal crashes occurred during the night, while 10 percent of fatal crashes occurred during rain, snow or sleet conditions.¹ Although many of these are single vehicle run off the road crashes, they also include vehicles that leave their lane and crossover into oncoming traffic, one of the causes of head-on crashes. During reduced visibility, under such conditions as nighttime and wet weather, drivers require more assistance in identifying and maintaining their travel lane and require additional preview time to drive confidently and safely at night. To provide this preview time, effective roadway delineation is important. Sufficient roadway delineation can be achieved through a variety of means, including more visible pavement markings, which can make a significant contribution to safety.

More visible pavement markings can help address traffic crashes by providing a roadway that is more clearly marked so that drivers can identify and maintain their lane. AASHTO's *Strategic Highway Safety Plan* cites the use of pavement marking improvements as a strategy to reduce run-off-the-road crashes.² Among the low cost pavement marking solutions that are available include higher contrast markings, wider markings, higher retroreflective materials and raised pavement markers (reflectors). Each of these strategies offers improvements over standard markings, particularly at locations that may require enhanced delineation (ex. curves, work zones). An Iowa study found retroreflectivity to be a statistically significant factor in crash probability occurrence. For white edge lines and yellow center lines, crash occurrence

probability was found to increase with decreasing values of longitudinal pavement marking retroreflectivity.³

Wider pavement markings have shown to be effective in improving safety. Data from New York indicated that a 10 percent decrease in total crashes and a 33 percent decrease in fixed object crashes were observed when 8-inch wide pavement markings were used as opposed to 4-inch wide markings.⁴ Similarly, the Texas Transportation Institute found that in Michigan, wider markings produced different percentages of reductions for different crash types, including a 24.6 percent reduction in fatal and injury crashes, a 39.5 percent reduction for crashes at night and a 33.2 percent reduction in wet crashes at night.^{5, 6} The dimensions of wider markings can vary, ranging from 5 inches to 8 inches, with 6 inches being the most commonly used according to the TTI study 4. The cost of a wider pavement marking is generally 20 to 50 percent higher than standard markings, which can cost between 10 cents to \$2.35 per foot depending on location and material (paint, thermoplastic, tape).⁷

Raised pavement markers are reflective markers used on longitudinal lines which provide additional delineation and can also provide auditory and tactile warning if driven over. They may be retroreflective (reflecting light back to the source) or non-retroreflective and can be installed in a raised position on the pavement or in a recessed groove to allow for snow plowing. The effectiveness of this countermeasure on local roads varies. NCHRP *Report 518* found that raised pavement markings were only effective on high-volume two-lane roads (Annual Average

Daily Traffic (AADT) greater than 15,000 vehicles per day) with degrees of curvature less than 3.5 degrees, reducing crashes by 24.3 percent.⁸ A Kentucky study found that raised pavement markers on two-lane roads with AADTs greater than 2,500 produced slightly lower crash rates than on roads without markers (2.65 versus 2.70).⁹ The cost, including installation, per raised pavement marker ranges from \$2 to \$38, depending on whether the marker is non-snowplowable, snowplowable, recessed, etc.¹⁰ Note that no discussions of the maintenance costs at locations where regular plowing is necessary were available.

Even where standard pavement markings may be used, they have been shown to have a positive effect on safety. Using data from a number of different states, it was found that an average crash reduction of 21 percent could be attributed to pavement markings, producing a benefit-cost ratio of 17.0.¹¹ As an example, the addition of an edgeline where one is not already present has been shown to have the potential to improve safety for a low cost and should be considered. However, the addition of a centerline on low-volume rural roads (500 vehicles per day) was only beneficial to safety when roadway widths were 20 feet or greater.¹²

All pavement markings can be beneficial, but by their nature, they will wear out, fade and lose their effectiveness over time. Therefore, it is important to

have a plan for maintaining pavement markings and upgrading them when necessary. The plan should consider traffic, environmental conditions and potential safety needs. Using this systematic approach will allow for the planning and justification of resources needed to keep pavement markings maintained and effective.

Retroreflectivity is a good practice to employ when pavement markings are present on a roadway. Whenever pavement markings are installed or rehabilitated, they should incorporate retroreflectivity performance to the greatest extent possible. For some types of markings, such as liquid pavement markings (i.e. paint, thermoplastic), this is achieved by dropping glass beads onto the liquid binder. For other types of markings, such as preformed tape, the pavement marking material already contains retroreflective beads manufactured into the product.

Warrants for and details of pavement markings can be found in the MUTCD,¹³ and supplemental guidelines on implementation can be found in the *Roadway Delineation Practices Handbook*.⁸ The reader is encouraged to review each of these references for details as they pertain to their specific application. Additionally, the reader should reference local guidance (ex. state Department of Transportation manuals) regarding pavement marking standards and applications for their locale. n

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Better pavement markings delineate travel lanes for drivers during all conditions.

Rumble Strips and Stripes Alert Drivers to Lane Departure

According to the Federal Highway Administration (FHWA), roadway departures account for over half of all fatal crashes.¹ A large proportion of these crashes occur along rural, two lane roadways. The majority of these crashes are driver behavior related, including speeding, alcohol, distraction or inattention. A common, low cost solution to provide warning that a vehicle has left the travel lane is the use of shoulder and center line rumble strips and stripes. Such strategies are one of the top short term strategy recommendations of the National Cooperative Highway Research Program's (NCHRP) *Report 500 Volume 6*, which focuses on the reduction of run off the road crashes.²

Rumble strips and stripes in all forms are crosswise grooves milled into a pavement that produce an auditory rumbling sound and vibratory sensation to the vehicle when driven on, alerting the driver that the vehicle has left the travel lane and is encroaching on the shoulder or crossing the center line. These sensory warnings provide an opportunity to take corrective action. Rumble strips were originally used on expressways and freeways along shoulders, but have seen increased use in two lane rural road applications on both the shoulder and the center line. When applied to the center or edge line, a rumble strip more often takes on the form of a stripe, as the line is painted over the milled grooves.

Rumble Strips

In general, it has been noted that there is a great deal of variability regarding rumble strip dimensions between states.³ The FHWA's Office of Safety has developed technical advisories for shoulder and center line rumble strips, including dimensions which are based on those provided in NCHRP *Report 641*.^{3,4} Shoulder rumble strip dimensions are 5 to 7 inches wide by up to 16 inches long, with varying depths and spacing's. Center line rumble strip dimensions can vary between agencies, ranging from 6.5 to 7 inches wide, 8 to 18 inches long, a half inch deep, and spaced between 12 and 24 inches apart. Note that shoulder and centerline rumble strips can be used together on a segment. The reader is encouraged to reference the standards which pertain to their locale for further information on dimensions.

The cost of a shoulder rumble strip ranges from 18 cents to \$1 per foot, installed, while center line rumble strips cost between 20 cents to 85 cents per foot, installed. Costs will vary by location and the type of rumble strip being installed. Their layout may vary, depending on conditions or needs, and include continuous strips which only break for intersections, or incorporate recurring gaps in the pattern. Installation of all types of rumble strips can

be performed at the time of paving/repaving (both asphalt and concrete) by rolling or forming the groove, or at a later time through milling. Note that milling is the preferred approach to installation, as rolling can produce construction problems and does not produce the same warning effect.

Rumble strips do raise noise concerns, particularly for adjacent residents. These concerns may be addressed by the removal of rumble strips in spot locations, increasing the distance between grooves, or modifying their dimensions.⁴ There have also been concerns from bicyclists regarding safety on roads with rumble strips.⁵ When center line rumble strips are used, a width of 14 feet of pavement beyond the strip should be provided, while shoulder rumble strip treatments can incorporate recurring gaps, adjusted design dimensions or the use of edgeline rumble strips.⁴

The effectiveness of rumble strips has been evaluated by several studies. In Connecticut rumble strips produced a 32 percent reduction in single vehicle fixed object off roadway crashes.⁶ Rumble strips on two-lane rural roads with limited shoulders in Kentucky produced statistically significant lower crash rates than roads without rumble strips.⁷ Data from California, Colorado, Delaware, Maryland, Minnesota, Oregon and Washington indicated that center line rumble strips reduced total crash frequencies by 14 percent and injury crash frequencies by 15 percent.⁸ Rumble strips also produce high benefit-cost ratios ranging from 2.0 to 221.0, depending on roadway volume and shoulder width.⁹

Edgeline Rumble Strips (Rumble Stripes)

Edgeline rumble strips (sometimes referred to as rumble stripes) involve the placement of rumbles on the edgeline of a roadway, with the edge line pavement marking painted over the rumbles.^{4,10} The dimensions of rumble stripes vary by locale, but in general, they are 6 to 12 inches wide, 7 inches long, and one half to five-eighths inches deep, with 5 inch gaps between each milling. They are installed by milling existing pavements, with a cost of between 25 cents and 53 cents per linear foot (depending on location). A shoulder does not need to be present for rumble stripes to be used.

An evaluation by the Michigan Department of Transportation found that dry and wet rumble stripes provide six to 20 times more retroreflectivity compared to standard edgelines.¹¹ In Texas it was found that wet night visibility was enhanced, with rumble stripes found to provide an additional 25 feet of visibility distance compared to traditional markings.¹² A Missouri study indicated

that a benefit-cost ratio of 59.3 was possible when rumble stripes were applied to rural, two-lane roads.⁴ In Texas, rumble stripes held the potential to produce benefit-cost ratios ranging from 50.0 to 200.0.¹³

Both rumble strips and stripes offer a low cost approach to addressing run off the road and center line crossover crashes. Evaluations performed to date for different installations have shown that they significantly reduce crashes and produce high benefit-cost ratios. In providing drivers with

an auditory and vibratory warning, rumble strips and stripes provide an opportunity to correct a vehicle's path and remain in the travel lane. Their low cost and ease of installation makes them an attractive safety solution. The reader is encouraged to reference other sections of this document that discuss the identification of safety issues for different approaches in identifying roadways where rumble strips and stripes might be employed.

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Rumble strips and stripes provide warning that a vehicle has left the travel lane. Rumble stripes also aid in enhancing edgeline visibility.

Lane Separators with Flexible Channelizer Posts

Lane separators, also called mountable raised curb systems, have predominately been utilized at highway-railroad crossings to discourage motorists from driving around lowered gate arms. Lane separators, as defined in the 2009 MUTCD, typically consist of a plastic or rubber curb section supplemented with an upright tubular marker or vertical panel.¹ States such as North Carolina, Florida, Arkansas and Michigan have implemented and documented their experiences with lane separators at highway-railroad crossings.^{2,3} More recently, a study in Iowa employed curb systems for traffic calming purposes in rural communities with mixed results. Finally, while curb systems have also been used along right-turn lanes or in medians to restrict access, limited evaluation results have been published to date. However, NCHRP Report 617⁴ identified the need for a safety evaluation of lane separators between through lanes and right-turn lanes.



Figure 2: Railroad-highway crossing with lane separators. Photo by Peter Speer.

An evaluation in Florida investigated the safety effects of the installation of curb systems at three highway-railroad grade crossings.² They used video cameras to record the violations in the before and after periods. Most installations had the curb systems extend for 197 feet on each side of the crossing unless the geometry of the crossing limited the length. A total of 25 violations across the three locations were observed in the before period. The length of the separators proved to be a factor: only one violation was observed in the after period where the flexible traffic separators extended for a shorter distance because of an adjacent intersection. The authors provided four recommendations based on the study results:

1. Consider the width of the pavement; some channelizers were damaged where the width was less than 11 feet
2. The length of the channelizing system should extend to the maximum expected queue length to discourage violations
3. The treatment should only be applied to locations with a violation history
4. The treatment should only be applied to locations with traditional geometry (i.e. 90 degree intersection, no intersections in close proximity)

The installation of curb systems in the median on the approach to railroad gates has been implemented at 18 locations along the North Carolina "Sealed Corridor."³ Curb systems were one

of nine total warning or "other improvement type" of devices being used to improve safety. The objective of installing the curb systems is to discourage motorists from going around lowered railroad gates. Each installation costs approximately \$10,000; this makes them the second least expensive of the nine options. Only closing a crossing is more cost-effective. An evaluation of the crashes was performed to quantify the safety effect of the curb systems and other treatments. It found that by themselves, the curb systems reduced gate violations by 77 to 80 percent.^{3,5} When combined with a 4-quadrant gate, they were found to be from 92 to 98 percent effective.^{3,5}

Lane separators were utilized as a traffic calming device in Slater, Iowa, a small, rural community.⁶ The county highway outside of the town has a posted speed of 55 mph whereas in town, the posted speed limit is 25 mph. The yellow curb systems were arranged to form two separate islands about a block apart. They were spaced such that 11 feet of roadway remained on either side. The authors planned the arrangement of the curb systems so that farm equipment and snowplows were not negatively impacted. At each end of the island, 25 mph speed limit signs were attached to a mountable sign support. The 85th percentile speeds observed before the installation were 40, 45, 36 and 40 mph.

As a result of snowplow blades extending wider than expected, the curb systems were removed about nine months after their installation, although reinstated when the weather allowed. Therefore, there were two periods during which the curb systems were installed. During both before and after periods, approximately one and three months after periods showed a reduction in 85th percentile speed from 1 to 3 mph. The 85th percentile speeds observed three months after the first installation were 39, 42, 35 and 39 mph. The 85th percentile speeds observed three months after the second installation were 40, 43, 35, and 40. Additionally, a reduction in the percentage of motorists traveling at speeds 5 and 10 mph over the speed limit was observed; however, speed counts of 15 and 20 mph over the speed limit remained fairly consistent. Because of the removal of the devices at nine months, there is a need to consider the longer term effects of the speed reductions. Additionally, installations similar to this one in areas with snow accumulation should be carefully considered to ensure that a snowplow has sufficient space to perform its duties.



Figure 1: Lane separators for through and right-turn lanes. Photo by Peter Speer.

Several states, including New Mexico, Florida and California, have installed flexible traffic separators in medians to convert full-medians to directional-medians or completely close off turning movements as shown in Figure 3.^{7,8} The installations of curb systems are both a quick and inexpensive way to address high-crash locations. A study in Florida employed an Empirical Bayes before-and-after study to analyze 45 sites where the flexible traffic separators converted full-access medians to either left-in or directional medians.⁷ They found a statistically significant 60 percent and 70 percent reduction in left-turn crashes, respectively, as a result of the conversion. Zhou et al. estimated the construction costs to be about \$25,000 per location.⁷



Figure 3: Median closures using lane separators. Photo by Peter Speer.

Lane separators are a low-cost option that can be used for railroad-highway crossing compliance, traffic calming and to close or restrict median turning movements. They have proven to be quite effective, achieving 80 percent compliance. Applications for traffic calming are limited, but initial results indicate a slight benefit. Finally, the use of curb systems with upright channelizers to restrict or eliminate turning movements in medians has shown a reduction or elimination of left-turn crashes. These applications are particularly appealing because they can be implemented in a relatively short period of time at a cost significantly lower than reconfiguring the curb and gutter of the median. n

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High Friction Treatments for Horizontal Curves Reduce Skid-Related Crashes

Federal Highway Administration (FHWA) statistics indicate that 28 percent of fatal crashes occur at horizontal curves, and over 80 percent of these crashes involve some form of roadway departure.¹ Over 50 percent of these fatal crashes occur on roadways classified as Local Roads and Collectors.² One contributor to vehicles leaving the roadway at horizontal curves is insufficient pavement friction. A Federal Highway Administration technical advisory on pavement friction management stresses that curves tend to lose friction at a faster rate than other locations and require higher friction.³ When a vehicle's frictional demand exceeds the frictional force between a tire and the pavement, a skid develops. Such skids are particularly a problem at horizontal curves when the pavement is wet, but may also be a problem because of low friction due to polished aggregate. On local roads, approaches to address low curve friction should be considered, such as the addition of high friction surface treatments. These treatments can address three conditions of concern: low friction, marginal friction affected by weather and friction values not compatible with approach speeds and geometrics.⁴

A high friction surface is different from other pavement treatments since it generally provides friction numbers in the range from 60 to the upper 90s. It is a thin application added on existing asphalt or concrete pavement and it provides no additional pavement structure. High friction surfaces consist of resin and polymer binders (urethane, silicon or epoxy) that are topped with extremely hard aggregates.⁵ One of the best performing commonly used aggregates is calcined bauxite but other less expensive aggregates have been successful for some conditions. The aggregate size is typically less than six millimeters, and its rough texture and greater surface area act together to increase friction. The binder acts to lock the aggregate in place, with the combined treatment able to withstand heavy braking and snowplowing. The result is a pavement surface that is resistant to polishing and provides improved friction and skid resistance. Since added friction is typically needed at spot locations (ex. curves), often the location only requires short sections. If the problem is high approach speed, pavement friction demand, the treatment may be needed in only one direction or approach lane.

The installation of high friction surfaces can be accomplished mechanically or manually. As the technology and application has evolved, the process has become more mechanized and easier to complete. However, for smaller treatment projects, a manual approach may be more practical. The installation of high friction surfaces is completed through a thin overlay process.⁵ Following implementation of any necessary traffic control, the pavement surface is swept clean and dried as needed. Large cracks may need to be sealed and weakened pavement repaired. The binder is mixed and spread over the treatment area using squeegees (manual) or a mechanical spreader. Aggregate is spread over the binder by hand or mechanically, with the excess swept away by brooms or sweepers. The binder takes two to four hours to set, depending on temperature, allowing for vehicles to drive on the treated area shortly after completion.

The use of high friction surface is not new and has shown to be effective over time, both internationally and in the U.S. Observations of the effectiveness of the treatment date back to 1976, when findings from 800 intersections in New York indicated crash reductions of 31 percent were achieved.⁶ In Florida, a before and after comparison found that two crashes occurred in the year following an overlay on an interchange ramp, compared to 12 crashes over a two year period prior to treatment.⁷ The New York DOT found that after high friction surfaces at 36 sites produced a reduction of more than 800 annually recurring wet pavement crashes.⁸ Finally, on a recent curve application in Kentucky which had experienced 59 crashes in the two years prior to installation (2009), two crashes have occurred since.⁴

The cost of high friction surfaces is low, ranging from \$16 to \$25 per square yard, including installation with traffic control.⁹ For a low speed curve requiring an assumed road section 300 feet long with a pavement width of 26 feet (867 square yards of surface), treatment would cost between \$13,872 and \$21,675. The exact cost will vary by the amount of surface being treated and locale. As indicated earlier, treatments can be applied to limited lengths of roadway manually or mechanically, providing an opportunity to achieve safety improvements quickly once a

site has been identified and materials acquired. Maintenance needs are not a significant issue, as aggregate materials have been observed to retain high friction numbers (exceeding 60), in long term testing under heavy traffic conditions.⁹

The key to effectively employing high friction surfaces is to identify the sites where they will achieve the greatest impact. One approach is to look for sites with high occurrences of skid related crashes, including during wet conditions. An agency can also perform field measurements of pavement friction, should testing equipment be available; however, note that some devices such as skid trailers do not measure friction in curves well. In light of this, other approaches such as the identification of most severe curves for treatment based on estimates of different aspects such as side friction demand and kinetic energy might be considered.¹⁰ In the case of friction numbers, studies have indicated that numbers less than 35 to 40 (measured at 40 mph using a ribbed tire) are associated with increased

crashes. Note that this does not take into account the additional friction needs of vehicles in curves.¹¹

High friction treatments on horizontal curves offer an opportunity to enhance friction and reduce skid crashes for low cost. Such treatments employ a binder and wear resistant aggregate to enhance friction in a small but critical area. These treatments can be applied on curves which have exhibited problems with skid-related crashes in a relatively short timeframe, allowing for safety improvements to be achieved quickly. Installation can be completed manually or mechanically and generally takes less than one day to complete. The cost of high friction treatments will vary by surface area and locale, but in general the overall project can be low cost, offering an opportunity to treat curve locations on a spot basis quickly. For further information on high friction surfaces, the reader is encouraged to visit the high friction roads website.¹² n

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Installation of high friction surfaces manually and mechanically.

Unsignalized Intersection Lighting Improves Site Visibility

Approximately 39 percent of fatal crashes occur at rural intersections, and more than 80 percent of these occur at unsignalized intersections.^{1, 2} These crashes take on a number of different forms, including right angle, rear end, left-turn and sideswipes. Many of the crashes at rural intersections occur at night and are the result of drivers being unaware of the presence of an intersection.³ One approach to address nighttime rural intersection crashes is the addition of overhead lighting.

The purpose of overhead lighting at rural intersections is to add to the illumination provided by a vehicle's headlights. Lighting can be full, to increase overall visibility, or destination, to guide a driver to the intersection or alert them to its presence.⁴ The application of lighting should be done at sites which experience substantial patterns of nighttime crashes. The installation of lighting at these sites will provide added illumination for drivers to improve perception-reaction times, see other vehicles and avoid conflicts. It also enhances sight distances and improves the visibility of non-motorists. The identification of such sites can be completed through the safety review processes outlined in other sections of this document.

A number of studies have found that lighting at rural intersections has produced a positive safety benefit. The Federal Highway Administration has reported that a crash reduction factor (i.e. the percentage of crashes that can be reduced) of 38 percent for injury crashes is associated with the installation of intersection lighting.^{2, 5} In Minnesota, a before and after study of 33 rural intersections found a 37 percent lower night time crash rate following the installation of lighting.^{6, 7} A previous Minnesota study of 12 rural intersections found reductions in nighttime crash frequencies of 25 to 40 percent and crash severities of 8 to 26 percent.⁸ Further analysis found that a lighting installation produced an average cost-benefit ratio of 15.0.⁸ Finally, an evaluation of nine rural intersections in Kentucky found a 45 percent reduction in nighttime crashes following the installation of lighting.⁹

The time required to implement lighting at a rural intersection can take up to one year due to design needs and arrangement of a connection to local power. The initial costs of lighting include design, materials and installation, which will vary by locale. Design must consider pole height, lighting wattage and type (light emitting diodes, mercury vapor, etc) and placement. In some cases placement can occur on a nearby utility pole (i.e. destination lighting) reducing material and installation costs. However, this may not always be practical from a proximity standpoint, and in other cases, illumination of the intersection itself (full lighting) is more desirable. In addition to initial costs, there are ongoing maintenance and power costs required for each installation. County figures from Minnesota (2006) indicated that the average cost to install a light ranged from less than \$500 to \$1,500, while

annual maintenance costs per light ranged from \$100 to \$300. However, as the number of sites with lighting increases, an agency must keep in mind that maintenance and electric costs will rise accordingly, and budgeting for these annual costs must be made. Still, rural lighting is a low-cost approach to address intersection safety in rural areas when applied in a systematic manner.

One limitation to the addition of rural intersection lighting is that it is feasible only where a supply of electrical power is available.³ Consequently, if power is not located nearby, an agency must be prepared to incur additional cost to bring power lines to the site. If running power to the site is cost-prohibitive, consideration should be given to other low-cost treatment strategies, such as supplemental signage, approach rumble strips or clearing sight triangles, among others, before choosing to add overhead lighting.

In considering the installation of intersection lighting, the reader should keep in mind is that some states or agencies have warrants or legal code statutes when intersection lighting may be installed. If a reader is unsure of whether warrants or legal code for lighting exist in their state, they are encouraged to contact the Local Technical Assistance Program (LTAP) for their state, which can be identified through the national LTAP website (<http://www.ltap.org/ntltpa/>). This will assist them in understanding local requirements (to the extent they exist) as well as help in identifying specific design criteria and considerations that might also be applicable in their area.

The installation of intersection lighting, particularly in rural areas, offers a low-cost opportunity to address nighttime crashes. Intersection lighting provides added illumination for drivers to see other vehicles and avoid conflicts, particularly at sites where they might not be aware of the presence of an intersection. The application of lighting should be made at sites that experience substantial patterns of nighttime crashes. Results from different states have indicated that the installation of intersection lighting produces reductions in various types of crashes and is also cost-effective. Material and installation costs per light are low, as are annual maintenance and operation costs. In determining whether intersection lighting should be installed, the reader should consult local warrants and legal code to determine what requirements may need to be met. n



Lighting provides the driver with a visual indication of the presence of an intersection.

Safety Improvements on Horizontal Curves with W-Beam Guardrail

Safety studies of local, rural systems in Minnesota have found that run-off-the-road crashes are overrepresented on horizontal curves.¹ Forty to fifty percent of the run-off-the-road crashes occurred on the horizontal curves, while horizontal curves represent only 10 percent of the county's system. Therefore, guardrail, which is used to redirect errant vehicles back into their traveled way, may be a good application where run-off-the-road crashes are an issue.

Guardrail is applied to locations where striking a barrier is expected to have less severe consequences than the terrain or object that the guardrail is protecting (Figure 1).^{2,4,3} While horizontal curvature is not listed as a typical roadside obstacle in the Roadside Design Guide, it could be considered an objective warrant for high performance barriers for adverse geometrics like sharp curves with limited sight distance or those with steep drop-offs.⁴

While guardrails may prevent vehicles from striking terrain or an object outside of the traveled way, they become an object that may be hit. Therefore, identifying the presence of the guardrail, particularly after dark, may help to reduce the number of hits that the guardrail sustains. This can be done through the use of reflective barrier delineation. For guardrail on horizontal curves, reflectors should be installed so that they are orientated perpendicular to oncoming headlights.⁵ The reflective sheeting should be the same color as the adjacent lines. Typically, sheeting is installed about eighteen to thirty-six inches apart. Keeping dirt and grime off of the reflectors can be a bit of a maintenance challenge. Individual reflectors cost about \$3 each and strips of four-inch linear reflective sheeting costs \$2.33 per linear foot. Adjusted to 2011 dollars, the cost is \$3.37 per reflector and \$2.61 per linear foot, respectively.¹¹

The blocked-out w-beam (strong post) is the "most common barrier system in use."⁴ The blocked-out w-beam reduces vehicle snagging on the posts and the probability that a vehicle is vaulted over the barrier because they help to maintain the height of the rail. Strong-post barrier systems are appealing because they "usually remain functional after moderate to low speed impacts, thereby minimizing the need for immediate repair."⁴ This may be appealing for local agencies that have limited personnel resources to handle significant repair issues.

In a study that drew from data from the Longitudinal Barrier Special Study, the New York Department of Transportation, the Alabama Highway Department, the Michigan Department of Transportation and the Illinois State Toll Highway Authority concluded that the "w-beam should be designed with a block-out when placed on horizontal curves."⁶ However, more recent research results imply that separate deformable release members may hold promise to replacing the block-outs, but the in-service experience is limited.⁷ While no in-service studies have been tied to the research results, Pend Oreille County in Washington State has installed some of the guardrails with the new release members that do not require the block-outs.⁸ The guardrails have been installed for about two to three years. The County installed them due to the width constraints

on the roadways that were identified for safety improvement projects as a result of their higher collision rate. All of the crashes observed at these installation locations to date have been with the guardrail terminal.



The cost of w-beam guardrail will vary regionally and over time. However, in-service studies reported a range of \$11.44 per foot (2004) to \$13.65 per foot (2003).^{9,10} Adjusted to 2011 dollars, these figures would be \$13.71 to \$16.80, respectively.¹¹

An analysis that drew from thirty-two studies performed both within and outside of the United States found that guardrails reduce the probability of a fatal injury and personal injury by 45 percent and 50 percent, respectively, when an accident occurs.²

Douglas County in Georgia was observing a significant number of run-off-the-road crashes.^{12,13} In addition to other low-cost solutions, Douglas County began implementing guardrail along horizontal curves. The horizontal curves that were targeted were high-priority locations as a result of steep drop-offs, no shoulders, or where speed studies and average daily traffic identified the location as a good fit. The applied guardrails were blocked-out w-beams. The installation of the guardrails combined with the other low-cost solutions resulted in a 50 percent reduction in crashes on the treated horizontal curves.¹³

An ongoing National Cooperative Highway Research Project entitled *Performance of Longitudinal Barriers on Curves, Superelevated Roadway Sections* is investigating the performance limits of barriers on superelevated roadway sections. The study involves computer simulation and full-scale crash testing. The results of this research will provide guidance for the design, selection and installation of longitudinal barriers on curved superelevated roadway sections. Therefore, the results of this study may be of interest to local entities with superelevated curved roadway sections when they become available.

In summary, w-beam guardrail may be installed on horizontal curves to protect motorists from hazardous terrain or objects. Therefore, the typical crash-type that such installations are intended to prevent are run-off-the-road crashes. Furthermore, guardrails are expected to reduce the severity of the crash. While their cost will vary by region, they offer a low-cost countermeasure to address spot safety issues. When impacted, they often remain functional, reducing the need for immediate repairs by local entities that are often faced with limited personnel resources. n

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COST EFFECTIVE LOCAL ROAD SAFETY PLANNING AND IMPLEMENTATION

The Safety Edge_{SM} Reduces Pavement Edge Drop Off Crashes

According to the Federal Highway Administration (FHWA), roadway departures account for approximately 53 percent of fatal crashes each year.¹ Among the roadway departure crashes that are most likely to be severe are those involving pavement edge drop offs. These crashes occur as the result of a vehicle leaving the paved surface and encroaching on an unpaved surface lower than the roadway, followed by an overcorrection to return to the travel lane. Pavement edge drop off is a condition where the pavement edge is at nearly a 90 degree angle to the pavement surface or on rounded shoulders. Study results suggest “drop-off becomes problematic at a depth between 2.25 inches and 2.5 inches”². The presence of pavement edge drop off may cause a “scrubbing” action to tires when drivers attempt to steer back onto the roadway. To overcome this scrubbing and climb back onto the roadway, drivers may over steer, losing control when the vehicle suddenly overcomes the scrubbing.³ The result may be a head-on, sideswipe, overturn or run off the road crash. Illustrations of pavement edge drop off are provided in the accompanying images

Previous work has established that pavement edge drop off represents a significant problem along the nation’s rural roadways.² Settling material adjacent to the pavement will create drop offs along all roads. On narrow pavements or at segments such as curves, vehicle tires will create greater drop-offs where gravel or earthen shoulder material migrates away from the pavement edge. Significant drop-offs are also created by erosion of this material where vegetation is lacking or grades create high-velocity run-off of water. In addition to maintenance to pull shoulder material back to the pavement edge/surface, a low cost solution to the drop off problem is the installation of the Safety Edge_{SM}. The Safety Edge_{SM} is a technique to shape and consolidate the pavement edge at a 30 degree angle to the pavement surface to provide a safer roadway edge and a stronger interface between the pavement and the shoulder. A pavement with the Safety Edge_{SM} eliminates the potential for scrubbing conditions by providing a vehicle with a smooth transition from the shoulder back onto the pavement. Illustrations of the Safety Edge_{SM} are provided in the accompanying images.

The installation of the Safety Edge_{SM} can be performed during any paving project, whether resurfacing or installing a new pavement (asphalt or concrete, with asphalt more common). It is accomplished by using a specialized “shoe” attachment or special end gate on the paver that acts as a screed extension (costs are \$2500 - \$5000 from different manufacturers), forming a compacted pavement edge at the desired angle.¹ Following the installation of the Safety Edge_{SM}, shoulder backing is restored as part of good practice, and is illustrated in an accompanying image. The Safety Edge_{SM} truly is a low cost safety treatment; the additional cost to incorporate the Safety Edge_{SM} represents less than 1 percent of the total material costs for a project, and requires no additional labor.⁴ In other words, on a \$1,000,000 resurfacing project, it would cost less than \$10,000 for the additional asphalt needed to incorporate the Safety Edge_{SM}. The cost savings through reduced fatalities, injuries, property damage and tort liability can exceed this additional cost to a project. It also improves the durability of the pavement edge and may extend the life of the pavement, providing further benefits.

Evaluation has found the Safety Edge_{SM} to be effective in reducing crashes. An evaluation performed on two lane roads in Georgia, Indiana and New York found that following installation, a 5.7 percent reduction in total crashes had occurred.⁵ Further analysis of the application in Georgia and Indiana found that cost-benefit ratios of 2.8 to 62.8 resulted from use on two lane roads, depending on the specific traffic and safety improvement scenario.

The FHWA has provided guidance on the application of the Safety Edge_{SM}, indicating that it should be incorporated into all Federal-aid new asphalt paving and resurfacing projects.⁶ By the end of 2012, the FHWA expects that 40 states will have used the Safety Edge_{SM} on projects and adopted it as a standard on paving projects, with corresponding design specifications established in each state.¹ The reader is encouraged to reference the design guidance specific to their state when considering the inclusion of the Safety Edge_{SM} in their particular project. If a state does not have guidance developed, a reader should refer to the FHWA’s specifications.^{7, 8}



FHWA



FHWA

Pavement edge drop off creates a height differential which a vehicle must climb to overcome tire scrubbing. In the left photo, the drop off is at an isolated location that lacks vegetation. The photo on the right is a roadway with consistent drop offs due to farm equipment using the shoulder.



FHWA



FHWA



FHWA

Installation of the Safety Edge_{SM} coincides with the paving operation.

In summary, the Safety Edge_{SM} offers a low cost solution to address pavement edge drop off issues and run off the road crashes. The Safety Edge_{SM} offers a gradual transition back onto the pavement surface when the pavement or shoulder edge has been encroached by a vehicle. It is a straightforward installation that can be made during any construction or repaving project for a minimal increase in materials and cost. The Safety Edge_{SM} has shown to be effective in reducing crashes and produces high cost-benefit ratios through a reduction in fatalities, injuries, property damage and tort liability claims. n

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FHWA

Technology Solutions on the Horizon

We are fortunate in the highway community that new life-saving technologies and innovations continue to emerge from our universities, highway agencies, and private sector. Through research, development, testing and deployment, the range of innovative technology solutions continues to expand and provide new tools for highway safety professionals. As with any research, not every new idea is ultimately successful; however, it is good to keep an eye out for these new ideas, particularly as they begin to emerge into the marketplace and begin showing results.

One example are Dynamic Curve Warning Systems (DCWS), a new product that uses solar power and microchip technology to provide added warnings on horizontal curves that continue to have a history of high crash rates, even after other approaches have been installed. Dynamic curve warning systems (DCWS) have been developed to both remind and persuade motorists to reduce the speed of their vehicles to the advisory speed limit on horizontal curves. They have been installed and used in addition to static signs because they have a greater effect on high-speed vehicles.¹

Several installations of dynamic curve warning systems have been implemented on interstates, whereas implementations on rural highways are limited. However, there are several installations on local roads which are currently in the process of being evaluated. In addition, the Federal Highway Administration

(FHWA) recently initiated an evaluation project deploying two different types of dynamic curve warning systems in a number of states, including Arizona, Florida, Iowa, Ohio, Oregon, Texas and Washington. The cost of these systems was \$6,000 and \$8,000 (2011)² Both systems generate messages based on the detected speeds of approaching vehicles. While the results will be published in an upcoming report, one of the manufacturers cites a 7 mph speed reduction sustained over five years and a 33 percent accident rate reduction over five years.³

Another new technology that is emerging is Intersection Warning Systems (IWS). These systems use low power vehicle detection sensors, Changeable Message Signs (CMS), wireless communications and solar power to provide active warning on cross roads that vehicles are approaching on the mainline. In general, the systems can be as basic as the addition of light emitting diodes to existing static signage (stop signs, advanced warning signs, etc.) to draw driver attention. Conversely, more complex systems have also been developed which use CMS signs to provide drivers with a visual indication of gap warning



Photo by FHWA

in real time.⁴ The FHWA provides an extensive discussion of different aspects of these systems online, including signing options, layout and placement, and cost (a maximum cost of \$35,000).⁵ An evaluation of IWS in Minnesota found that they reduced traffic conflicts at intersections from 3.9 per 1000 vehicles before installation to 1.8 per 1000 vehicles after installation.⁶ Surveys of drivers found that they were aware of the signs and understood their meaning. Intersection Warning Systems are still in the initial stages of deployment and evaluation on local roads, and the reader is encouraged to track their progress in the future through additional evaluations and reports.

With the development of high-tensioned cable barriers, there has been a renewed interest in the use of cable barriers in recent years. The majority of studies discuss cable barriers in terms of installations in medians, especially related to high-tensioned cable barriers. Furthermore, applications to date tend to be on interstates as compared with local roads. However, there are several appealing aspects of cable barriers including imparting less force on vehicles contained by them when compared with semi-rigid or rigid barriers, relatively low installation costs especially when compared with other barrier options and aesthetic appeal that make them a potential countermeasure on local roads in the future.

In contrast with low-tensioned cable barriers, high-tensioned cable barriers have shown to be able to withstand several hits.^{7,8,9} Even so, while the cables may maintain a serviceable height and are in theory functional, manufacturers do not assert that they are.¹⁰ When hit, they also exhibit less deflection as compared with low-tensioned cable barriers. However, these characteristics also result in high-tensioned cable barriers imparting more force on the vehicles contained by them when compared with low-tensioned cable barriers. Research results indicate that the benefits of installing high-tensioned cable barriers when considering accident severity may be small if not negligible.¹¹ However, when compared with rigid barriers, they still contain a vehicle rather than redirecting it back into traffic.¹² There have been reports of high-tensioned cable barriers

containing large vehicles which would otherwise “tear through the w-beam system.”⁸

There are additional drawbacks and benefits to cable barriers. First, there are concerns with the impact of cable barriers on motorcyclists. However, the Roadside Design Guide identifies concerns with a motorcycle's impact with w-beams as well.¹⁰ Second, in areas with significant snowfall, cable barriers can be damaged by snow plow operations.¹³ Third, special care is needed in the installation of the cable barriers – they are sensitive to correct installation height and maintenance.¹⁰ Where installations have not been to specification, reports of vehicles underriding or overriding the cable barriers have been occurred.^{13,14,15,16} There are also concerns with the performance of cable barriers on horizontal curves.^{10,14} In particular, cable barriers placed on the inside of horizontal curves will need additional deflection distance before the tensioning in the cables develops. Along with the drawbacks, there are several benefits. First, cable barriers reduce snow drifting.^{8,16} Second cable barriers are aesthetically appealing because they unobtrusive to the surrounding landscape.¹⁴

High-tensioned cable barriers were reported to cost between \$8 and \$15 per linear foot (2004, 2005).^{7,8,13} Adjusted to 2011 dollars, this equates to a range of \$9.27 to \$17.98.¹⁷ However, a potential user of cable barriers should consider that there may be more maintenance costs associated with cable barriers over their lifetime.

These examples simply highlight the kind of innovations that are “on the horizon” to address safety problems on rural roads and intersections. The cost of such systems will likely become even more attractive as additional applications are developed, and more autonomous power sources (solar power and batteries) are brought to market. While these technologies are still in the initial stages of deployment and evaluation, they may very well offer just the kind of solution that you need. This is why it would be good for you to keep an eye out for these new products and innovations, particularly as they are evaluated and tested in the coming years. n



Figure 1: Cable guardrail. Photo courtesy of Michigan DOT Photography Unit.

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Illinois' Towards Zero Deaths Partnership

Illinois had 911 traffic-related fatalities in 2009, which is the lowest number since 1921.¹ It is no coincidence that the drop corresponded with the creation and subsequent initiatives of the Bureau of Safety Engineering. The bureau made it a priority to direct more funding to local roads, where 50 percent of the fatalities occurred.²

Eighty percent of roadways in Illinois are under local jurisdiction. However, only 20 percent of total vehicle miles are traveled on these local roads.² Since 50 percent of the fatalities occurred on these roads, the Illinois Department of Transportation decided to "jump in both feet first" by allocating 20 percent of their State Highway Improvement Program and High Risk Rural Roads Program money toward infrastructure improvements on local roads.² While this may not seem like a significant change, consider the expenditures before and after the creation of the Bureau of Safety Engineering. Before its creation, \$750,000 of the \$17 million allocated for safety improvements went to local roads. The funding level, which was about 4 percent, could only address one or two major projects. Now with the Highway Safety Improvement Program investments, the Bureau of Safety Engineering has \$50 million to operate with, of which \$8 to \$10 million is invested at the local level. That is a significant increase in investment. The only "challenge" that Illinois has with investing the funds at the local level is identifying appropriate projects. However, the Statewide Local Safety Summits and development of county safety improvement plans will assist with identifying more appropriate projects.

Illinois holds annual Statewide Local Safety Summits. These summits serve the purpose of helping to inform people on the State Strategic Highway Safety Plan, allowing discussions on the emphasis areas for Illinois and current crash statistics. Participants are also given an overview on how to perform data analyses and countermeasure selections and identify potential funding sources. In addition, initiatives like Road Safety Assessments (RSAs) and system-wide improvements are presented. The summits benefit participants by helping them understand the process of identifying types of projects, what projects are eligible for funding and how to receive funding for their projects. It allows local entities to meet one-on-one with state employees where they can determine if they need additional assistance on addressing a local problem.

Illinois is in the process of working with eight counties to develop a county-specific safety plan that ties in to the larger State Strategic Highway Safety Plan. These counties were chosen because they had a higher number of fatalities when compared with the other 94 counties. The DOT is organizing a workshop where representatives of the 4Es (engineering, education, enforcement and emergency response) will convene to develop a plan with the counties. Illinois is facilitating the process by providing manpower and funding for a consultant to assist in the development of the plan.

The Bureau of Safety Engineering with key safety team members and representatives from state and local law enforcement has supported counties with RSAs,² by providing training and conducting RSAs. The RSAs conducted on the local system have resulted

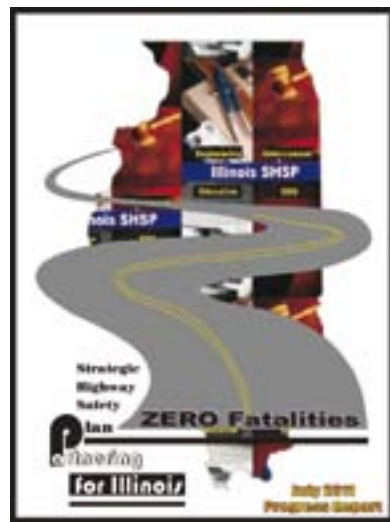
in coordinated infrastructure, enforcement and education programs to address areas with high concentrations of severe crashes. These RSAs typically result in funded safety projects. The use of law enforcement has helped expand the use of RSAs on the local roadway system.

The state of Illinois was not always able to provide crash reports to the local entities.¹ Similar challenges are found within other states throughout the United States. Legislation had to be modified to allow local entities engaged in highway safety research access to the crash reports. The Illinois Municipal League, the County Engineers Association and the Public Works Association worked with their lobbyists to get legislation passed that would allow local entities to access the crash data. Privacy concerns were the biggest issue in allowing access to these documents because of the personal information contained in the crash reports. As a result of their efforts, the local agencies are now able to access crash reports, which assist local entities in addressing safety in their area.

As another means to analyze local crash data, Illinois partnered with the AAA to pilot usRAP, a program designed to help cut death and serious injury rates through systematic risk assessment, to ensure that strategic decisions are linked to risk assessment, and to forge partnerships among those responsible for a safe road system.² Illinois and AAA worked with one of the urban counties in Illinois to analyze data and develop risk maps using usRAP. This program has been an efficient method for identifying high priority locations that meet benefit-cost efficiencies. This program will be expanded to seven additional counties of focus.

The Illinois Department of Transportation also credits the Federal Highway Administration's (FHWA) Illinois Division, a partner, with the improvements to traffic safety in the State. The partnership with the FHWA is so fluid that it has been described as an "extension of staff" as a result of working closely with the local agencies and the state.²

Illinois has demonstrated that significant investments at the local level can provide notable results. Working with local entities through workshops and Statewide Safety Summits helps further engage the local entities. The state is currently working on developing county-specific safety plans that tie into the state plans which will only help advance transportation safety in Illinois. Finally, Illinois shows that while some hurdles, like outdated legislation may exist, being proactive at the local level can help to remove such barriers. n



Illinois ZERO Fatalities. Photo by Illinois Department of Transportation.

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Minnesota's Towards Zero Deaths Partnership

In 2003, the Minnesota Department of Transportation (MnDOT), in conjunction with the Department of Public Safety, initiated a Towards Zero Deaths program.¹ The program focuses on implementing an interdisciplinary approach to traffic safety through the use of the 4Es: education, engineering, enforcement and emergency medical and trauma services. The success of the program speaks for itself: Minnesota went from 655 traffic fatalities in 2003 to 411 in 2010 (Figure 1), a 37 percent decrease. Furthermore, the state can now boast the second lowest number of fatalities per 100 million vehicle miles traveled in the nation. Since the program's inception, MnDOT estimates that 900 lives were saved. As a result of the program's success, MnDOT was recognized in 2009 with the Global Road Achievement Award by the International Road Federation.^{2,3}

What was the key to Minnesota's success? Local investment. Minnesota realized that the crash data was telling them that money should be spent on local highways, not just on state roads.³ Redistributing funding solely from state to a combination of state and local roads did not happen overnight. To begin, Minnesota started out small. In the first year, a very small amount of the funding that Minnesota received from the federal government was allocated to local roads.² This funding was only used for smaller projects like safety inventories. As the program matured, the safety projects at local levels advanced from safety inventories to low-cost treatments like chevron installations and rumblestrip implementations.²

As the program grew, additional initiatives were implemented, including the creation of a State Aid Safety Engineer position, providing funding for each county to develop county-wide safety



Minnesota Fatalities Over Time.¹

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plans, and the requirement for a county to initiate a 4E Coalition in order to receive funding. All of these initiatives will be discussed in the following sections.



MnDOT utilized funding provided by the federal government to develop the State Aid Safety Engineer position.³ What does a State Aid Safety Engineer do? Looking at the position holistically, the engineer is there to assist the local entities. They are the glue that connects the state and local level in the partnership Towards Zero Deaths. In addition, the State Aid Safety Engineer helps ensure that the money is being spent appropriately, and they take good ideas from other locations and share them with the local entities.² Most importantly, the individual holding this position helps the local entities implement the most effective safety project, not just a safety project.³ While it is true that using funding to create a position may take some funding away from other projects, the MnDOT says that the benefits far outweigh not being able to implement the projects.

Minnesota developed a State Highway Safety Plan in 2004.⁴ Yet, as Minnesota began to address local roadway safety, it realized that it needed a "data-driven" plan for local entities.³ This realization led to the idea of developing county-wide plans that spoke to the statewide safety plan.² The state utilized funding to hire consultants to work with each county to develop county-wide safety plans so as not to overburden the counties with this task.³

Minnesota may have a bit of an edge when compared with other states as they had already had crash data available at the local level; however, the data was not very user friendly. Therefore, Minnesota borrowed a crash analysis tool called CMAT from its neighbor, Iowa, and modified the tool to fit Minnesota's needs.² Minnesota has named their version MnCMAT. The State Aid Safety Engineer assisted with the conversion.³

MnDOT addresses safety through the 4Es, and these initiatives are carried out at the county level through County 4E Coalitions.² Any county that received safety money from the state must establish a County 4E Coalition. The coalition is composed of educators, law enforcement, city engineers, a county engineer and the Minnesota regional traffic engineer. They meet on a quarterly basis to discuss crashes or future planning. The outcomes of these meetings further advance the safety initiatives. For example, the group discussed a crash that was on the border of two counties. Because of its location, it was not clear which entity would respond. Therefore, the group developed a future protocol to identify the responding agency for future crashes that may occur along borders.

An important part of sustaining Minnesota's Towards Zero Deaths initiative is the dramatic reduction in fatal crashes. To get to this point, Minnesota started out small by investing in small projects at the local level. Due to the success of these initial investments, larger projects requiring more financial investment, forming the State Aid Safety Engineer position and providing funding for county-wide safety plans were made. n

Utah's Towards Zero Deaths Partnership

In 2006, Utah launched its "Zero Fatalities: A Goal We Can All Live With" program.² Zero Fatalities is a "mutual effort between various state partners to address the top behaviors that lead to road fatalities in Utah."¹ The program has already seen success when in 2009 Utah had its lowest number of traffic fatalities, with 244, in 35 years.²

To help promote its safety initiatives, Utah hosts Safety Summits. The Safety Summits provide two primary benefits: bringing the focus to safety issues during the summits and generating new ideas.³

Like other states, Utah has found that roadway fatalities are overrepresented in rural parts of Utah.⁴ Therefore, it is no surprise that rural road safety remains one of the 10 Continuing Safety Areas for the Utah Department of Transportation. For each Continuing Safety Area, leaders from the partnership are identified. For the Rural Road Safety Continuing Safety Area, the Utah DOT, Federal Highway Administration and Utah Local Technical Assistance Program Center are the identified leaders. Their strategies to address rural road safety include three initiatives:

1. Continue the rural roadway signing program
2. Continue Road Safety Audits
3. Implement a High Risk Rural Roads Program.

The rural roadway signing program benefits local entities by providing them with additional guidance and expertise.³ For this program, state department of transportation personnel and local entities work collaboratively to look at the roadway signing.

The Road Safety Audits (RSAs) benefit local entities by considering a problem from a wider perspective.³ Collaboratively working with law enforcement on RSAs is a very important part of the partnership. As a result of the broader perspective from participants of an RSA, a more diverse set of solutions may be proposed.

Although the High Risk Rural Roads Program was initiated in 2006, the *High Risk Rural Roads Program Manual* was recently updated for Utah in April 2011.^{5,6} Utah has a unique challenge from many states due to the rural nature of many roads. The definition of rural in Utah differs from that in the east because a motorist can travel for hours on a rural road in Utah without crossing paths with another person or vehicle. In addition, counties within Utah operate with a very small staff typically consisting of an office manager, law enforcement person and maintenance person. Therefore, the "grant application" style of program administration seen in other more populous states may deter counties from participating. As a result, the state worked to partner more directly with counties. After identifying counties with above average fatality statistics, state employees sat down with county staff to gain an understanding of operational observations. The results of these collaborations are projects that include installing warning signs, like curve chevrons, and delineators along the roadside. One of the partners, the Utah Local Technical Assistance Program, followed up with the counties that had installed signs as a result of the High Risk Rural Roads Program to assist the county in creating an inventory.

Finally, the Utah Department of Transportation provides additional support to local entities by providing equipment, like speed monitor trailers, in-car video cameras and other safety equipment, which local entities might not otherwise be able to afford.⁴ For example, the speed monitor trailers can help to address local speeding issues.

In summary, Utah is working Towards Zero Deaths by addressing safety problems in local areas. It holds Safety Summits, coordinates a rural highway signing program, RSAs, and it loans out safety-related equipment to local entities. All of these initiatives have helped to contribute to the success of the Utah Department of Transportation in reducing the number of traffic fatalities. n

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Washington State's Towards Zero Deaths Partnerships

The state of Washington began working toward the objective of achieving zero deaths by 2030 in 2000.¹ The pay-offs of this program have already generated successes: traffic fatalities are the lowest that they have been in 60 years, even with an increase in vehicle miles traveled.¹

Sixty-one percent of traffic fatalities occur on rural roads in Washington.¹ When diving deeper into these traffic fatalities, the major crash type identified is run-off-the-road.^{1,2} There were approximately 3,900 crashes between 2002 and 2006 on approximately 39,000 miles of roadway. Addressing each crash would likely only address a random occurrence, not solve the larger problem. Therefore, Washington considered the issue at the county level. It ranked the 39 counties based on the rate of fatal and serious injury run-off-the-road crashes per mile. Counties were also ranked based on the rate of fatal and serious injury run-off-the-road crashes per million vehicle miles traveled. Using these rankings a funding/programming target was developed for each county. Again, because there were many miles over which the crashes occurred, systematic safety improvements are being implemented at the local level by each county. Some examples of improvements include edgeline and centerline rumblestrip installation, adding striping on the centerlines and edgelines, removing and delineating fixed objects, limited guardrail installations, addition of safety edges to pavement or upgraded the signage.^{2,3} A similar approach was developed based on intersection related crashes on county roads, which considered intersection related crashes per mile. An additional funding/programming target was provided to each county for intersection improvements. The final scope of each county level program was required to be consistent with the Strategic Highway Safety Plan and was negotiated between the state and each county.

A unique agency in Washington is the County Road Administration Board (CRAB). It has been in existence since 1965, originally to

provide statutory oversight of Washington's counties.^{4,5} Now CRAB is also in charge of overseeing the Rural Arterial Program (RAP) and County Arterial Preservation Program (CAPP). It also administers Certificates of Good Practice. RAP's money is generated through fuel tax revenues. The money is directed to road and bridge reconstruction. RAP funding is competitive, and safety is a big part of the competition. RAP projects may encompass corrections to site distances or getting pedestrians off of the roadway. The level to which a proposed RAP project incorporates safety contributes to its likelihood of funding. CAPP assists counties with the preservation of existing, paved arterial road networks. CAPP is not competitive. There are no points for safety considerations in the projects. However, aspects of the program, including ensuring that fog lines are on the road, bring their own safety benefits. Finally, when a county maintains a Certificate of Good Practice, it is eligible to receive a portion of the gas tax funding.⁶ To receive a Certificate of Good Practice, a county is required to submit accident reports to the state in a timely fashion. Counties must also promptly respond to unsafe or insufficient aspects, like a downed stop or yield sign.

Maintaining County Roads Accident Reports is included as an aspect of the Certificate of Good Practice. Counties are required to submit accident reports to the state in a timely fashion.

Washington illustrates that significant improvements in safety can be achieved when safety funding is channeled down to the local level. By identifying the counties with the most significant safety problems and providing funding to address those problems, Washington was able to make advances in addressing a number of different crash types along local roads in partnership with various counties. This was achieved through the use of low-cost countermeasures which could be applied in a short time period to address different safety problems in a comprehensive manner. n

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